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GROWTH AND CHANGE IN INNOVATIVE MANUFACTURING INDUSTRIES AND FIRMS

Morgan D. Thomas

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

ABOUT THE AUTHOR

Professor Morgan D. Thomas comes from the Department of Geography, University of Washington, Seattle, Washington, USA. He has been associated with the Regional Science Association since the mid-1950s and has served as President of the Association as well as Editor of the Regional Science Association Papers. Professor Thomas's research interests have been primarily focused on regional economic growth theory and the role of technical change in the process of economic development.

FOREWORD

Declining rates of national population growth, continuing differential levels of regional economic activity, and shifts in the migration patterns of people and jobs are characteristic empirical aspects of many developed countries. In some regions they have combined to bring about relative (and in some cases absolute) population decline of highly urbanized areas; in others they have brought about rapid metropolitan growth.

The objective of the Urban Change Task in IIASA's Human Settlements and Services Area is to bring together and synthesize available empirical and theoretical information on the principal determinants and consequences of such urban growth and decline.

Evolution of the industrial composition and locational requirements of manufacturing firms are major factors affecting observed settlement trends. In this report, Professor Morgan D. Thomas, of the University of Washington in Seattle, presents a survey of concepts pertaining to the spatial dimension of the innovation process. This process is discussed from the perspective of the behavior of the manufacturing firms and the growth and change of the industrial sector.

A list of publications in the Urban Change Series appears at the end of this paper.

Andrei Rogers
Chairman
Human Settlements
and Services Area

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ABSTRACT

This paper examines relationships between technical innovations and industrial development. Part I contains a survey of recent literature on the role of innovations in the growth of manufacturing firms. Attention is focused on the firms' responses and strategies such as investments in research and development activity, foreign investments, and the internalization process. In Part II the perspective shifts from the individual firm to industrial sectors and groups of commodities. A number of concepts pertaining to industrial structure, interindustry linkages, and product cycles are evaluated.

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PART I. GROWTH, CHANGE, AND THE INNOVATIVE FIRM

INTRODUCTION

In this paper it is assumed that technical progress is a major contributory factor to the process of regional economic development. Manufacturing firms, as sources of innovations and vehicles of technical change and progress, are therefore important to this process. Modifications in scale and product diversification in these firms contribute to the process of structural change and economic development within the areal units in which these firms are located. Large, fast growing, innovative firms, for example, contribute to economic growth through their direct and indirect employment and income-generating impacts. These impacts are more likely to be generated for a longer period of time if the firms are capable of developing new product lines and markets that will more than offset the contracting demand for their older product lines. A perusal of the literature reveals that there is a need and a strong interest in obtaining a greater understanding of how and why innovative firms grow and change.

Unfortunately, "orthodox" theories of the firm seem to have little utility in explaining how and why large, high technology, innovative, multiproduct, multiregional manufacturing firms come into existence (Nelson 1972:39-40). They are also unsatisfactory in explaining the economic behavior of these innovative firms over time and geographic space. However, over the last two decades revisionists have attempted to modify the orthodox theory of the firm. It is the thesis of this paper that the recently developed behavioral-managerial notions are useful in the conceptualization of the expansion and product-diversification processes found in these firms. Many of these notions have been articulated by scholars who have attempted to explain or predict the postwar growth of the high technology U.S. multinational firms (MNFs) (Buckley and Casson 1976:31).

Initially, I will discuss briefly a number of behavioral-managerial concepts that are useful in understanding the development of corporate strategies devised for these large firms, which seem to result in scalar-geographical expansion and product diversification. In the main section I provide a skeletal conceptualization of some of the processes and activities that facilitate growth and change in innovative, multiproduct, multiregional firms. This section also underscores the importance of the dynamic relationships between a firm and its product industries within a temporal framework.

CORPORATE GROWTH STRATEGIES

Motivation of Firm Behavior

What motivates the firm's decision makers to establish a firm or to produce a particular kind and level of output: what motivates the firm's activity pattern? The orthodox theory asserts maximization behavior for the firm, that is, the subjective and objective function of the firm is to maximize profits. In general, contemporary theories regarding the multinational firm do not assume such extreme, purposeful behavior by the firm but they do assume that decision makers in these firms have certain objectives in mind and therefore definite reasons for behaving as they do.

Clearly such differences are to be expected when one is articulating theory in which assumptions are tractable and correspond with the real world. Usually when a set of assumptions are manageable they tend to be less realistic than desired and vice versa. At this embryonic stage of theoretical development, realism is stressed somewhat at the expense of formalism, rigor, and elegance. Perhaps this is prudent considering the state-of-the-art with respect to the existing theory of firms in general and that of oligopolistic firms in particular.

How and why do multinational firms grow and change over time and geographic space? Maximizing behavior, in terms of profits, growth, or psychic satisfaction, is infrequently postulated in the contemporary literature. The consensus, however, is that these three factors together are powerful motivational forces in theory and in fact in the growth and development of multinational firms. The relationships between these motivational forces appear to be indeterminate and ambiguous, yet they have strong intuitive appeal.

Major decision makers in multinational firms are sensitive to the need for a profit level that will prevent stockholders from seeking new managerial leadership. At the same time, the decision makers must realize that high profits may encourage "take-over" actions by other, larger firms. Recently, decision makers in high technology multinational firms appear to have another especially important reason for attaining high profit levels--that of funding research and development investments.

Research and development (R & D) investments are essential for the expansion and continued existence of the firm in the face of competition. To retain or improve a competitive edge, the firm must generate new information of interest and value through R & D, which in turn ensures the achievement of designated "objective functions". The specification of the appropriate objective functions requires information that may well be unique to each firm and highly subjective in nature. Unfortunately, in the literature one infrequently encounters a thorough discussion of these important, yet difficult, aspects.

It is assumed that materialistic and psychic elements that make up the objective functions of high technology multinational firms are best achieved through the attainment and maintenance of high growth rates and high levels of profit. We have, however, little idea as to how high growth rates or profit levels must be to be satisfactory. Reference is sometimes made in the literature to average growth rates and profit levels in the manufacturing sector or in the firm's industry. The former may be too coarse a measuring rod, and the latter may have little meaning in an industry dominated by a few, very large firms.

Appropriability Problem

Major theories that explain the growth of high technology multinational firms underscore the role of the technical factor and the contribution of research and development investments (Buckley and Casson 1976; Vernon 1971, 1977). Innovations represent a most important means of enhancing the firm's competitive position. Precise measures of the degree of importance of various innovations, however, remain elusive! Firms wishing to grow and attain high profit levels, for example, must ensure a flow of innovations as a necessary condition. Investment in R & D therefore becomes a necessary activity, generating information that enhances efficiency of the firm with respect to choice and use of inputs. Such decisions facilitate the firm's discovery, development, production, marketing, and/or use of new and improved products and processes. Normally, current resources derived from profits are required to obtain and evaluate this information. The future growth or survival of the innovative firm may depend on how well the firm carries out its R & D investments and activities.

Current theories stress the importance of the firm's ability to use the information obtained from research and development as well as to assure the confidentiality of the information that is central to long-term competitiveness and growth potential. Use by a second party of this firm-specific information will reduce the return on R & D investments. Arrow has called the preservation of confidentiality of firm-specific information the *appropriability problem* (Arrow 1962).

Firms operating under conditions of perfect competition, where all information is available to all producers, have no appropriability problem. For innovative, multinational firms, however, operating under imperfect conditions, there is an important incentive to protect the confidentiality of the technology that might provide a competitive edge. Indeed, Magee has suggested that a firm must be assured of an "acceptable level" of appropriability before it will even embark on developing a new product (Magee 1977b). Privately discovered information concerning complex "science-based" or "high" technologies is more easily kept from second parties than simpler "nonscience-based" or "low" technologies.

Clearly the legal and property rights systems also have a great bearing on the relevance of the appropriability problem wherever these multinational firms operate. Literature focused on the question of technology transfer by multinational firms across national boundaries has emphasized, especially where developing countries are concerned, the major significance and sensitivity of the appropriability question (Bhagwati 1977).

Uncertainty and the Multinational Firm

An important postulate of revisionist-firm theories is the major decision makers' dislike of conditions of uncertainty. It is because of this dislike that the condition of uncertainty is *internalized* whenever possible. It is assumed that if the firm can establish control, or some measure of influence over the uncertainty in its environment, the condition is at least alleviated. The firm in this way attempts to convert unmeasurable uncertainty into quantifiable uncertainty or risk. Such firms are believed to prefer taking calculated risks rather than coping with states of true uncertainty (Mansfield 1976). The generation, collection, evaluation, and use of relevant information thus plays a crucial role in these conversion attempts.

Recent studies have clarified the concept of uncertainty by developing classification schemes that suggest qualitative variations in the degree of uncertainty associated with different types of innovation and research and development activities (Freeman 1974). Freeman, in his classification scheme, states that only basic research activities are associated with conditions of true uncertainty, and radical product or process innovations are associated with conditions representing high degrees of uncertainty. Innovations represented by minor technical improvements and product differentiation, however, are associated with conditions that exhibit little uncertainty (Freeman 1974:226). The latter are conditions that more closely approximate those faced by the orthodox firm!

Internalization Responses of the Firm

Because of the importance of the concept of "internalization" in the theory of multinational firms, a brief discussion of this notion as it relates to growth and change is in order.

