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Preface

The research project on *Systems Analysis of Technological and Economic Dynamics* at IIASA is concerned with modeling technological and organisational change; the broader economic developments that are associated with technological change, both as cause and effect; the processes by which economic agents – first of all, business firms – acquire and develop the capabilities to generate, imitate and adopt technological and organisational innovations; and the aggregate dynamics – at the levels of single industries and whole economies – engendered by the interactions among agents which are heterogeneous in their innovative abilities, behavioural rules and expectations. The central purpose is to develop stronger theory and better modeling techniques. However, the basic philosophy is that such theoretical and modeling work is most fruitful when attention is paid to the known empirical details of the phenomena the work aims to address: therefore, a considerable effort is put into a better understanding of the 'stylized facts' concerning corporate organisation routines and strategy; industrial evolution and the 'demography' of firms; patterns of macroeconomic growth and trade.

From a modeling perspective, over the last decade considerable progress has been made on various techniques of dynamic modeling. Some of this work has employed ordinary differential and difference equations, and some of it stochastic equations. A number of efforts have taken advantage of the growing power of simulation techniques. Others have employed more traditional mathematics. As a result of this theoretical work, the toolkit for modeling technological and economic dynamics is significantly richer than it was a decade ago.

During the same period, there have been major advances in the empirical understanding. There are now many more detailed technological histories available. Much more is known about the similarities and differences of technical advance in different fields and industries and there is some understanding of the key variables that lie behind those differences. A number of studies have provided rich information about how industry structure co-evolves with technology. In addition to empirical work at the technology or sector level, the last decade has also seen a great deal of empirical research on productivity growth and measured technical advance at the level of whole economies. A considerable body of empirical research now exists on the facts that seem associated with different rates of productivity growth across the range of nations, with the dynamics of convergence and divergence in the levels and rates of growth of income, with the diverse national institutional arrangements in which technological change is embedded.

As a result of this recent empirical work, the questions that successful theory and useful modeling techniques ought to address now are much more clearly defined. The theoretical work has often been undertaken in appreciation of certain stylized facts that needed to be explained. The list of these 'facts' is indeed very long, ranging from the microeconomic evidence concerning for example dynamic increasing returns in learning activities or the persistence of particular sets of problem-solving routines within business firms; the industry-level evidence on entry, exit and size-distributions – approximately log-normal – all the way to the evidence regarding the time-series properties of major economic aggregates. However, the connection between the theoretical work and the empirical phenomena has so far not been very close. The philosophy of this project is that the chances of developing powerful new theory and useful new analytical techniques can be greatly enhanced by performing the work in an environment where scholars who understand the empirical phenomena provide questions and challenges for the theorists and their work.

In particular, the project is meant to pursue an 'evolutionary' interpretation of technological and economic dynamics modeling, first, the processes by which individual agents and organisations learn, search, adapt; second, the economic analogues of 'natural selection' by which interactive environments – often markets – winnow out a population whose members have different attributes and behavioural traits; and, third, the collective emergence of statistical patterns, regularities and higher-level structures as the aggregate outcomes of the two former processes.

Together with a group of researchers located permanently at IIASA, the project coordinates multiple research efforts undertaken in several institutions around the world, organises workshops and provides a venue of scientific discussion among scholars working on evolutionary modeling, computer simulation and non-linear dynamical systems.

The research focuses upon the following three major areas:

1. Learning Processes and Organisational Competence.
2. Technological and Industrial Dynamics
3. Innovation, Competition and Macrodynamics

Technological Regimes, Industrial Demography and the Evolution of Industrial Structures

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Abstract

The purpose of this paper is to weave together the new theories and empirical evidence analyzing firms and industries in motion, or what has been termed as *industry demographics*. In particular, the links between the technological regime underlying an industry and the observed patterns of industry demography are emphasized. Although a major conclusion of this new literature is that the structure of industries is perhaps better characterized by a high degree of fluidity and turbulence than stability, the patterns of industry demographics vary considerably from industry to industry. And what apparently shapes the evolution of firms particular to a specific industry is, as much as anything else, the knowledge conditions shaping the technological regime underlying that industry.

1 Introduction

Schumpeter (1942, p. 132) predicted that, due to scale economies in the production of new economic knowledge, large corporations would not only have the innovative advantage over small and new enterprises, but that ultimately the economic landscape would consist only of giant corporations: "Innovation itself is being reduced to routine. Technological progress is increasingly becoming the business of teams of trained specialists who turn out what is required and make it work in predictable ways." Certainly the perceived economic threat posed by the Soviet Union in the late 1950s and early 1960s was attributable to its ability to concentrate economic assets and exhaust scale economies to a degree that was unthinkable in the West, where a commitment to political democracy seemingly translated into a concomitant commitment to economic decentralization.

Perhaps the ascendancy of industrial organization as a field in economics during this period came from the recognition not only by scholars but also by policymakers that industrial organization matters. And it became the task of the industrial organization scholars to sort out the issues involving this perceived trade-off between economic efficiency on the one hand and political and economic decentralization on the other. The scholars of industrial organization[1] responded with a massive literature focusing on essentially three issues: (1) how much economic concentration is there?, (2) what are the economic welfare implications of an oligopolistic market structure? and (3) given the evidence that economic concentration was associated with efficiency, what were the public policy implications? A characteristic of this literature was not only that it was obsessed with the concentration/oligopoly question, but it was essentially static in nature. There was considerable concern about what to do about the firms and industrial structures that existed, but little attention paid to where they came from and where they were going. Oliver Williamson's classic 1968 article, "Economies as an

[1] This literature is best documented in Scherer and Ross (1990).

Antitrust Defense: The Welfare Tradeoffs," became something of a final statement demonstrating this seemingly inevitable tradeoff between the gains in productive efficiency that could be obtained through increased concentration and gains in terms of competition that could be achieved through decentralizing policies, such as antitrust. But it did not seem possible to have both, certainly not in Oliver Williamson's completely static model.

Yet what has become striking about the industrial structure of the United States is not its stability, but rather the opposite -- its dynamic, turbulent nature. According to *Business Week*, "In recent years, the giants of industry have suffered a great comeuppance -- as much from the little guys as from fierce global competition. IBM continues to reel from the assaults of erstwhile upstarts such as Microsoft, Dell Computer, and Compaq Computer. Big Steel was devastated by such minimills as Nucor, Chaparral Steel, and Worthington Industries. One-time mavericks Wal-Mart Stores and The Limited taught Sears, Roebuck a big lesson. Southwest Airlines has profitably flown through turbulence that has caused the big airlines to rack up $10 billion in losses over the past three years. And a brash pack of startups with such names as Amgen Inc. and Centocor Inc. has put the U.S. ahead in biotechnology -- not Bristol-Myers, Squibb, Merck, or Johnson & Johnson.

The industrial landscape of the United States has been radically transformed in a relatively short period of time. A number of corporate giants such as IBM, U.S. Steel, RCA and Wang have lost their aura of invincibility. Only slightly more than a decade ago Peters and Waterman, in their influential best-selling management book, *In Search of Excellence: Lessons from America's Best Run Companies*, identified IBM as the best-run corporation in America and possibly in the entire world. At the same time has come the breathtaking emergence of new firms that hardly existed two decades ago, such as Microsoft, Apple Computer, Intel, Dell, and Compaq Computer. In the 1950s and 1960s it took two decades for one-third of the Fortune

500 to be replaced. In the 1970s it took one decade. By contrast, in the 1980s it took just five years for one-third of the Fortune 500 firms.

Perhaps even more impressive than the handful of new enterprises that grow to penetrate the Fortune 500 are the armies of startups that come into existence each year -- and typically disappear into oblivion within a few year. In the 1990s there are around 1.3 million new companies started each year (Audretsch, 1995). That is, the modern economy is characterized by a tremendous degree of turbulence. It is an economy in motion, with a massive number of new firms entering each year, but only a subset surviving for any length of time, and an even smaller subset that can ultimately challenge and displace the incumbent large enterprises.

Despite the high degree of fluidity and turbulence in modern economies, very little is actually known about the dynamic process through which industries and firms evolve over time. Perhaps this lack of knowledge motivated Edwin Mansfield (1962, p. 1023) some thirty years ago to make a plea for a greater emphasis on the dynamic process by which industries change over time: "Because there have been so few econometric studies of the birth, growth, and death of firms, we lack even crude answers to the following basic questions regarding the dynamic processes governing an industry's structure. What are the quantitative effects of various factors on the rates of entry and exit? What have been the effects of successful innovations on a firm's growth rate? What determines the amount of mobility within an industry's size structure?" In the intervening three decades a new literature has emerged focusing on industrial markets in motion. In particular, this literature examines the process by which new firms enter into industrial markets, either grow and survive or exit from the industry, and possibly displace incumbent corporations. At the heart of this evolutionary process is innovation, because the potential for innovative activity serves as the driving force behind much of the evolution of industries. And it is innovative activity that explains why the patterns of industry evolution vary from industry to industry, depending upon the underlying knowledge conditions, or what Nelson and Winter (1982) term *technological regimes*.

The purpose of this paper is to weave together the new theories and empirical evidence analyzing firms and industries in motion, or what has been termed as *industry demographics*. In particular, the links between the technological regime underlying an industry and the observed patterns of industry demography are emphasized. In the following section the traditional static view of industrial organization provided by the literature of industrial economics is portrayed. The concept of technological regimes and their influence on innovative activity is explained in the third section. The fourth section focuses on entry, and the fifth section on survival and growth. In the sixth section the role that wages and non-wage employee compensation plays is examined. The theories and evidence is synthesized in the seventh section to provide a coherent model of industrial organization within an evolutionary framework. Finally, in the eighth section a summary and conclusions are provided.

2 The Static View of Industrial Organization

Two stylized facts that have emerged from a plethora of studies pose something of a puzzle to scholars of industrial organization. The first, which has received considerable attention at least since the seminal study by Herbert Simon and Charles Bonini (1958) more than three decades ago, is the persistence of an asymmetric firm-size distribution predominated by small enterprises. Ijiri and Simon (1977, p. 2) characterize this "regularity in social phenomena that is both striking and observable in a number of quite diverse situations. It is a regularity in the size distribution of firms."[2] In fact, virtually, no other economic phenomenon

[2] Ijiri and Simon (1977, pp. 1-2) observe that, "Nature, as it presents itslef to the physical scientist, is full of clearly defined patterns...The patterns that have been discovered in social phenomena are much less neat. To be sure, economics has evolved a highly sophisticated body of mathematical laws, but for the most part, these laws bear a rather distinct relation to empirical phenomena...Hence, on those occassions when a social phenomenon

has persisted as consistently as the skewed asymmetric firm-size distribution. Not only is it almost identical across every manufacturing industry, but it has remained strikingly constant over time, at least since the Second World War, and even across developed industrialized nations (Acs and Audretsch, 1993).

The persistence of this skewed asymmetric firm-size distribution is consistent with the common observation in industrial organization that the bulk of firms in most industries are operating at a suboptimal level of output. Building on his earlier studies on the extent of suboptimal scale plants and firms in industrial markets, Leonard Weiss in 1991 concluded that, "In most industries the great majority of firms is suboptimal. In a typical industry there are, let's say, one hundred firms. Typically only about five to ten of them will be operating at the MES (minimum efficient scale) level of output, or anything like it."[3] Not only did Weiss find that the MES level of output exceeds that of most firms (enterprises) and plants (establishments), but that, "On the average, about half of total shipments in the industries covered are suboptimal in scale, and a very large percentage of output is from suboptimal plants in some unconcentrated industries." The persistence of what has traditionally been classified as suboptimal plants to dominate the firm-size distribution in industrial markets over time raises the question of not only why do suboptimal scale plants exist but how are they able to exist.[4]

The second puzzling stylized fact has been established by a number of studies that have found that the entry of new firms into an industry is apparently not substantially deterred in industries where scale economies play an important role. Taken together, these two stylized facts raise two troubling questions, *Why is it that the preponderance of enterprises in virtually*

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appears to exhibit some of the same simplicity and regularity of pattern as is seen so commonly in physics, it is bound to excite interest and attention."

[3] Quotation from p. xiv. of the "editor's introduction" to Weiss (1991).

[4] Weiss (1991, p. 404) observed that, "The survival of smaller plants within any given industry may be due to their specialization in items with short production runs or to their service of small geographic markets within which their relatively small national market share is irrelevant. To the extent that such explanations hold, small plants are not necessarily suboptimal. However, such explanations seem unlikely to hold for a number of the industries where the percentage of suboptimal capacity is large."

every U.S. manufacturing industry are small? and *Why are entrepreneurs not more noticeably deterred from entering industries characterized by substantial scale economies?* The traditional static view has been able to shed little light on resolving these two empirical paradoxes.

3 Innovation and Technological Regimes

3.1 The Knowledge Production Function

The starting most for most theories of innovation is the firm.[5] In such theories the firms are exogenous and their performance in generating technological change is endogenous.[6] For example, in the most prevalent model found in the literature of technological change, the model of the *knowledge production function*, formalized by Zvi Griliches (1979), firms exist exogenously and then engage in the pursuit of new economic knowledge as an input into the process of generating innovative activity.