Price theory asserts that where there are constant returns to scale, "the coordination of interdependent activities by a complete set of perfectly competitive markets cannot be improved upon" (Buckley and Casson 1976:36). However, we know that large, growing MNFs operate (over parts of their life cycles) under conditions of increasing returns to scale in interdependent activity markets. When firms operate under these conditions they cannot be adequately coordinated by the market. Consequently, uncertainties result and in the imperfect external markets some firms choose to reduce or eradicate these uncertainties by serving as coordinators in interdependent activities.

Firms that establish control or some desired level of influence in relevant markets are, in effect, attempting to substitute their internal organization for market exchange. This process of substitution is referred to as "internalization" (Williamson 1971). Forward and backward integration by firms through the use of mergers and other means of coordination are a manifestation of the "internalization" process. Such integration activities usually result in the growth of the firms and in changes in their product mixes. This pattern of growth and structural change is thought to be typical in the case of multilocational firms as they extend their coordinative role across political and cultural boundaries.

However, the remarkable properties of firms that distinguish internal from market coordination have been neglected in the literature on market failure and vertical integration. The fact that internalization is attractive is not fully appreciated by theorists (Williamson 1971). Clearly there are costs as well as benefits associated with the process of internalization. It would seem to be prudent for the firm not to extend the scale of its internalization beyond a point where its marginal costs become greater than its marginal benefits, for there are diseconomies as well as economies associated with scalar changes at plant, firm, and industry levels. The process of internalization may also cause unwanted social costs.

Multiplant firms, such as MNFs, find internalization attractive if they encounter a market failure or an imperfection. There are many types of market imperfections that encourage firms to seek internalization solutions. These conditions are found, for example (1) where necessary markets are absent; (2) where, in an external market, discriminatory pricing is impractical yet desirable if the firm is to achieve efficient exploitation of market power over an intermediate product; (3) where a bilateral concentration of market power leads to an unstable or indeterminate bargaining situation; (4) where there is inequality between the seller and buyer with respect to knowledge of the nature or value of the product; (5) where governments intervene in international markets by imposing *ad valorem* tariffs or restricting capital movements and by carrying out actions that result in discrepancies in rates of income and profit taxation between countries (Buckley and Casson 1976:37-39).

The conventional economic reasons explaining why multiplant firms can expect to benefit from internalization under these conditions are largely to be found in the literature on vertical integration (Jacquemin and Jong 1977; Howe 1978; Lall 1978). Discussion is focused on imperfections in commodity markets. In the more recent literature, however, a number of authors have argued persuasively that knowledge or information on market failure provides an especially strong incentive to internalize (Buckley and Casson 1976:56-59). Firms that possess certain monopolistic advantages (such as advanced firm-specific technology, product differentiation, uncommon mix of skills, and access to capital) encounter costly difficulties when attempting to appropriate the gains expected from the possession of superior information in open markets (Lall 1978:213). Such market-failure information encourages these firms to seek solutions through internalization responses. A recent study of intrafirm exports by U.S. multinational firms provides tentative support for the notion that market-failure information contributes significantly to direct foreign investment and to internalization of trade by high technology MNFs (Lall 1978).

Direct Foreign Investments by the Firm

An evaluation of the variables presented above, which purport to explain the growth and change characteristics of high technology multinational firms during the last thirty years, is conceptually interesting and plausible but the variables are largely untested. One could, however, use the same variables and arguments to explain the growth and change of large uninational, multiregional firms. In other words, a theory of the multinational firm must explain the transformation that results from a uninational firm becoming a multinational enterprise. We need to know what changes occur in a firm and/or in its environment to induce it to become multinational in order to achieve its "motivational" objective function.

High technology U.S. firms usually engage in export activities before they carry out direct investment in foreign countries. Various conditions are thought to be responsible for inducing such firms to carry out production in host countries. Hirsch has suggested that some firms in the early part of the mature, expansionary phase of their product cycle saturate their domestic market (Hirsch 1967). To utilize their excess "expansion capacity" the firms seek necessary markets in foreign countries. The imposition by host countries of various kinds of restrictions such as quotas and high tariffs on imports provide additional inducements for exporting firms to engage in direct foreign investment and licensing (Buckley and Davies 1979). We know that these conditions and inducements have been increasingly prevalent during the last three decades. Unfortunately, however, there is a paucity of sound information on how thoroughly a firm evaluates expected benefits and costs associated with direct foreign investment as well as alternative forms of investments.

Indigenous firms are believed to have certain competitive advantages over foreign producers, especially those that have a greater understanding of the "cultural environment" of the host country and its economic implications. Before multinational firms carry out direct foreign investment, they must possess competitive advantages that offset the advantages of indigenous firms (Hymer 1970). The prevalent contemporary belief, primarily based on studies of U.S. MNFs in recent decades, is the confidence shown by firms in their technological superiority that more than offsets the costs of cultural and spatial distance to be overcome (Vernon 1966, 1977). In general this has been the case during the recent decades. However, significant changes appear to be already under way that reflect relative, if not absolute, changes in the competitive strength of U.S. high technology multinationals in foreign countries, especially those in Western Europe.

Illustrative of some of these changes in the period 1959-1976 is the decline in the number of U.S. companies among the world's top 12 multinationals in all of the 13 major industry groups except aerospace. European companies during the same time period increased their representatives among the 12 largest multinationals in 9 of the 13 industry groups and the Japanese scored gains in 8 (Streeten 1979). Reasons advanced for these patterns of change include:

> ...the decline of U.S. predominance in technology transfer ... the steady growth of European and Japanese capacity to innovate; and in the greater adaptability--both politically and economically--of these companies to the needs of host countries (Streeten 1979:40).

These tentative causal factors merit further study (Vernon 1979).

It is interesting to observe, however, that competition among the multinational firms in host countries appears to have been primarily based on interfirm system-specific differentials in technology. Nevertheless, there is reason to believe that a firm's capability to adapt successfully in response to institutional changes and differences will play an even greater role in interfirm competition among multinationals in the future, especially in developing countries (Bhagwati 1977).

"Follow-the-Leader" Behavior

Domestic market saturation, perceived technological superiority, and impediments to international trade are plausible explanatory factors for direct foreign investment by MNFs. Vernon has also placed the location behavior of MNFs into a framework of oligopolistic competition (Vernon 1977). Vernon suggested that when a multinational firm establishes a subsidiary in a foreign market other multinational competitors tend to follow. Although this notion of "follow-the-leader" behavior does not address the question as to why the initial location decision was made, it does indicate one possible reason for the locational behavior of "counterpunching" MNFs. Knickerbocker, using the unique data bank of the Harvard Multinational Enterprise project, tested the follow-the-leader notion and found that it was largely supported by the empirical evidence (Knickerbocker 1973).

Many interesting and plausible explanations have been offered in response to such questions: how, when, and why does a firm carry out direct foreign investment? It is evident, and no surprise, that these difficult questions have not been answered to everyone's satisfaction. Many deficiencies and ambiguities remain in contemporary theory of the MNF and some of these have already been noted and briefly discussed in this paper.

Many contemporary geographers and economists appear to be interested in attaining a greater knowledge and understanding of the factors and conditions within both the firm and host countries that contribute to, or detract from, a firm's successful direct investment in foreign countries (Vernon 1975). Geographers, in particular, focus their attention primarily on the spatial dimension of the behavior of MNFs, seeking greater understanding of the location decision-making processes within these large multiplant, multiregional (uninational and multinational) firms (Hamilton 1976). They seek better explanations not only for the diffusion of these firms to foreign countries but also for the specific location patterns of units of MNFs within their countries of origin. There is a need to explain location decision-making with respect to "leader" and "follower" firms. Innovative firms do not always retain leadership roles as innovators. One might, therefore, not expect a firm to be a "leader" in all new foreign country markets nor, for that matter, in subnational regional markets. The nature of the support for such speculations, however, still awaits further empirical study.

INNOVATIVE FIRM RELATIONSHIPS: INDUSTRY AND PRODUCT

In this section attention will be focused on selected relationships between innovative firms and their industries and products. It is hoped that these relationships will throw additional light on the process of growth and product diversification within innovative firms and, to some extent, within their constituent business unit components. Changes in hypothesized firm behavior and innovative activity patterns over time are examined and evaluated within industry and product cycle frameworks.

On *a priori* grounds it is reasonable to assume that the pattern of growth of a firm will be strongly influenced by the pattern of growth of its industry. By the term "industry", one means "any groupings of firms which operate similar processes and could produce technically identical products within a given planning horizon" (Nightingale 1978). A firm, of course, could, and large firms usually do, produce different kinds of products. Depending on the level of aggregation, a multiple product firm may belong to a number of industries. The market for a product produced by a firm in a single product industry, e.g., timber truss, may also represent a market for an output from another single product industry, e.g., steel truss (Nightingale 1978).

In the United States the majority of the largest manufacturing firms are high technology, multinational, multiproduct, multi-industry firms. A strong case has been made supporting the thesis that the innovativeness of these U.S. multinational firms was a major explanatory factor in their dramatic growth and global spread in the period between the late 1940s and the present.