The most decisive input in the knowledge production function is new economic knowledge. And as Cohen and Klepper conclude, the greatest source generating new economic knowledge is generally considered to be R&D.[7] Certainly a large body of empirical work has found a strong and positive relationship between knowledge inputs, such as R&D, on the one hand, and innovative outputs on the other hand.

Audretsch (1995) proposes shifting the unit of observation away from exogenously assumed firms to individuals -- agents with endowments of new economic knowledge. As J. de V. Graaf (1957) observed nearly four decades ago, "When we try to construct a transformation function for society as a whole from those facing the individual firms comprising it, a

[5] See for reviews of this literature Baldwin and Scott (1987), Cohen and Levin (1989), Scherer (1984 and 1992), and Dosi (1988).
[6] See for example Scherer (1984 and 1991), Cohen and Klepper (1991, 1992a and 1992b), and Arrow (1962 and 1983).
[7] Cohen and Klepper (1991 and 1992a and 1992b).

fundamental difficulty confronts us. There is, from a welfare point of view, nothing special about the firms actually existing in an economy at a given moment of time. The firm is in no sense a 'natural unit'. Only the individual members of the economy can lay claim to that distinction. All are potential entrepreneurs. It seems, therefore, that the natural thing to do is to build up from the transformation function of men, rather than the firms, constituting an economy. If we are interested in eventual empirical determination, this is extremely inconvenient. But it has conceptual advantages. The ultimate repositories of technological knowledge in any society are the men comprising it, and it is just this knowledge which is effectively summarized in the form of a transformation function. In itself a firm possesses no knowledge. That which is available to it belongs to the men associated with it. Its production function is really built up in exactly the same way, and from the same basic ingredients, as society's."

3.2 The Appropriability Problem Revisited

A large literature has emerged focusing on what has become known as the *appropriability problem*.[8] The underlying issue revolves around how firms which invest in the creation of new economic knowledge can best appropriate the economic returns from that knowledge (Arrow, 1962). But when the lens is shifted away from focusing upon the firm as the relevant unit of observation to individuals, the relevant question becomes, *How can economic agents with a given endowment of new knowledge best appropriate the returns from that knowledge?*

The appropriability problem confronting the individual may converge with that confronting the firm. Economic agents can and do work for firms, and even if they do not, they can potentially be employed by an incumbent firm. In fact, in a model of perfect information with no agency costs, any positive economies of scale or scope will ensure that the

[8] See Cohen and Levin (1989) and Baldwin and Scott (1987).

appropriability problems of the firm and individual converge. If an agent has an idea for doing something different than is currently being practiced by the incumbent enterprises -- both in terms of a new product or process and in terms of organization -- the idea, which can be termed as an innovation, will be presented to the incumbent enterprise. Because of the assumption of perfect knowledge, both the firm and the agent would agree upon the expected value of the innovation. But to the degree that any economies of scale or scope exist, the expected value of implementing the innovation within the incumbent enterprise will exceed that of taking the innovation outside of the incumbent firm to start a new enterprise. Thus, the incumbent firm and the inventor of the idea would be expected to reach a bargain splitting the value added to the firm contributed by the innovation. The payment to the inventor -- either in terms of a higher wage or some other means of remuneration -- would be bounded between the expected value of the innovation if it implemented by the incumbent enterprise on the upper end, and by the return that the agent could expect to earn if he used it to launch a new enterprise on the lower end. Or, as Frank Knight (1921, p. 273) observed more than seventy years ago, "The laborer asks what he thinks the entrepreneur will be able to pay, and in any case will not accept less than he can get from some other entrepreneur, or by turning entrepreneur himself. In the same way the entrepreneur offers to any laborer what he thinks he must in order to secure his services, and in any case not more than he thinks the laborer will actually be worth to him, keeping in mind what he can get by turning laborer himself."

Thus, each economic agent would choose how to best appropriate the value of his endowment of economic knowledge by comparing the wage he would earn if he remains employed by an incumbent enterprise, w, to the expected net present discounted value of the profits accruing from starting a new firm, π . If these two values are relatively close, the probability that he would choose to appropriate the value of his knowledge through an external mechanism such as starting a new firm, Pr(e), would be relatively low. On the other hand, as the gap between w and π becomes larger, the likelihood of an agent choosing to appropriate the value of his knowledge externally through starting a new enterprise becomes greater, or

$$\Pr(e) = f(\pi - w) \tag{1}$$

3.3 Asymmetric Knowledge, Transaction Costs, and the Principal-Agent Relationship

As Knight (1921), and later Arrow (1962) emphasized, new economic knowledge is anything but certain. Not only is new economic knowledge inherently risky, but substantial asymmetries exist across agents both between and within firms. (Milgrom and Roberts, 1987). Which is to say that the expected value of a new idea, or what has been termed here as a potential innovation, is likely to be anything but unanimous between the inventor of that idea and the decisionmaker, or group of decisionmakers,[9] of the firm confronting with evaluating proposed changes or innovations. In fact, it is because information is not only imperfect but also asymmetric that Knight (1921, p. 268) argued that the primary task of the firm is to process information in order to reach a decision: "With the introduction of uncertainty -- the fact of ignorance and the necessity of acting upon opinion rather than knowledge -- into this Eden-like situation (that is a world of perfect information), its character is entirely changed...With uncertainty present doing things, the actual execution of activity, becomes in a real sense a secondary part of life; the primary problem or function is deciding what to do and how to do it."

Alchian (1950) pointed out that the existence of knowledge asymmetries would result in the inevitability of mistaken decisions in an uncertain world. Later, Alchian and Demsetz (1972) attributed the existence of asymmetric information across the employees in a firm as resulting in a problem of monitoring the contribution accruing from each employee and setting

[9] For example, as of 1993 a proposal for simply modifying an existing product at IBM had to pass through 250 layers of decisionmaking to gain approval ("Überfördert und Unregierbar," *Der Spiegel*, No. 14, 1993, p. 127).

the rewards correspondingly. This led them to conclude that, "The problem of economic organization is the economical means of metering productivity and rewards" (Alchian and Demsetz, 1972, p. 783).

Combined with the bureaucratic organization of incumbent firms to make a decision, the asymmetry of knowledge leads to a host of agency problems, spanning incentive structures, monitoring, and transaction costs. It is the existence of such agency costs, combined with 'asymmetric information that not only provides an incentive for agents with new ideas to appropriate the expected value of their knowledge externally by starting new firms, but also with a propensity that varies systematically from industry to industry.

Coase (1937) and later Williamson (1975) argued that the size of an (incumbent) enterprise will be determined by answering what Coase (1937, p. 30) articulated as, "The question always is, will it pay to bring an extra exchange transaction under the organizing authority?" In fact, Coase (1937, p. 24) pointed out that, "Other things being equal, a firm will tend to be larger the less likely the (firm) is to make mistakes and the smaller the increase in mistakes with an increase in the transactions organized."