The study of the processes of growth and change in multinational, multiproduct, multi-industry innovative firms has been facilitated over the last fifteen years by the use of the Product Life Cycle (PLC) notion (Hirsch, 1967; Vernon 1966; Wells 1972). I propose to use this potent concept as an organizing framework for commenting on a number of technical and spatial behavioral dimensions associated with growth and change in innovative firms.

Technical Change and the Firm

A new product begins its life cycle as an innovation. The duration of this cycle varies from product to product. The new-product life cycle follows the familiar general S form. Sales rise slowly at first, and this phase is followed by a "take-off" or growth phase. In the third phase, sales stabilization occurs, to be followed in phase four by the decline in sales and the eventual commercial exit of the product. Of course, the commercial exit of a specific product may occur during any one of the four phases of the cycle.

One may argue, however, that if we wish to achieve a better understanding of the role of technology factors in bringing about growth and change in innovative firms, then we need to focus attention also on what is happening during the period of time that precedes an innovation. Clearly, the behavior of firms in this pre-innovation phase is not embraced by the PLC notion.

This pre-innovation phase was incorporated by Magee into his Industry Technology Cycle (Magee 1977a). He referred to the pre-innovation phase as the Invention or First Stage. The Second Stage or Innovation seems to be equivalent to the first two phases of the PLC. The Third Stage of the Industry Technology Life Cycle is the standardized product and industry stage and is equivalent to the third and fourth--mature and decline--phases of the PLC.

The form and duration of Magee's Industry Technology Life Cycle is based on the notion that there is a relationship between the total number of patents and the age of the industry. Over long periods of time this relationship tends to follow an S curve. The eventual leveling off of the total number of patents is expected to be associated with diminishing marginal returns on the stock of information created in the industry. The expected decline in successive research and development expenditures as a percentage of industry sales appears to coincide with the leveling-off stage of the total number of patents.

What meaning these relationships, such as those between the number of patents, R & D expenditures, and age of industry, may have with respect to industry or firm growth patterns is not discussed explicitly by Magee. One may note that for many reasons a patent does not necessarily result in an innovation and even an innovation does not necessarily have a successful commercial life. Patents and innovations vary greatly in their commercial importance. Furthermore, not all innovations are patented, and not all technical advances are patentable.

Clearly both product and industry technology life cycles have a strong technical bias or focus and Magee's discussion of the importance of research and development activities carried out by firms in the industry represents an important contribution. A brief commentary on the role of R & D is desirable at this time.

"Industrial" Research and Development

Freeman (1974) has called attention to the professionalization of modern industrial R & D associated with the increasing scientific character and complexity of technology. In addition, he has noted that the continuing trend toward a greater division of labor has given some advantages to the specialized research laboratories. Important inventions, however, are still made by private inventors, production engineers, and production workers (Freeman 1974:26; Hollander 1969). During the last 60 years most large firms in industrialized countries have established their own full-time specialized R & D sections and departments. By 1970 over 1.5 million people in the United States, and over .25 million in the United Kingdom were employed in R & D activities in these specialized sections and departments in large, private firms, and in the laboratories of government agencies and universities. This level of professionalized employment in R & D in 1970 represented a tenfold increase over the previous half-century (Freeman 1974:26).

Nevertheless, individuals and small firms having fewer than 200 employees continue to be important sources of radical inventions, some of which eventually become radical innovations. However, in the United States and many other countries, increasingly specialized R & D sections and departments in large, private manufacturing firms are growing, important sources of invention. Some of these within-firm inventions, together with a number of inventions obtained from external sources, are developed by these firms to the point where they become innovations.

Research and Development Output

Many studies have attempted to measure the results of investments in R & D activities by firms and industries (Terleckyj 1980). Such efforts, however, are beset by severe methodological and measurement problems. Despite their substantial limitations, many persuasive empirical studies are available suggesting that R & D and technological innovations have a significant positive effect on productivity increase in many industries and firms (Griliches 1978; Nadiri and Bitros 1978; Terleckyj 1974). Terleckyj estimated that over the period 1948-1966, R & D activities by the manufacturing sector contributed, directly and indirectly, one-third of the total productivity growth and one-fifth of the total economic growth in the private U.S. domestic economy (Terleckyj 1974). "*Ex post* returns to R and D investment, both social and private, appear to be high, evidently appreciably higher than returns from fixed capital investment" (Terleckyj 1980:57).

Of the $29.9 billion company and federal funding of industrial R & D in 1977 in the United States, more than four-fifths was accounted for by six industries. Ranked by the size of their R & D expenditures they were: aircraft and missiles (23.8%), electrical equipment and communication (19.9%), non-electrical machinery (13.3%), motor vehicles and motor vehicle equipment (11.1%), chemical and allied products (10.9%), and professional and scientific instruments (4.7%) (National

Science Board 1979:205). There is also a high degree of concentration of R & D expenditures in relatively few companies in each of these six industries (National Science Board 1979:204).

Since 1962 there has been a shift away from basic research expenditures by industry in the United States. At present, approximately 3%, 19%, and 78% of total industrial R & D funding are used respectively for basic research, applied research, and developmental activities. Furthermore, the percentage of R & D expenditures to total sales in R & D industries in the United States has fallen since 1964 (National Science Foundation 1978:4).

A recent study (Brinner and Alexander 1977:11) shows that high R & D-intensive industries manifest significant growth in productivity and outputs as compared to medium and low R & D-intensive industries. There appears to be a strong association between the ratios of their R & D spending to sales and their growth of output and labor productivity.

There are very few studies of expenditures for R & D and their impacts on output and productivity at the firm level and especially for firms in different kinds of industries. Furthermore, it may well be that there are no such studies for individual firms since they produce over the life cycles of their individual products. Nevertheless, it is interesting and useful to speculate or hypothesize as to what one may expect with respect to an innovative firm's R & D behavior over the pre- and post-innovation life cycle of a product. A tentative conceptualization of a few dimensions of such a firm's behavior follows.

The Innovation Process

At the outset we will assume that the innovative firm is producing a number of products that are in different phases of their respective life cycles. Little attempt is made in this paper, however, to evaluate the full impact of the nature of the product mix on the behavior of the firm.

The choice of which product to develop is assumed to be connected with the corporate strategy of the multiproduct, multiregional (uninational and multinational) innovative firm. A number of recent studies of innovation concluded that "demand-pull" strategies were more common than "capabilities-push" strategies (Pavitt 1971). Trenchant and persuasive criticism, however, has been leveled at this thesis by Mowery and Rosenberg (1979) who stress that both demand and supply forces are at work, and their influences must be evaluated and assessed if we are to understand the innovation process. It is their view that too often these studies reflect an exclusive preoccupation with only one set of these forces, usually the "demand-pull" forces.

The important relationship between the R & D investments and activities and the creation and development of new products was noted earlier and there is a rapidly growing literature that deals with this subject (Freeman 1974; Mansfield 1968, 1972, 1976; Pavitt 1971). In contrast to the customary use of "production function" models in the development of theoretical frameworks of the innovation process, Nelson and Winter (1977) have suggested the development and use of evolutionary models. They view the innovation process as involving a continuing disequilibrium. Innovation is defined as almost any nontrivial change in product or process, providing there has been no prior experience. An innovation involves considerable uncertainty before and after its commercial introduction.

We may thus perceive that within innovative firms:

> At any time there is a coexistence of ideas that will evolve into successful innovations and those that will not, and actual use of misjudged or obsolete technologies along with profitable ones. Over time selection operates on the existing set of technologies, but new ones continually are introduced to upset the movement toward equilibrium (Nelson and Winter 1977:48).

The selection by an innovative firm of an R & D project to transform an idea into an innovation and the development of procedures used to identify and screen R & D projects may be viewed as interacting heuristic search processes (Nelson and Winter 1977:52). A firm's R & D strategy would, therefore, be reflected by its heuristic search processes.

Nelson and Winter (1977:56) hypothesize that there is a precommitment by a firm to the advancement of a particular technology (embodied or disembodied) or "technological regime" with which it is familiar. The firm tends to advance its particular technology in a certain direction, which is referred to as the firm's natural trajectory. These concepts seem to be related to the notions of firm-specific and the firm's system-specific technologies used in technology-transfer literature (Hall and Johnson 1970).

Natural trajectory and technological regime concepts seem to have considerable merit in seeking an understanding of the process of diversification by a firm into new product-markets. Penrose (1959), over 20 years ago, noted that such product diversification decisions by a firm may reflect a reponse to specific opportunities or a solution to specific problems of demand. Diversification may also represent a general policy for growth. Penrose also observed that in practice the three motives for diversification are inextricably intertwined. Furthermore, she stated that internal inducements to expansion by the firm included not only the "specific opportunities presented by a firm's resources, but also the unused services of management" (Penrose 1959:144).

These ideas generated by Nelson and Winter and Penrose are useful in the search for a better understanding of the relationships between R & D and innovation, between innovation and product and firm diversification, and between diversification and growth and change processes in large innovative, multiregional firms.

Innovation, Diversification, and Entry

Before moving to the innovation phase of the product life cycle it may be useful to remind oneself that present evidence, incomplete and spotty though it may be, suggests that only an infinitesimally small number of new ideas become innovations. Rothwell (1977) noted that only about two per cent of the relatively few new ideas chosen for careful consideration and evaluation reached a stage beyond development, the start-up and prototype production stage. Furthermore, he also observed that figures for the United States suggest that with respect to the new ideas that reach the innovation stage there is a failure rate of around 40% (Rothwell 1977:41). These observations underscore the belief that there is a sobering environment of uncertainty associated with the process of innovation in the manufacturing sector.