Holmstrom (1989) and Milgrom (1988) have pointed out the existence of what they term as a *bureaucratization dilemma*, where, "To say that increased size brings increased is a safe generalization. To note that bureaucracy is viewed as an organizational disease is equally accurate" (Holmstrom, 1989, p. 320).

To minimize agency problems and the cost of monitoring, bureaucratic hierarchies develop objective rules. In addition, Kreps (1991) has argued that such bureaucratic rules promote internal uniformity and that a uniform corporate culture, in turn, promotes the reputation of the firm. These bureaucratic rules, however, make it more difficult to evaluate the efforts and activities of agents involved in activities that do not conform to such bureaucratic rules. As Holmstrom (1989, p. 323) points out, "Monitoring limitations suggest that the firm seeks out activities which are more easily and objectively evaluated. Assignments will be chosen in a fashion that are conducive to more effective control. Authority and command systems work better in environments which are more predictable and can be directed with less investment information. Routine tasks are the comparative advantage of a bureaucracy and its activities can be expected to reflect that."

Williamson (1975, p. 201) has also emphasized the inherent tension between hierarchical bureaucratic organizations and the ability of incumbent organizations to appropriate the value of new knowledge for innovative activity outside of the technological trajectories associated with the core competence of that organization, "Were it that large firms could compensate internal entrepreneurial activity in ways approximating that of the market, the large firm need experience no disadvantage in entrepreneurial respects. Violating the congruency between hierarchical position and compensation appears to generate bureaucratic strains, however, and is greatly complicated by the problem of accurately imputing causality." This leads Williamson (1975, pp. 205-206) to conclude that, "I am inclined to regard the early stage innovative disabilities of large size as serious and propose the following hypothesis: An efficient procedure by which to introduce new products is for the initial development and market testing to be performed by independent investors and small firms (perhaps new entrants) in an industry, the successful developments then to be acquired, possibly through licensing or merger, for subsequent marketing by a large multidivision enterprise...Put differently, a division of effort between the new product innovation process on the one hand, and the management of proven resources on the other may well be efficient.

3.4 The Role of Technological Regimes

The degree to which agents and incumbent firms are confronted with knowledge asymmetries and agency problems with respect to seeking out new economic knowledge and (potential) innovative activity would not be expected to be constant across industries. This is because the underlying knowledge conditions vary from industry to industry. In some industries new economic knowledge generating innovative activity tends to be relatively routine and can be processed within the context of incumbent hierarchical bureaucracies. In other industries, however, innovations tend to come from knowledge that is not of a routine nature and therefore tends to be rejected b y the hierarchical bureaucracies of incumbent corporations. Nelson and Winter (1972, 1978 and 1982) described these different underlying knowledge conditions as reflecting two distinct technological regimes -- the entrepreneurial and routinized technological regimes: "An entrepreneurial regime is one that is favorable to innovative entry and unfavorable to innovative activity by established firms; a routinized regime is one in which the conditions are the other way around." (Winter, 1984, p. 297).[10]

Gort and Klepper (1982) argued that the relative innovative advantage between newly established enterprises and incumbent firms depends upon the source of information generating innovative activity. If information based on nontransferable experience in the market is an important input in generating innovative activity, then incumbent firms will tend to have the innovative advantage over new firms. This is consistent with Winter's (1984) notion of the routinized regime, where the accumulated stock of nontransferable information is the product of experience within the market, which firms outside of the main incumbent organizations, by definition, cannot possess.

By contrast, when information outside of the routines practiced by the incumbent firms is a relatively important input in generating innovative activity, newly established firms will tend to have the innovative advantage over incumbent firms. Arrow (1962), Mueller (1976), and Williamson (1975) have all emphasized that when such information created outside of the incumbent firms cannot be easily transferred to those incumbent enterprises -- presumably due

[10] See also Malerba (1991) and Malerba and Orsenigo (1993).

to the type of agency and bureaucracy problems described above -- the holder of such knowledge must enter the industry by starting a new firm in order to exploit the expected value of his knowledge.

While the concept of technological regimes does not lend itself to precise measurement, the major conclusion of Acs and Audretsch (1988 and 1990) and Audretsch (1990) was that the existence of these distinct regimes can be inferred by the extent to which small firms are able to innovate relative to the total amount of innovative activity in an industry. That is, when the small-firm innovation rate is high relative to the total innovation rate, the technological and knowledge conditions are more likely to reflect the entrepreneurial regime. The routinized regime is more likely to exhibit a low small-firm innovation rate relative to the total innovation rate. The existence of these two distinct technological regimes is documented in Audretsch (1995).

In the most innovative four-digit standard industrial classification (SIC) industries, large firms, defined as enterprises with at least 500 employees, contributed more innovations in some instances, while in other industries small firms proved to be more innovative. For example, in both the electronic computing equipment and process control instruments industries, the small firms contributed most of the innovations. By contrast in the pharmaceutical preparation industry and in aircraft the large firms were much more innovative.

Probably the best measure of innovative activity is the total innovation rate, which is defined as the total number of innovations per 1,000 employees in each industry. The large-firm innovation rate is defined as the number of innovations made by firms with at least 500 employees, divided by the number of employees (thousands) in large firms. The small-firm innovation rate is analogously defined as the number of innovations contributed by firms with fewer than 500 employees, divided by the number of employees (thousands) in small firms.

The innovation rates, or the number of innovations per 1,000 employees, have the advantage in that they measure large- and small-firm innovative activity relative to the presence of large and small firms in any given industry. That is, in making a direct comparison between large- and small-firm innovative activity, the absolute number of innovations contributed by large firms and small enterprises is somewhat misleading, since these measures are not standardized by the relative presence of large and small firms in each industry. Hence the innovation rates are presumably a more reliable measure of innovative intensity. Thus, while large firms in U.S. manufacturing introduced 2445 innovation, and small firms contributed slightly fewer, 1954, small-firm employment was only half as great as large-firm employment, yielding an average small-firm innovation rate of 0.309, compared to a large-firm innovation rate of 0.202.

In a series of studies, Acs and Audretsch (1988 and 1990) found that not only does market concentration negatively influence the total amount of innovative activity, but also the relative innovative advantage of large and small enterprises, that is the technological regime underlying the particular industry. Whether an industry can be better characterized by the routinized technological regime or the entrepreneurial technological regime is shaped by:

1. the degree of capital intensity;

2. the extent to which an industry is concentrated;

3. the total amount of innovative activity in the industry; and

4. the extent to which an industry is comprised of small firms.

In particular, the routinized technological regime, where the large incumbent firms tend to have the relative innovative advantage, tends to be characteristic of industries that are capital intensive, advertising intensive, concentrated and highly unionized. By contrast, the entrepreneurial technological regime tends to be characteristic of industries that are highly innovative and comprised predominantly of large firms.