Small Firms

In contemporary industrial economies, small firms play a declining role in the innovative process. Lack of agreement, however, on measures that should be used and lack of suitable information fuels the continuing debate concerning the role of firm size in the innovative process. Nevertheless, there is a consensus that small firms continue to play an important role as a source of innovations. Their creative role is probably even more important in the inventive stage of the innovation process. The high development costs in so many industries frequently prevent small firms from carrying new ideas all the way through to the innovation stage.

Recently Freeman (1978) notes that when industries are classified and ranked according to their physical capital intensity, there is

> ...almost complete correlation between capital intensity and share of innovations in that industry. So that in the most capital intensive industries--aluminum, chemicals, and so forth, there were scarcely any innovations from small firms. In the industries of very low capital intensity, which includes science-intensive industries like scientific instruments and electronics, small firms account for quite a high proportion of innovations--often more than their share of production (Freeman 1978:11).

Technical Progress and the Firm

As mentioned earlier, R & D activities and investments within an innovative firm are believed to be a very important source of information on technical advancement. Search activities by such a firm frequently result in the accumulation of useful information generated by the R & D expenditures of other firms and governmental agencies. Conventional and unconventional sources and methods are used in gathering this information, including published information intelligence networks and the use of roving technical scouts (Schon 1964, 1967). Formally identified R & D investments and activities are not the only source of improvements in the final products and in the tools and processes used within firms. Production workers as well as scientists, engineers and technologists are involved in the process of effecting embodied technical change. Disembodied technical change in the form of improved organization structures and management practices is also an important source of progress, and one expects corporate officials and professional managers to be initiators of such changes. The quality of these corporate officials and managers has a great bearing on the nature and speed of the firm's responsiveness to its varying needs over time for organizational and management change (Maidique 1980). Consultant "gatekeepers" also appear to be major sources of significant disembodied technical change in the United States and the United Kingdom (Channon 1973).

The R & D activities of the firm contain an important *learning component*, which on *a priori* grounds, one would expect to have a significant impact on the firm's innovating activity. There is reason to believe that the nature of R & D activities and investments tend to be different in innovator firms as compared to counterpunching imitator firms (Peck and Goto, forthcoming). Over the firm's life cycle, and over a specific product life cycle, an innovative firm may change from being an active seeker-innovator to being an adaptive reactor-imitator. Sometimes these changes are the result of deliberate strategies and sometimes they may result from the ascendancy or eclipse of key decision makers who may possess varying supportive or resistant attitudes towards uncertainty-creating innovative activities (Allen, Piepmeier and Cooney 1971; Peterson 1967; Schon 1963).

Innovation Impact Sequences

Technical change may be conceived of as an impact sequence manifested by product change and improvement and as new products. For the firm, the production of new products usually means product diversification, which in turn, may reflect a deliberate growth strategy. Conceptually, new products may be thought of as new industries with, of course, varying lengths of longevity. Product diversification contributes to changes in the industrial composition of geographic areas within which firms are diversifying their product mix. Innovative firms are expected to continue to produce new or improved products that will enhance the competitive position in a behavioral sense over time and thus intensify growth prospects.

For the same firm, technical change may also be conceptualized as an impact sequence manifested by changes in economic efficiency. Innovations that bring about cost reduction and productivity increase facilitate the use of price competition as a means of bringing about scalar changes in output, given appropriate price and income elasticities of demand for products. These two developmental sequences associated with technical change will now be discussed within a product life-cycle framework.

The Product Life Cycle and the Innovative Firm

Innovation occurs when the new product is produced commercially. What then are some of the conditions and factors that may be expected to influence the behavior of the innovating and the competitive firms over the product life cycle? This conceptualization will draw on concepts and explanatory notions used earlier in the paper.

The literature on the PLC focuses little attention on the innovative act or the factors that may have an important influence on the decision to innovate. Although the literature on firm entry does not focus exclusively on innovation, it is an important source of useful concepts and information concerning the first phase of the PLC.

Many economists have studied entry conditions. However, Biggadike (1979) recently noted that research has primarily been done on

> ...newborn entrants, the total firm, corporate strategy, broadly defined industries, or organizational processes. But, newborn firms are not the only kind of entrants, total firms do not implement entry, corporate strategy is not business unit strategy, entry is not usually planned as entry into industries defined by S.I.C. codes, and market processes are as likely to affect entrant performance as are organizational processes (Biggadike 1979:4).

Earlier Hines (1957) and Andrews (1959) called attention to the fact that established firms face significantly different entry conditions than do newborn firms. Gort (1962) and others have noted the dominant role of established firms in product diversification. The large multiregional, high technology firms are especially well known for their range of products; for example, in 80 years General Electric moved from serving the incandescent-lamp market to serving more than 700 product markets (Biggadike 1979:1).

Even though the importance of entry by established firms is now well-recognized there is very little known about the strategy and performance of the firm's *business units* that make the entry (Biggadike 1979:2). Entry by an established firm is defined as occurring when it begins to compete in a product market where it did not previously operate. The start-up or entrant business unit requires the parent company to obtain new commercial and operating knowledge, to add new equipment facilities and people, and to make a significant investment of the firm's resources in order to accomplish a result beyond the year in which the expenditure is made (Biggadike 1979:6-7).

In his recent study of a sample of highly diversified and large (*Fortune* top 200) companies Biggadike (1979:9) also developed an interesting, new analytical framework, which he used to examine entry, strategy, and performance. The framework was based on the concepts of relatedness, market structure, entry strategy, and incumbent reaction.

Relatedness refers to the likelihood that an entrant launched by an established company inherits skills from the parent company that it tries to transfer to the entered market. In Biggadike's (1979) study, relatedness proved to be a most useful concept. It is, however, reminiscent of Nelson and Winter's (1977) concept of natural trajectory and technological regime. There is also the suggestion in the relatedness concept that the business unit entering the new product market seeks to utilize to its advantage technological, organization and marketing slack and the firm-specific technologies of the parent firm. The business unit, in turn, may be expected to develop its own business unit-specific technology over time, which it and the parent firm will attempt to keep confidential for as long as possible.

The Product

What happens to the product during its life cycle? The commercial entry of the new product begins with the first or the uncertainty-development phase of the cycle. Production runs tend to be small "... product specifications are loose, and frequent changes are introduced into the manufacturing process, production sequence, product specification and equipment" (Hirsch 1967:18). In the second or growth phase the product receives widespread acceptance in a growing market. Large-scale production and distribution methods are increasingly introduced. Production processes that tend to be skilled-labor intensive in the development phase become more physical capital-intensive and the demand for less skilled labor increases. These processes may have profound social as well as economic impacts (Thwaites 1978; Massey 1979). At the plant level, products are standardized. In phase three, or the mature phase, industry-wide standardization of product and stabilization of production processes occur (Slome 1973). Phase four, or the decline phase, eventually witnesses the commercial exit of the product.

The Firm

What happens to the firm and the "entry business unit" over the product life cycle? Clearly this may be significantly different from what happens to the total multiproduct firm. No attempt is made at this time to deal systematically with the respective behaviors of these different types of organizational firm units.

For the firm the act of innovation must be preceded by, among other things, location and production plant decisions. Will the new product be produced in existing or new plants? If new plants are to be constructed, where should they be located? Estimating the correct plant size before it is built to meet the needs of the firm over the planning period is an important decision with considerable cost implications (Pratten 1971).

Barriers-to-entry in the new product market for follower firms conditions the duration of the market monopoly of the innovator firm. In addition, the more radical or innovative the new product, the slower the growth rate in phase one of the product cycle. The degree of uncertainty connected with the innovation, in other words its degree of innovativeness, appears to affect the rate of adoption or purchase of the new product (De Kluyver 1977).

Industries with fast changing technologies tend to grow quickly, significant modifications occur in their existing products, and the number of new products increases rapidly. Industries with fast changing technologies offer "strong inducements to entry in the form of opportunities for gains to innovating firms" (Gort 1962:105).

In general, these innovating firms are large in size. "In 1970, firms employing more than 5,000 accounted for 80 per cent of all industrial R and D expenditure in the U.S., 75 per cent in West Germany and 60 per cent in France" (Rothwell 1979:365). However, radically innovative new technology firms, such as those producing semiconductors in the United States, tended to be new entrepreneurial firms and small in size. Firms in this industry in Europe and Japan, however, tended to be larger, established firms (Rothwell 1979:363). In the semiconductor industry there may be a connection among firm's size, newness of its product(s), and relationship to the rapidly moving technological frontier. Semiconductor firms in the United States tend to be the innovative leaders. Their Western European and Japanese counterparts carry out less risk entailing production usually associated with "follower" firms.

Costs of entry for business units from established multiproduct firms studied by Biggadike (1979) were unexpectedly high, and normal profit conditions were not reached for a number of years. His tentative findings show that entry by these business units occurred mainly in the development and growth phases of the PLC. Business units with technological and vertical integration relatedness were the dominant entrants during these phases. Only rarely did business units enter during the mature phase and these units seemed to rely primarily on proved, inherent marketing skills.

Initially, competition between firms tend to be based on qualitative dimensions of the product rather than its price. Product and process innovative activities are focused on product improvement with greater emphasis on product innovative activities. Outputs and sales usually expand rapidly during the growth phase and production capacity is enlarged at existing sites or at new locations. Some firms export part of their output, and towards the end of the growth phase a number of firms may decide to invest directly in foreign countries. As mentioned earlier in this paper, the multinationalization of some firms appears to coincide with the saturation of the domestic market.

The growing demand for the product and the responsive growth in output facilitate and require production efficiency within firms. Production within plants becomes more capital intensive and products become standardized. Greater emphasis is placed on innovative activities that enhance process efficiencies rather than product improvement within plants. During this growth phase of the PLC, expenditures and effort on product innovative activities decline absolutely and relatively (Abernathy and Utterback 1978:40).

In the mature phase of the PLC the firm's product and process innovative activities, directed at the specific product or line of products, are at a low level, and they are directed toward the achievement of cost reductions. Price competition becomes increasingly important. The firm tends to stress advertising more heavily and other means of differentiating its product from that of other firms in a product industry that is now characterized by its standardized products and production technology (Slome 1973).

In this phase there is a great incentive to reduce production costs. Competitive advantages in production due to innovative activities and technical advances have largely run their course. Increasingly, more traditional avenues in search of cost reduction are intensively explored, such as scalar economies of various kinds. Sources of scalar economies include indivisibilities, specialization, massed resources, superior techniques or organization or production, learning effect, and control of markets (Pratten 1971:8-14). Of course, if they are to be successful, firms in this phase of production need to reduce the adverse impact on their competitive position of diseconomies of scale stemming from such sources as factor limitations, technical forces, management, labor relations, and selling and distribution.

Scale, of course, is only one factor that influences the efficiency of resource use and increased productivity. Leibenstein (1966) has, for example, called attention to a set of behavioral factors that affect the economic efficiency of the firm. His concept of x-efficiency suggests that "for a variety of reasons people and organizations normally work neither as hard nor as effectively as they could" (Leibenstein 1966:413). If a firm is able to change the behavior of those who work for it so that they

> ...raise their output by producing more with the same means of production ... a higher static x-efficiency is reached. Growth may also result from the development and application of new techniques, and this affects the dynamic efficiency of the company. If the latest techniques are indeed employed, i.e., if the most recent production function applies, we can also speak of an x-efficiency in the dynamic sense (Heertje 1977:218-219).

Location considerations by the firm may well increase in importance during the mature phase of production. In the growth phase, import restrictions and oligopolistic forces may contribute to the multinationalization of many firms exemplified by the spread of U.S. high technology firms to Western Europe after World War II. However, the more recent establishment of these plants in developing countries usually represents the production of commodities in mature or declining phases of their cycles. Labor cost differentials appear to exert a strong influence on the location of production of such commodities.

Indeed, Hansen (forthcoming) suggested labor cost differentials are also a major reason for much of the recent rapid growth of employment in southern U.S.A. He indicates that a significant proportion of this employment is in plants producing "mature" products. Such production requires relatively unskilled labor. The availability of sufficient relatively low-wage labor in the South is thus an attractive locational force for firms producing mature products. Low-labor input costs appear to offset other higher costs that may be associated with production in southern U.S.A. and developing countries. Of course, other favorable factors may also be partly responsible for the location of these plants in these areas.

In the declining phase of the PLC the firm may carry out production rationalization schemes. Less efficient plants are often closed down and production consolidation in fewer and more efficient plants and locations takes place. This tends to be the case where firms do not have a sufficient number of product lines in the developing, growth, and mature phases of their life cycles. Where this phenomenon is generally found in the manufacturing sector, a secular decline may well occur in specific industries and even in the whole sector. In this respect, it is interesting to note that since 1973 there has been an absolute decline in employment in manufacturing in the United States and in almost all other industrialized countries.

CONCLUSION

An examination of several explanatory behavioral notions suggests that there is a strong motivation for a corporate strategy among innovative, multiregional firms to seek scalar and geographic expansion. The associated corporate strategy of diversifying product mix facilitates the achievement of expansionary goals. The examination of the innovative firm within industry and product life cycle frameworks suggests that the competitive behavior in a successful firm should change over the life cycles of its products. It seems that for each of its products, or family of products, the firm's R & D activities and investment patterns would need to change over the product's pre-innovation and post-innovation life cycles. Early in the life of a new product, innovative activity in the firm is, and needs to be, concentrated on product enhancement. The growth phase of the product life cycle, however, heralds a need for greater cost consciousness by the firm, and this need intensifies if the firm is to remain competitive over the remainder of the product life cycle. An increase in cost-efficiency activities enhances the importance of innovative activities, which emphasize improvements in processes. Process innovations for one firm are often the product innovations of other firms, usually in other industries. Innovative firms tend to obtain process innovations from other innovative firms.

Furthermore, significant changes occur over a product life cycle in the number of workers and job skills required, and important changes occur in the attraction of specific geographic areas as production locations. These changes have obvious employment and income generation implications and they will, of course, tend to have significant regional economic development and social change implications.

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PART II. PERSPECTIVES ON GROWTH AND CHANGE IN THE MANUFACTURING SECTOR

INTRODUCTION

Industrial structure mirrors the result of various changes in national and subnational economies stemming from the influence of such forces as the application of advances in technical knowledge and the differential responses of demand to changes in both productive capacity and per capita real incomes. Changes in industrial structure reflect concomitant changes in the location and size of industries and firms and associated scalar, qualitative, and distributional changes in population. Those seeking a greater understanding of how and why industrial development takes place must focus their attention on the process of change in industrial structure. Similarly, those seeking ways of improving the economic conditions of national or subnational regions that are experiencing such problems as high chronic unemployment, unacceptably low per capita income levels, or secular decline in major industries, must also be aware of the importance of the transformations occurring in the industrial structures.

The purpose of this paper is to provide a better understanding of the industrial development process. Attention is focused on the role of technical change in the processes of industrial growth and structural change in general--and in large oligopolistic industries in particular. The role of technical change in these processes is examined within frameworks provided by aspatial macro and micro theories of economic growth.

The first section discusses certain characteristics of contemporary economic theories: development-stages theory, which provides insights into industrial development sequences associated with the process of economic growth; export-base and staple-goods theories, which stress the importance of net imports in the growth of an economy; and growth-pole theory, which analyzes the hypothesized major roles of large, fast-growing oligopolistic industries in inducing economic growth and facilitating structural change. The remainder of the paper focuses on the recent contributions made in the vast literature on economic growth, technical change, oligopoly, and industrial organization. Industrial growth and structural change are viewed from the perspectives of the innovation life cycles of industries and products, especially those associated with oligopolistic, high-technology industries.

Finally, a brief evaluation is provided of the usefulness of technical change concepts, and of analytical frameworks discussed in the paper, in explaining long period processes of change within and between manufacturing industries in market economies.

CONTEMPORARY GROWTH THEORIES: SELECTED ASPECTS

Industrial Development Sequences

Contemporary macro- and micro-economic growth theories have attributed great importance to technical change as an explanatory variable. However, macro-economic literature usually treats technical change as a predominantly automatic or mechanical process. Exogenous and autonomous "technical change as such is not explained and the rise in the level of production is simply attributed to the passage of time" (Heertje 1977:174). Induced or endogenous technical change represents primarily a particular perspective rather than a characteristic of technical development itself. Induced technical change or the expansion of technical possibilities is explained by one or some combination of such factors as "(a) long-term changes in the ratio between prices of the factors of production, (b) learning processes concerning production, and (c) investment in education and research" (Heertje 1977:174).

Nevertheless, macro-economic literature provides a number of insights into the relationship between economic and industrial growth and technical change. One finds that with the "passage of time" technical change is associated not only with increases in outputs in various sectors but also with increases in the economic efficiency of producing these enlarged outputs. Neutral and non-neutral technical changes also occur and are said to contribute to increases in productivity in the sectors or subsectors experiencing technical change. Consequently, in economies where population growth rates are not as great as productivity growth rates, rises in per capita incomes are possible. Income elasticity of demand in such situations provides a simplistic explanatory mechanism for how and why economic growth is induced and changes occur in the industrial composition of economies.

Studies of Engel curves for simple products, which may conceptually be viewed as specific industries, provide a number of useful insights concerning the concept of income elasticity of demand. These curves indicate the relationship between changes in the quantities of simple products purchased that are associated with changes in income. The familiar S form of this relationship does suggest that at some level of per capita income the Engel curve for the simple product will flatten and even turn down. However, we have little idea as to the nature of the simple product's time horizon or as to when the Engel curve begins to flatten out or turn down. The form of the curve suggests that at a particular level of per capita income, consumption functions will reflect the effect of growing substitution of other innovations. Changes in population levels and/or the size of income groups will, of course, also have an impact on changes in the size of the simple product industry, but again we have little idea as to the nature of these impacts over the entire life of the simple product industry (Thomas 1964).

The empirical bases for the role of income elasticity of demand as a significant explanatory mechanism for structural change is not well established. However, Bruton (1960) and Leser (1963) have noted that the hypothesis concerning the form of the Engel curves is not inconsistent with the data. The hypothesis appears to have been primarily used

> ... to explain the decline in the size of agricultural output, relative to total output, as an economy emerges from a very low and constant per capita income status into a situation where per capita income is increasing (Bruton 1960:264).