4 Entry

4.1 The Traditional View

Coase (1937) was awarded a Nobel Prize for explaining why a firm should exist. But why should more than one firm exist in an industry?[11] One answer is provided by the traditional economics literature focusing on industrial organization. An excess level of profitability induces entry into the industry. And this is why the entry of new firms is interesting and important -- because the new firms provide an equilibrating function in the market, in that the levels of price and profit are restored to the competitive levels.

In this traditional theory, outputs and inputs in an industry are assumed to be homogeneous. That is, the entry of new firms is about business as usual -- it is just that with the new entrant there is more of it. For example, Geroski (1991a, p. 65) assumes that, "If we think of entry as an error-correction mechanism which is attracted by and serves to bid away excess profits, it is natural to suppose that entry will occur whenever profits differ from their long-run levels. Given this maintained hypothesis, observations of actual entry rates and current (or expected post-entry) profits can be used to make inferences about the unobservable of interest -- long-run profits. In particular, entry in an industry is hypothesized to occur whenever expected post-entry profits exceed the level of profits protected in the long run."

This leads to the traditional model of entry:

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[11] Coase (1937, p. 23) himself asked, "A pertinent question to ask would appear to be (quite apart from the monopoly considerations raised by Professor Knight), why, if by organizing one can eliminate certain costs and in fact reduce the cost of production, are there any market transactions at all? Why is not all production carried on by one big firm?"

$$E_{jt} = \lambda(P_{jt} - b_j) + \mu_{jt} \qquad (2)$$

where E_{jt} represents entry in industry j at time t, P_{jt} represents expected post-entry profits, and b_j represents the level of profits protected in the long run by entry barriers b_j, and u_{jt} represents stochastic disturbance. In this standard model of entry, which theoretically dates back to Bain (1956) and empirically to Orr (1974), λ measures the speed with which entrants respond to excess profits, and has the dimension of a flow per unit of time. The level of profits which can be sustained in perpetuity without attracting entry is b_j, and serves as a limit to what Geroski (1991a, pp. 65-66) terms as "limits profits", and is a natural measure of the height of barriers to entry.

The point to be emphasized here is that this traditional model assumes that the impact that the new entrant has on the market, and on equilibrium price and industry profits, is through the additional amount of output that is contributed. And the fundamental motivation for entering an industry, either through a new firm or through diversified entry, as reflected in equation (2) , is that profits exceed their long-run equilibrium level, even after accounting for structural barriers to entry.

In fact, little consensus has emerged in the growing plethora of studies trying to link industry profitability, growth, and structural barriers to entry rates, as implied by equation (2). The level of industry profitability has been found to have only a weak and sometimes ambiguous impact on entry.[12] A positive relationship has generally been found to exist between industry growth rates and entry rates. Presumably higher rates of growth enable incumbent enterprises to raise prices, thereby inducing more entry, or else raise expectations about future profits. For example, in five of the six country studies (Germany, Norway, Portugal, Belgium, and Korea) contained in Geroski and Schwalbach (1991) entry rates were found to be

[12] These studies are reviewed in Geroski (1995).

positively influenced by industry growth rates. Only for the United Kingdom did a negative relationship emerge between entry rates and industry growth.

One of the most startling results that has emerged in empirical studies is that entry by firms into an industry is apparently not substantially deterred or even deterred at all in capital-intensive industries in which scale economies play an important role (Austin and Rosenbaum, 1990; Siegfried and Evans, 1992; and Audretsch, 1995; Acs and Audretsch, 1990, chapter five).

Empirical evidence in support of the traditional model represented by equation (2) is ambiguous at best, leading Geroski (1991b, p. 282) to conclude, "Right from the start, scholars have had some trouble in reconciling the stories told about entry in standard textbooks with the substance of what they have found in their data. Very few have emerged from their work feeling that they have answered half as many questions as they have raised, much less that they have answered most of the interesting ones."

Perhaps one reason for this trouble is the inherently static model used to capture an inherently dynamic process. Manfred Neumann (1993, pp. 593-594) has criticized this traditional model of entry, as found in the individual country studies contained in Geroski and Schwalbach (1991), because they "are predicated on the adoption of a basically static framework. It is assumed that startups enter a given market where they are facing incumbents which naturally try to fend off entry. Since the impact of entry on the performance of incumbents seems to be only slight, the question arises whether the costs of entry are worthwhile, given the high rate of exit associated with entry. Geroski appears to be rather skeptical about that. I submit that adopting a static framework is misleading...In fact, generally, an entrant can only hope to succeed if he employs either a new technology or offers a new product, or both. Just imitating incumbents is almost certainly doomed to failure. If the process of entry is looked upon from this perspective the high correlation between gross entry and exit reflects the inherent risks of innovating activities...Obviously it is rather difficult to break loose from the inherited mode of reasoning within the static framework. It is not without merit, to be sure, but it needs to be enlarged by putting it into a dynamic setting."

4.2 The Evolutionary View

The model proposed by Audretsch (1995) refocuses the unit of observation away from firms deciding whether to increase their output from a level of zero to some positive amount in a new industry, to individual agents in possession of new knowledge that, due to uncertainty, may or may not have some positive economic value. It is the uncertainty inherent in new economic knowledge, combined with asymmetries between the agent possessing that knowledge and the decision making vertical hierarchy of the incumbent organization with respect to its expected value that potentially leads to a gap between the valuation of that knowledge.

How the economic agent chooses to appropriate the value of his knowledge, that is either within an incumbent firm or by starting or joining a new enterprise will be shaped by the knowledge conditions underlying the industry.

Thus, when the underlying knowledge conditions are better characterized by the routinized technological regime, there is likely to be relatively little divergence in the evaluation of the expected value of a (potential) innovation between the inventor and the decisionmaking bureaucracy of the firm. Under the routinized regime a great incentive for agents to start their own firms will not exist, at least not for the reason of doing something differently. When the underlying knowledge conditions more closely adhere to the entrepreneurial technological regime, however, a divergence in beliefs between the agent and the principal regarding the expected value of a (potential) innovation is more likely to emerge. Therefore, it is under the entrepreneurial regime where the startup of new firms is likely to play a more important role, presumably as a result of the motivation to appropriate the value of economic knowledge; due to agency problems, this knowledge cannot be easily and costlessly transferred to the incumbent enterprise.

Under the routinized technological regime the agent will tend to appropriate the value of his new ideas within the boundaries of incumbent firms. Thus, the propensity for new firms to be started should be relatively low in industries characterized by the routinized technological regime.

By contrast, under the entrepreneurial regime the agent will tend to appropriate the value of his new ideas outside of the boundaries of incumbent firms by starting a new enterprise. Thus, the propensity for new firms to enter should be relatively high in industries characterized by the entrepreneurial regime.

Thus, when the underlying knowledge conditions are better characterized by the routinized technological regime, there is likely to be relatively little divergence in the evaluation of the expected value of a (potential) innovation between the inventor and the decisionmaking bureaucracy of the firm. Under the routinized regime a great incentive for agents to start their own firms will not exist, at least not for the reason of doing something differently. When the underlying knowledge conditions more closely adhere to the entrepreneurial technological regime, however, a divergence in beliefs between the agent and the principal regarding the expected value of a (potential) innovation is more likely to emerge. Therefore, it is under the entrepreneurial regime where the startup of new firms is likely to play a more important role, presumably as a result of the motivation to appropriate the value of economic knowledge; due to agency problems, this knowledge cannot be easily and costlessly transferred to the incumbent enterprise.[13]

This model analyzing the decision of how best to appropriate the value of new economic knowledge confronting an individual economic agent seems useful when considering the actual decision to a new firm taken by entrepreneurs. For example, Chester Carlsson started Xerox after h is proposal to produce a (new) copy machine was rejected by Kodak. Kodak based its decision on the premise that the new copy machine would not earn very much money, and in any case, Kodak was in a different line of business -- photography. It is perhaps no small irony that this same entrepreneurial startup, Xerox, decades later turned down a proposal from Steven Jobs to produce and market a personal computer, because they did not think that a personal computer would sell, and, in any case, they were in a different line of business -- copy machines (Carrol, 1993). After seventeen other companies turned down Jobs for virtually identical reasons, including IBM and Hewlett Packard, Jobs resorted to starting his own company, Apple computer.

Similarly, IBM turned down an offer from Bill Gates, "the chance to buy ten percent of Microsoft for a song in 1986, a missed opportunity that would cost $3 billion today."[14] IBM reached its decision on the grounds that "neither Gates nor any of his band of thirty some employees had anything approaching the credentials or personal characteristics required to work at IBM."[15]

Divergences in beliefs with respect to the value of a new idea need not be restricted to what is formally known as a product or even a process innovation. Rather, the fact that economic agents choose to start a new firm due to divergences in the expected value of an idea

[13] There is considerable evidence that geographic proximity plays an important role in the transfer of such knowledge (Audretsch and Feldman, 1995; Audretsch and Stephan, 1995; and Acs, Audretsch and Feldman, 1994)

[14] "System Error," *The Economist*, 18 September 1993, p. 99.

[15] Paul Carrol, "Die Offene Schlacht," *Die Zeit*, No. 39, 24 September 1993, p. 18.

applies to the sphere of managerial style and organization as well. One of the most vivid examples involves Bob Noyce, who founded Intel. Noyce had been employed by Fairchild Semiconductor, which is credited with being the pioneering semiconductor firm. In 1957 Noyce and seven other engineers quit *en masse* from Schockley Semiconductor to form Fairchild Semiconductor, an enterprise that in turn is considered the start of what is today known as *Silicon Valley*. Although Fairchild Semiconductor had "possibly the most potent management and technical team ever assembled" (Gilder, 1989, p. 89), "Noyce couldn't get Fairchild's eastern owners to accept the idea that stock options should be part of compensation for all employees, not just for management. He wanted to tie everyone, from janitors to bosses, into the overall success of the company...This management style still sets the standard for every computer, software, and semiconductor company in the Valley today...Every CEO still wants to think that the place is run the way Bob Noyce would have run it" (Cringley, 1993, p. 39). That is, Noyce's vision of a firm excluded the dress codes, reserved parking places, closed offices, and executive dining rooms, along with the other trappings of status that were standard in virtually every hierarchical and bureaucratic U.S. corporation. But when he tried to impress this vision upon the owners of Fairchild Semiconductor, he was flatly rejected. The formation of Intel in 1968 was the ultimate result of the divergence in beliefs about how to organize and manage the firm.

The key development at Intel was the microprocessor. When long time IBM employee Ted Hoff approached IBM and later DEC with his new microprocessor in the late 1960s, "IBM and DEC decided there was no market. They could not imagine why anyone would need or want a small computer; if people wanted to sue a computer, they could hood into time-sharing systems" (Palfreman and Swade, 1991, p. 108).

While studies have generally produced considerable ambiguity concerning the impact of scale economies and other measures traditionally thought to represent a *barrier to entry*, Audretsch (1995) found conclusive evidence linking the technological regime to startup activity. New-firm startup activity tends to be substantially more prevalent under the entrepreneurial regime, or where small enterprises account for the bulk of the innovative activity, than under the routinized regime, or where the large incumbent enterprises account for most of the innovative activity. These findings are consistent with the view that differences in beliefs about the expected value of new ideas are not constant across industries but rather depend on the knowledge conditions inherent in the underlying technological regime.

5 Survival and Growth

5.1 Theory

The theory proposed by Audretsch (1995) suggests that divergences in the expected value regarding new knowledge will, under certain conditions, lead an agent to exercise what Albert O. Hirschman (1970) has termed as *exit* rather than *voice*, and depart from an incumbent enterprise to launch a new firm. But who is right, the departing agents or those agents remaining in the organizational decision making hierarchy who, by assigning the new idea a relatively low value, have effectively driven he agent with the potential innovation away? *Ex post* the answer may not be too difficult. But given the uncertainty inherent in new knowledge, the answer is anything but trivial *a priori*.

Thus, when a new firm is launched, its prospects are shrouded in uncertainty. If the new firm is built around a new idea, i.e., potential innovation, it is uncertain whether there is sufficient demand for the new idea or if some competitor will have the same or even a superior idea. Even if the new firm is formed to be an exact replica of a successful incumbent enterprise, it is uncertain whether sufficient demand for a new clone, or even for the existing incumbent, will prevail in the future. Tastes can change. And new ideas emerging from other firms will certainty influence those tastes.

Finally, an additional layer of uncertainty pervades a new enterprise. It is not known how competent the new firm really is, in terms of management, organization, and workforce. At least incumbent enterprises know something about their underlying competencies from past experience. Which is to say that a new enterprise is burdened with uncertainty as to whether it can produce and market the intended product as well as sell it. In both cases the degree of uncertainty will typically exceed that confronting incumbent enterprises.