Subsequently, changes in the structure of demand that accompany increases in real per capita incomes provide one level of explanation for the growing proportions of the expanding per capita incomes allocated to the purchase of manufactured products and the various kinds of services. The development stages theory based on the empirical observations of Colin Clark and Allan Fisher attempts to provide an explanation for these structural changes (Thomas 1964). However, there is a paucity of discussion in this theory as to how and why changes occur in the structure of demand and what are the required kinds of relationships between savings and consumption. Yet such discussions seem desirable if we are to gain a clearer and fuller understanding of the processes of structural change. In addition, how did the initial real increase in per capita income come about in such a way as to trigger the income elasticity of demand mechanism that in turn brings about changes in the structure of the economy? Presumably an increase in productivity provides a plausible primary explanation--but then how and why did such an initial rise in productivity take place and what was the nature of the role played by technological change? Samuelson (1978:1417) recently noted that:

> What observers like Kuznets have observed this past century is that the growth of technology has been enough *to keep the real wage growing at something like an exponential rate*, with the growth in population and savings not being fast enough to wipe out the rising trend in real wages.

The sequence of structural change is another topic of considerable academic and policy interest, which has not been definitively dealt with in development-stages theory. Early versions implied a deterministic sequence of development beginning with primary and moving through secondary and tertiary sectors. The achievement of absolute economic importance by tertiary activities reflects the highest known level of economic development. The theory, however, does not give a clear indication of when and under what conditions each of the broad three sectors in the national economies expand and contract.

The attempt by Hoffmann (1958) to provide a sequence of structural change within the manufacturing sector is also deficient with respect to the provision of necessary conditions and timing for changes from Stage I to Stage IV. He simply indicates that in Stage I the manufacturing sector is dominated by consumer-goods industries and successively the sector is dominated in Stage II by capital-goods industries, followed by Stage III with a balance of consumer- and capital-goods industries (with a tendency for the capital-goods industries to expand rather more rapidly than the consumer-goods industries). In the case of Stage IV, which appeared to be emerging in the United States, Germany, and Britain, Hoffmann offered empirical evidence of the redomination of the capital-goods industries.

Trenchant criticism of the development stages theory and Hoffmann's theory of industrial (manufacturing) growth in the late 1950s and early 1960s contributed to the apparent disinterest of geographers and regional economists in the refinement of these theories. Macro explanations of the kind provided in these theories seem to assume inevitably a mechanistic character. Interest in the economic development processes in subnational areas in the last twenty years further revealed the weaknesses of theories that seem best suited for explaining structural change in large nations sufficiently well endowed with human and other resources necessary to support successive changes in the economy from a subsistence to the highest known commercial level.

In the early 1950s and 1960s the economic and staple-goods theories had considerable appeal in cities, metropolitan areas, and subnational areas in developed countries (Innis 1933; Thomas 1964). The export or basic sector was the mechanism that ensured the growth of both the basic and nonbasic components of the economy. The dichotomization of the regional economy into usually two sectors--export and service or residentiary--served to highlight the important strategic growth component, but it also suggested a mechanistic pattern of economic growth. Export-base theorists provided insufficient information on the necessary and sufficient conditions that would allow the export sector to continue to provide the means of ensuring the viability of and necessary changes in the structure of the region's export and residentiary sectors. Despite the availability of a number of input-output studies of urban and subnational economies in that period, little effort was made to disaggregate the export and residentiary sectors and to identify and evaluate the economic significance of some of the associated linkage patterns in these open regional economies. The unsatisfactory discussion in export-base theory of the mechanism needed to explain the pattern and process of growth and structural change led many to conclude that, at best, it was but a short-run growth theory.

During the last decade or so in North America, Western Europe, and other parts of the world the unbalanced growth-pole theory captured the imaginations of regional development theorists, and interest in both development-stages and export-base theories seems to have waned.

Propulsive Industries

Unbalanced-growth theorists (Perroux 1955; Chenery and Watanabe 1958; Hirschman 1958) have provided interesting insights concerning the process of industrial growth and structural change, especially in the manufacturing sector. They have shown that certain industries seem to have a more significant role than other industries in effecting the growth of the manufacturing sector and the economy. These major growth-inducing industries are referred to by such names as motor, lead, or propulsive industries. These modern, large-scale propulsive industries tend to be oligopolistic; they also have growth rates that are higher than the average growth rate for both the industrial productions and the product of the national economy.

Unbalanced-growth theories focus considerable attention on the growth-inducing role of interindustry technological linkages of the input-output variety. Propulsive industries tend to have extensive backward and forward technological linkages that link them to what Perroux calls their "affected" industries. Growth impulses are transmitted through this network following an initial expansion of output by a propulsive industry. Similarly, the concomitant and consequent increase in incomes generated by the propulsive and "affected" industries results in economic growth induced by the operation of the income multiplier. The initial growth in output by the propulsive industry may induce additional growth in industries whose outputs contribute to the creation of additional productive capacity. If existing capacity is inadequate, the rise in effective demand generated by the propulsive industry and its linked industries and/or the expected continued increase in effective demand may well induce expansion in the output of required capital goods.

A round of economic growth induced by an initial expansion of output by a propulsive industry comes to an end normally after a short period of time, varying from a few months to a few years. Further rounds of growth by an individual propulsive industry system require stimuli in the form of new rounds of expansion initiated by that propulsive industry and continued by its induced growth system until the growth stimuli are expended.

Some industries seem to achieve the characteristics of propulsive industries only during a part of their lifetime. Other industries do not seem to reach the required growth rates and scale, nor do they exhibit the kind of market structure or extensive network of linkages that significantly affect the growth of the economy or the growth of the manufacturing sector. Furthermore, they do not appear to qualify as propulsive industries even during some part of their lifetime. A knowledge of the nature and form of the expansionary paths for these non-propulsive as well as propulsive industries is necessary if we are to understand the process of industrial growth and development in both spatial and nonspatial contexts.

Clearly, for the *short* period the round-of-growth concept associated with the propulsive industry system provides useful explanatory insights with respect to the process of industrial growth and related variations in activity levels in the linked industries. However, this concept does not provide an acceptable level of understanding of the process of growth at the industrial level over a *long* period of time--many decades, rather than a few months or years. Such understanding requires the development of an explanatory framework that is complementary to that provided for the short period by the propulsive industry system's round of growth. An appropriate conceptual framework should provide explanatory insights concerning the process of technical change, the intra- and interindustry diffusion of innovations, and the birth, life, and death of industries, for these dimensions mirror the changing structural, temporal, and spatial patterns of growth in the specific industries and in the economies within which they nest.

Macro-growth Theories

A satisfactory explanation of economic growth over a long period must give adequate, explicit attention to the role of such factors as technical change, quantitative and qualitative population changes, and changes in societal "tastes" or consumption functions (those of households, private, and public sectors). Unbalanced-growth theories, especially the growth-pole theory, give inadequate attention to the influence of these variables with respect to economic growth and structural change in the long run.

Over the last four decades macro-economic growth theories, such as the capital-stock-adjustment, development-stages, and unbalanced-growth theories, have provided for some scholars and policy makers seemingly plausible explanations for the process of economic growth and industrial change (Hoselitz et al. 1960; Bhatt 1964). These theories, among other things, have provided useful insights concerning, for example, the general sequence of industrial change, the role and importance of capital and technical change and income elasticity of demand, and the transmission of growth and change through various propulsive industry system networks. However, many students of economic growth and industrial change have become dissatisfied, during the last two decades, with many of the features of macro-economic growth theories. Frequently stated dissatisfactions include those concerning the seemingly mechanistic processes associated with scalar and compositional changes in industrial sectors and economies viewed primarily at national levels; the processes of industrial and technical change that appear to be independent of human will and behavior; the concept of the firm that tends to be that of the economist's black box and the concept of the entrepreneur who lacks flesh and blood; the great frequency with which growth and especially technical change are considered only within the static neoclassical framework; and a lack of explicit recognition of the spatial dimensions of economies, industries, and firms.

The merits of these dissatisfactions with macro "non-behavioral" and "nonspatial" economic growth theories will not be argued at this time. However, the merits of using a complementary micro-economic approach to the study of the processes of industrial growth and change are explored in the remainder of this paper. Such an approach with its complementary and supplementary sets of insights should enrich our understanding of the many complex dimensions of these processes.

INDUSTRY GROWTH AND CHANGE

Industry and Product Cycles

Economic growth theories in general give scant attention to identifying and explaining such growth patterns as those for specific manufacturing industries or those for specific subsectors within the agricultural or services sectors. Yet studies of industrial growth patterns would seem to be relevant for those interested in furthering their understanding of the processes of long-period industrial growth and structural change. Those corporate executives or government officials who make strategic choices at the international, national, or subnational levels and are concerned with the articulation of economic, industrial, or firm development policies, should also benefit from having a greater understanding of the nature and implications of the life patterns of industries under their jurisdiction. Thus for many reasons a brief discussion of the topic of industry growth patterns is desirable.