This initial condition of not just uncertainty, but greater degree of uncertainty vis-à-vis incumbent enterprises in the industry is captured in the theory of firm selection and industry evolution proposed by Boyan Jovanovic (1982). Jovanovic presents a model in which the new firms, which he terms *entrepreneurs*, face costs that are not only random but also differ across firms. A central feature of the model is that a new firm does not know what its cost function is, that is its relative efficiency, but rather discovers this through the process of learning from its actual post-entry performance. In particular, Jovanovic (1982) assumes that entrepreneurs are unsure about their ability to manage a new-firm startup and therefore their prospects for success (Jovanovic, 1994). Although entrepreneurs may launch a new firm based on a vague sense of expected post-entry performance, they only discover their true ability -- in terms of managerial competence and of having based the firm on an idea that is viable on the market -- once their business is established. Those entrepreneurs who discover that their ability exceeds their expectations expand the scale of their business, whereas those discovering that their post-entry performance is less than commensurate with their expectations will contact the scale of output and possibly exit from the industry. Thus, Jovanovic's model is a theory of *noisy selection*, where efficient firms grow and survive and inefficient firms decline and fail.

The role of learning in the selection process has been the subject of considerable debate. On the one hand is what has been referred to as the *Larackian* assumption that learning refers to adaptations made by the new enterprise. In this sense, those new firms that are the most flexible and adaptable will be the most successful in adjusting to whatever the demands of the market are. As Nelson and Winter (1982, p. 11) point out, "Many kinds of organizations commit resources to learning; organizations seek to copy the forms of their most successful competitors." In fact, Pakes and Erikson (1995) extend Jovanovic's original theory by incorporating strategies that entrepreneurs can pursue to accelerate the learning process, such as investing in knowledge-creation activities like R&D.

On the other hand is the interpretation that the role of learning is restricted to discovering if the firm has the *right stuff* in terms of the goods it is producing as well as the way they are being produced. Under this interpretation the new enterprise is not necessarily able to adapt or adjust to market conditions, but receives information based on its market performance with respect to its *fitness* in terms of meeting demand most efficiently vis-à-vis rivals. The theory of organizational ecology proposed by Michael T. Hannan and John Freeman (1989) most pointedly adheres to the notion that, "We assume that individual organizations are characterized by relative inertia in structure." That is, firms learn not in the sense that they adjust their actions as reflected by their fundamental identity and purpose, but in the sense of their perception. What is then learned is whether or not the firm has the right stuff, but not how to change that stuff.

The theory of firm selection is particularly appealing in view of the rather startling size of most new firms. For example, the mean size of more than 11,000 new-firm startups in the manufacturing sector in the United States was found to be fewer than eight workers per firm

(Audretsch, 1995).[16] While the minimum efficient scale (MES) varies substantially across industries, and even to some degree across various product classes within any given industry, the observed size of most new firms is sufficiently small to ensure that the bulk of new firms will be operating at a suboptimal scale of output. Why would an entrepreneur start a new firm that would immediately be confronted by scale disadvantages?

An implication of the theory of firm selection is that new firms may begin at a small, even suboptimal, scale of output, and then if merited by subsequent performance expand. Those new firms that are successful will grow, whereas those that are not successful will remain small and may ultimately be forced to exit from the industry if they are operating at a suboptimal scale of output.

Subsequent to entering an industry, a firm must decide whether to maintain its output expand, contract, or exit. Two different strands of literature have identified several major influences shaping the decision to exit an industry. The first, and most obvious strand of literature suggests that the probability of a business exiting will tend to increase as the gap between its level of output and the minimum efficient scale (MES) level of output increases.[17] The second strand of literature points to the role that the technological environment plays in shaping the decision to exit. As Dosi (1982 and 1988) and Arrow (1962) argue, an environment characterized by more frequent innovation may also be associated with a greater amount of uncertainty regarding not only the technical nature of the product but also the demand for that product. As technological uncertainty increases, particularly under the entrepreneurial regime, the likelihood that the business will be able to produce a viable product and ultimately be able to survive decreases.

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[16] A similar start-up size for new manufacturing firms has been found by Dunne, Roberts and Samuelson (1988 and 1989) for the United States, Mata (1993) and Mata and Portugal (1994) for Portugal, and Wagner (1994a and 1994b) for Germany.

[17] For example, Weiss (1976, p. 126) argues that, "In purely competitive long-run equilibrium, no suboptimal capacity should exist at all."

An important implication of the dynamic process of firm selection and industry evolution is that new firms are more likely to be operating at a suboptimal scale of output if the underlying technological conditions are such that there is a greater chance of making an innovation, that is under the entrepreneurial regime. If new firms successfully learn and adapt, or are just plain lucky, they grow into viably sized enterprises. If not, they stagnate and may ultimately exit from the industry. This suggests, that entry and the startup of new firms may not be greatly deterred in the presence of scale economies. As long as entrepreneurs perceive that there is some prospect for growth and ultimately survival, such entry will occur. Thus, in industries where the MES is high, it follows from the observed general small size of new-firm startups that the growth rate of the surviving firms would presumably be relatively high.

At the same time, those new firms not able to grow and attain the MES level of output would presumably be forced to exit from the industry, resulting in a relatively low likelihood of survival. In industries characterized by a low MES, neither the need for growth, nor the consequences of its absence are as severe, so that relatively lower growth rates but higher survival rates would be expected. Similarly, in industries where the probability of innovating is greater, more entrepreneurs may actually take a chance that they will succeed by growing into a viably sized enterprise. In such industries, one would expect that the growth of successful enterprises would be greater, but that the likelihood of survival would be correspondingly lower.

Summarizing these arguments, the theory of firm selection and industry evolution leads to the following predictions, or hypotheses, concerning the likelihood of survival and growth rates of those surviving new firms:

1. The likelihood of new-firm survival should be lower in industries exhibiting greater scale economies. The growth rates observed in surviving firms in high MES industries should be greater.

2. The likelihood of firm survival should be higher for larger firms but growth rates should be lower.

3. The likelihood of firm survival should be lower under the entrepreneurial technological regime but the growth rates of surviving firms should be greater

4. Both firm growth and the likelihood of survival should be greater in high-growth industries.

5.1.1 Empirical Evidence

Geroski (1995) as well as Audretsch and Mata (1995) point out that one of the major conclusions from studies about entry is that the process of entry does not end with entry itself. Rather, it what happens to new firms subsequent to entering that sheds considerable light on industry dynamics. The early studies (Mansfield, 1962; Hall, 1987; Dunne, Roberts and Samuelson, 1988 and 1989; and Audretsch, 1991) established not only that the likelihood of a new entrant surviving is quite low, but that the likelihood of survival is positively related to firm size and age. More recently, a wave of studies have confirmed these findings for diverse countries, including Portugal (Mata and Portugal, 1994; and Mata, 1994), Germany (Wagner, 1994), and Canada (Baldwin and Gorecki, 1991; and Baldwin, 1995).