In the United States a search for uniformities in the growth patterns of individual industries culminated in work published on the subject by Kuznets (1930) and Burns (1934) almost a half century ago. Thereafter, work in this area of investigation was minimal until the early 1960s when Gaston (1961) and Gold (1964) reexamined and extended results obtained in earlier studies, especially those generated by Burns. Contemporary interest in industry growth patterns in the United States appears to be directed toward the growth rates of fairly highly aggregated industries (two and three SIC digit levels) over a period of time of a few decades. Frequently in these studies interest is focused on comparative evaluations and on the economic development implications of interindustry or intersectoral growth rates in, for example, developed and developing countries or some other areal units or unit (Kádár 1976). In the last decade and a half, a growing number of studies of growth patterns of similarly aggregated industries over portions of their life cycles have also appeared. These studies mostly address the growth patterns of oligopolistic industries, especially those in high technology sectors such as aircraft and missiles, electrical equipment and communication, non-electrical machinery, motor vehicles and motor vehicle equipment, chemical and allied products, and professional and scientific instruments (Vernon 1977; Dunning 1974).

Half a century ago in his study of secular movements in production by various industries, Kuznets (1930:254) perceptively noted:

> As we observe various industries within a given national economy, we see that the lead in development shifts from one branch to another. A rapidly developing industry does not retain its vigorous growth forever but slackens and is overtaken by others whose period of rapid development is beginning. Within one country we can observe a succession of different branches of activity in the vanguard of the country's economic development, and within each industry we can notice a conspicuous slackening in the rate of increase.

Economic historians and geographers have shown that these insights concerning the dynamic process of structural change are relevant with respect not only to national but also to subnational economies, and that different industries may serve in leadership roles during similar development phases in different countries. In other words, there does not appear to be an identical deterministic temporal sequence of highly disaggregated industries or groupings of such industries associated with the economic or industrial development of economies whatever their areal scales.

Kuznets notes that over time we observe a conspicuous slackening in the rate of increase in an industry's rate of growth. Burns's study based on 104 continuous series of production trends in the United States industries beginning between 1870 and 1885 and ending in 1929 led to the formulation of his law of industrial growth. He summarized his "law" thusly: "An industry tends to grow at a declining rate, its rise being eventually followed by a decline" (Burns 1934:173). As we see, Kuznets and Burns reflect a similarity in viewpoint concerning industry expansion paths.

In his study Burns attached two alternative views with respect to industry growth: (1) the conception of indefinite growth of industries, and (2) the notion that industries grow until they approximate some maximum size and then maintain a stationary position for an indefinite period. "Once an industry has ceased to advance [it] soon embarks on a career of decadence" (Burns 1934:120). Burns's significant work won a general acceptance among economists.

However, thirty years later Gold (1964) leveled trenchant criticism at Burns's work. He extended a number of Burns's series, largely representing industries with a single or a small number of products, over the subsequent 25 years. Gold's series show a variety of forms with respect to both single-product and multiple-product industry expansion paths. We do not, however, know the nature of the expansion paths of the firms that contribute to the industry or product series evaluated. In many instances individual industries exhibit a number of distinct peaks. According to Burns, the estimated peak for each industry represents the year in which the logarithmic parabola fitted by him reached its maximum. In many cases Burns's estimates of production peaks were exceeded subsequently by actual production (Gold 1971). Gold's findings were in conflict with the expectations based on Burns's law. Doubtless differences in the nature and use of "form-fitting" techniques such as Gold's linear linkages, Burns's logarithmic parabola, and Gaston's Gompertz curve account at least in part for such conflicts arising among their respective findings.

The variety of single-product growth patterns or the variety in the form of single-product expansion curves revealed by Gold raises intriguing questions with respect to the implicit suggestion in Burns's law that there are systematic forces at work in the economic system that result in universally uniform expansion paths for all industries, especially single-product industries. It is intriguing to note, however, that contemporary business economists still invariably use the S-shaped curve to depict the form of the product cycle.

At this point we should note that empirical problems such as those connected with changes over time in the nature, classification, and aggregation of industries and products add to the difficulties of identifying forces that influence the form of industry and product life cycles. Gold suggests that we should not be surprised that results showing the great variety of industry expansion paths should raise doubts about the universal applicability of Burns's progressive retardation growth model. He believes that economic theory suggests an array of factors whose influence affect differentially the prospective outputs of individual products

> ... including the possible expansion of current markets through lower costs and prices, product improvement, increased population and incomes, as well as the creation of new markets through geographical extensions and the development of new uses for the product (Gold 1971:263).

Gold's findings do not prove an absence of forces at work systematically affecting the form of an industry or product expansion curve. The findings, however, suggest that forces, if acting systematically, are interacting with one another in different ways over time, or that different mixes of systematic forces are interacting so as to result in different patterns of life cycles at industry and product levels. The identification of the characteristics of forces that influence the form of industry, product, and firm expansion paths is still a challenging task and necessary to undertake if we are to improve our theories of industrial and firm growth patterns. This task will be discussed briefly later in this paper.

Product Life Cycle

During the early 1960s when Gold and Gaston were reexamining Burns's retardation growth model, other economists were using notions introduced in Kuznets's 1930 study and Burns's 1934 study to develop a product life-cycle model (Hirsch 1967; Wells 1972). As mentioned earlier, Gold's findings raised questions with respect to the existence of universally uniform industry and product expansion paths. He also showed that Burns's model was not a reliable predictor of future output levels. In spite of this, in 1967 Hirsch advocated the use of the product cycle when examining the characteristics of an industry's growth path. Hirsch was an early forerunner of a growing group of scholars who have used for this purpose the product life cycle and more recently the industry life cycle. Contrary to Gold's finding, Hirsch (1967:16) noted that changes in the rates of growth of industries "occur in a fairly systematic fashion, and are therefore predictable". He defines a new product as satisfying one of the following criteria: (1) it is manufactured by methods that were not previously used by the industry, or (2) it is based on a recent invention or unfamiliar developments (p. 18). Clearly the product life cycle has a technological focus. The product's expansion path, measured in sales or percent saturation of its market, is one kind of manifestation of an innovation's "diffusion" path.

The product life cycle as depicted by Hirsch has the familiar S form and represents in essence a single-product industry growth path. In the first phase of the cycle the new product is launched commercially and sales rise slowly. During the second or growth phase the sales "take off". Later, sales stabilize and phase three or the maturity stage sets in. The decline or fourth phase follows, and this phase ends with the commercial exit of the product. There are, of course, many variations in the number and descriptive titles for the various components of the product life cycle.

A number of contemporary authors have explored the potentials of the product cycle in the formulation of marketing strategy (Kotler 1965; Levitt 1965). Some authors (Bass 1969; Ehrenberg 1971), however, have been more interested in the product life cycle as a prediction model for product sales. Other recent authors have stressed the value of the product life cycle as a guiding principle for activities, known under such names as new product planning, new product research, and the management of innovation (de Kluyver 1977). The product cycle has also found application in studies of the process of regional economic development (Thomas 1975; Rees 1979; Norton and Rees 1979). Its potentialities merit further exploration and study.

De Kluyver (1977) has indicated an interesting avenue of empirical evaluation when he recently examined the relationship between the degree of innovation that selected industrial component products represent and the shape of their product life cycle. He found three types of product life cycles for these industrial components. The highly innovative products tend to follow a Type I product life-cycle form; "medium degree innovations" seem to have Type II form; and Type III product life cycles appear to represent the expansion curve for products with a low degree of product newness as shown in the accompanying figure. The degree of uncertainty connected with innovation or, in other words, its degree of innovativeness, appears to affect the rate of adoption or purchase of the product. Different learning curves are probably involved in the purchase of the products represented by the three types of product life cycles. In the case of these industrial components the average length of the commercial life for Types I, II, and III product life cycles was, respectively, 48.7 months; 50.7 months; and 43.5 months.

"A discriminant analysis was performed on the three types of product life cycles with a product newness index and customer firm variables" (de Kluyver 1977:29). Product newness was defined in terms of its engineering design family, degree of

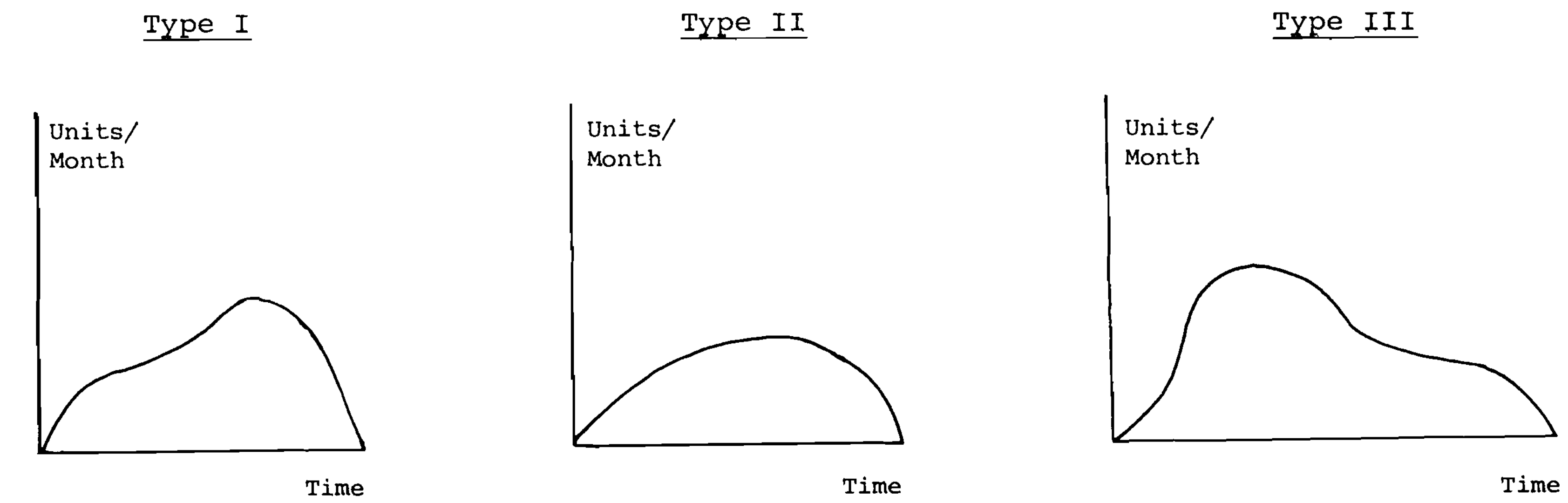

Figure 1. Product life cycles for industrial components. (Source: adapted from de Kluyver, 1977:26.)

newness of application, and its elasticity of substitution. Customer firm descriptor variables used in the study were firm size, growth rate, and profitability. The high degree of multicollinearity among these customer firm variables, however, adversely affected their discriminatory power.

The analysis revealed that "a statistically significant correlation exists between the degree of product newness ... and the shape of the product life cycle. The product newness index was found to be the most significant variable" (de Kluyver 1977:29). Among the customer firm variables, size and growth rate, measured either in terms of sales or assets, were shown to be weakly significant. Tentative support was also given to the hypothesis that smaller firms are likely to adopt innovations faster than larger firms in an oligopolistic market because they have a greater need to enhance their competitive positions. This hypothesis, however, requires further rigorous testing.

As noted earlier, the apparent existence of product life cycles with different forms was indicated by Gold in his examination of the product expansion curves developed by Burns. De Kluyver's study tends to support some of Gold's findings. His product life cycles, however, have a much shorter life and they probably represent the life of "purer" single products than those examined by Gold. In other words, Burns's product cycle may well represent the composite birth and death of the members of a product family. We need more empirical studies before we can comment more definitively about the apparent variations in the forms of product life cycles and before we can provide good reasons why these variations occur. De Kluyver's study represents a good and stimulating contribution to this field of enquiry. Indeed he may well have focused attention on certain "systematic forces" of the kind Burns had discussed and searched for in an earlier era.

Industry Life Cycle

Recently Magee (1977) has introduced and described the stages of the industry technology cycle, which he wishes to differentiate from the product cycle. Magee's industry technology cycle has three stages: (1) first stage - invention, (2) second stage - innovation (which includes phases one and two of the product cycle), and (3) third stage - standardized product and standardized industry.

The form and duration of the industry technology cycle is based on the notion suggested by Nelson (1962) that there is a relationship between the total number of patents and the age of the industry. Over long periods of time this relationship tends to follow an S curve. The eventual leveling off of the total number of patents is expected to be associated with the diminishing marginal returns on the stock of information created in the industry. The expected decline in successive research and development (R & D) investments as a percentage of industry sales appears to coincide with the "leveling-off stage" of the total number of patents. In 1967, for 29 U.S. three-digit industries for which industry age data were available, the simple correlation between R & D investments as a percentage of sales and industry age was minus .34 (Magee 1977:306).

What meaning these relationships, such as those between the number of patents, R & D expenditures, and age of industry, may have with respect to industry growth patterns is not discussed explicitly by Magee. For many reasons a patent does not necessarily result in an innovation and even an innovation does not necessarily have a successful commercial life. Patents and innovations vary greatly in their commercial importance. Furthermore, not all innovations are patented and not all technical advances are patentable. These and other aspects need further discussion and elaboration.

The concept of an industry-technology cycle is, however, intriguing and worth investigating. It would be useful to examine, for example, the impact of changing the levels of industry aggregation on the relationship between the variables correlated by Magee. What is the nature of the relationship between the number of patents and suitably lagged industry outputs? To what degree is it possible and useful to differentiate between patents that are used to bring about qualitative changes in specific industry products and those patents that contribute to changes in production costs and productivity? To what extent does a patent or a stream of related patents affect the various production costs, qualitative dimensions, and range of products produced by the different subindustry components of a specific industry? Answers to these and related questions should provide greater understanding of the nature and significance of the impact of patents on processes that determine patterns of growth and structural change within an industry.

R & D Activities

Magee's concept of an industry-technology life cycle is in some ways disappointing because it is so similar to the "simple" product life cycle, despite its suggestive promise of emphasis on the more comprehensive and complex industry. Both product and industry life cycles have a strong technical bias or focus. Magee's explicit discussion of the importance of research and development activities carried out by firms in the industry represents a major contribution. He confines R & D activities to the invention stage of a product life cycle. However, many scholars would question the apparent termination of R & D investment when the invention becomes an innovation. Indeed, one may argue that there is merit to viewing R & D investments and activities as being desirable, if not necessary, over the life cycle of an industry. The level and nature of such investments would, however, be expected to change as the industry moved along its life cycle through the invention, innovation, and standardized product stages. The industry would tend to need different kinds of information from its R & D activities during these stages.

One might speculate that early in the industry cycle R & D activities may be focused primarily on innovations that affect the nature of the industry's product. Interindustry and interfirm competition are greatly influenced at this stage by the nature of their products. Production function changes would be expected to be common initially and their number would tend to decline with the passage of time. R & D activities focused on enhancing marketing and cost efficiencies would be expected to grow in importance as the industry enters its standardization stage of development.

There is general agreement among researchers in the field that research and development activities merit much greater study at both industry and firm levels. To date there appears to be a paucity of reliable studies because of serious problems associated with data and methodological deficiencies. The subject is of great interest to those seeking a greater knowledge and understanding of industrial growth and structural change because R & D "funds represent investment in knowledge and technology to increase factor productivity and salable output" (Leonard 1971:233). The generally advanced, although little tested, hypothesis suggests that R & D expenditures are directly related to sales, profits, and productivity.

During the 1960s and 1970s a number of studies were carried out to estimate the relationship between output and various inputs such as R & D. Notwithstanding admitted data and methodological deficiencies, Mansfield (1977) believed that such studies provided reasonably persuasive results. They show that the rates of productivity increase, in the industries and time periods studied, appeared to be significantly affected by R & D inputs. For example, Mansfield (1968) and Minasian (1969) estimated that in the chemicals and petroleum industries a firm's marginal rate of return on R & D investments varied from 30 to 40 percent in the chemical industry and 40 percent or more in the petroleum industry. Other researchers, such as Terleckyj (1974), Nadiri and Bitros (1978), and Griliches (1978), have examined the relationship between productivity and R & D in many industries and firms. Their results also indicate that the rate of R & D expenditures had a significant effect on the rate of productivity increase in the industries and firms they studied. However, they show that the marginal rate of return on R & D investment was much higher in some industries than others. The significance of the nature of the relationship established between productivity and R & D investments in these studies suggests that it would be important to find out what determines the level and composition of investments in R & D in different industries over time.

In a recent colloquium on the relationship between R & D and economic growth and productivity sponsored by the U.S. National Science Foundation, Nadiri (1977) calls attention to a shift away from basic research investments in the United States since 1962. The percentage of R & D expenditures to total sales in R & D industries in the United States has fallen since 1964 (National Science Foundation 1978:4). One wonders what impact these declines may have now and in the foreseeable future on productivity in individual industries and throughout the economy. The indirect or "spill-over" effects from R & D expenditures on the rate of productivity and quality changes in inputs and outputs are believed to be transmitted from industry to industry through input-output linkages. Although they are thought to be an important source of productivity increase and quality multiplier effect, they nevertheless have not received much attention (Thomas 1969:51). Nadiri (1977) also believes that the underlying technical change diffusion mechanism is not well understood. Clearly this general topic concerning the role of R & D in influencing new product creation and increasing factor cost and use efficiency is replete with research challenges. In this brief discussion it has not been possible even to mention many important aspects of the topic.

CONCLUSION

A number of conceptual frameworks have been examined in terms of their usefulness in providing a greater understanding of the processes of industrial growth and structural change.

Contemporary macro-economic growth theories, such as the development stages, have emphasized the importance of technical change as an explanatory variable even though it is given mechanistic characteristics. Attention was also focused on the role of income elasticity of demand in effecting structural change. It was shown that the concept of a propulsive industry as used in unbalanced growth theories has been a suggestive and useful explanatory notion. Perroux's seminal work on growth pole theory, in particular, provided many perceptive insights and fruitful lines of enquiry into the process of industrial growth and change. However, his emphasis on the importance of interindustry technological linkages in this process appears to be more useful in the study of short-period rather than long-period industrial growth and structural change. The latter requires a much stronger focus on the significant role of technical change.

Micro studies of industry and product expansion curves by Kuznets, Burns, Gold, and others have provided stimulating insights and perspectives on growth and change in the manufacturing sector. A recently revived interest in product and industry life cycles is providing a new major impetus to the study of how and why manufacturing industries grow and change. The concomitant studies of the nature and significances of relationships between research and development activities and innovations are providing interesting and useful information for those who are examining the relationships between innovations and industrial growth and change. This is an exciting period for those interested in investigating the many perspectives on economic growth and structural change, especially in the manufacturing sector.

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