Audretsch (1991), Audretsch and Mahmood (1995), Mata and Portugal (1994) and Mata (1994) shifted the relevant question away from *Why does the likelihood of survival vary systematically across firms?* to *Why does the propensity for firms to survive vary systematically across industries?* The answer to this question suggests that what had previously been considered to pose a barrier to entry may, in fact, constitute not an entry barrier but rather a barrier to survival. The answer to this questions suggests that what had previously been considered to pose a barrier to entry may, in fact, constitute not an entry barrier but rather a barrier to survival.

What has become known as *Gibrat's Law*, or the assumption that growth rates are invariant to firm size, has been subject to numerous empirical tests. Studies linking firm size and age to growth have also produced a number of stylized facts (Wagner, 1992). For small and new firms there is substantial evidence suggesting that growth is negatively related to firm size and age (Hall, 1987; Wagner, 1992 and 1994; Mata, 1993, and Audretsch, 1995). However, for larger firms, particularly those having attained the minimum efficient scale (MES) level of output, the evidence suggests that firm growth is unrelated to size and age.

An important finding of Audretsch (1991 and 1995) and Audretsch and Mahmood (1995) is that although entry may still occur in industries characterized by a high degree of scale economies, the likelihood of survival is considerably less. People will start new firms in an attempt to appropriate the expected value of their new ideas, or potential innovations, particularly under the entrepreneurial regime. As entrepreneurs gain experience in the market they learn in at least two ways. First, they discover whether they possess *the right stuff*, in terms of producing goods and offering services for which sufficient demand exists, as well as whether they can product that good more efficiently than their rivals. Second, they learn whether they can adapt to market conditions as well as to strategies engaged in by rival firms. In terms of the first type of learning, entrepreneurs who discover that they have a viable firm will tend to expand and ultimately survive. But what about those entrepreneurs who discover that they are either not efficient or not offering a product for which their is a viable demand? The answer is, *It depends -- on the extent of scale economies as well as on conditions of demand*. The consequences of not being able to grow will depend, to a large degree, on the extent of scale economies. Thus, in markets with only negligible scale economies, firms have a considerably greater likelihood of survival. However, where scale economies play an important role the consequences of not growing are substantially more severe, as evidenced by a lower likelihood of survival.

6 Compensating Factor Differentials

How are the new firms, many of which operate at a suboptimal scale of output, able to exist? The answer according to the studies on post-entry survival and growth is that they cannot -- at least not indefinitely. Rather, they must growth to at least approach the MES level of output. An alternative answer is provided by recent studies focusing on the relationship between firm size, age and employee compensation (Audretsch, 1995). By deploying a strategy of *compensating factor differentials*, where factor inputs are both deployed and remunerated differently than they are by the larger incumbent enterprises, suboptimal scale enterprises are to some extent able to offset their size-related cost disadvantages.

Just as it has been found that the gap between the MES and firm size lowers the likelihood of survival, there is evidence suggesting that factors of production, and in particular labor, tend to be used more intensively (that is, in terms of hours worked) and remunerated at lower levels (in terms of employee compensation). Taken together, the empirical evidence on survival and growth combined with that on wages and firm size suggests how it is that small, suboptimal scale enterprises are able to exist in the short run. In the initial period of learning, during which time the entrepreneur discovers whether he has the *right stuff* and whether he is able to adapt to market conditions, new firms are apparently able to reduce the cost of production in order to compensate for their small scale of production.

In the current debate on the relationship between employment and wages it is typically argued that the existence of small firms which are sub-optimal within the organization of an industry represents a loss in economic efficiency. This argument is based on a static analysis, however, When viewed through a dynamic lens a different conclusion emerges. One of the most striking results is the finding of a positive impact of firm age on productivity and employee compensation, even after controlling for the size of the firm. Given the strongly confirmed stylized fact linking both firm size and age to a negative rate of growth (that is the smaller and younger a firm, that faster it will grow but the lower is its likelihood of survival), this new finding linking firm age to employee compensation and productivity suggests that not only will some of the small and sub-optimal firms of today become the large and optimal firms of tomorrow, but there is at least a tendency for the low productivity and wage of today to become the high productivity and wage of tomorrow.

7 Industrial Organization through an Evolutionary Lens

What emerges from the new theories and empirical evidence on innovation and industry evolution is that markets are in motion, with a lot of firms entering the industry and a lot of firms exiting out of the industry (Dosi et al., 1995). But is this motion horizontal, in that the bulk of firms exiting are comprised of firms that had entered relatively recently, or vertical, in that a significant share of the exiting firms had been established incumbents that were displaced by younger firm? In trying to shed some light on this question, Audretsch (1995) proposes two different models of the evolutionary process of industries over time. Some industries can be best characterized by the model of the conical revolving door, where new businesses enter, but where there is a high propensity to subsequently exit from the market. Other industries may be better characterized by the metaphor of the forest, where incumbent establishments are displaced by new entrants. Which view is more applicable apparently depends on three major factors -- the underlying technological conditions, scale economies, and demand. Where scale economies play an important role, the model of the revolving door seems to be more applicable. While the rather starting result discussed above that the startup and entry of new businesses is apparently not deterred by the presence of high scale economies, a process of firm selection analogous to a revolving door ensures that only those establishments successful enough to grow will be able to survive beyond more than a few years. Thus the bulk of new entrants that are not so successful ultimately exit within a few years subsequent to entry.

There is at least some evidence also suggesting that the underlying technological regime influences the process of firm selection and therefore the type of firm with a higher propensity to exit. Under the entrepreneurial regime new entrants have a greater likelihood of making an innovation. Thus, they are less likely to decide to exit from the industry, even in the face of negative profits. By contrast, under the routinized regime the incumbent businesses tend to have the innovative advantage, so that a higher portion of exiting businesses tend to be new entrants. Thus, the model of the revolving door is more applicable under technological conditions consistent with the routinized regime, and the metaphor of the forest, where the new entrants displace the incumbents -- is more applicable to the entrepreneurial regime.

Why is the general shape of the firm-size distribution not only strikingly similar across virtually every industry -- that is, skewed with only a few large enterprises and numerous small ones -- but has persisted with tenacity not only across developed countries but even over a long period of time? The dynamic view of the process of industry evolution is that new firms typically start at a very small scale of output. They are motivated by the desire to appropriate the expected value of new economic knowledge. But, depending upon the extent of scale economies in the industry, the firm may not be able to remain viable indefinitely at its startup size. Rather, if scale economies are anything other than negligible, the new firm is likely to have to grow to survival. The temporary survival of new firms is presumably supported through the deployment of a strategy of compensating factor differentials that enables the firm to discover whether or not it has a viable product.

The empirical evidence supports such a dynamic view of the role of new firms in manufacturing, because the post-entry growth of firms that survive tends to be spurred by the extent to which there is a gap between the MES level of output and the size of the firm. However, the likelihood of any particular new firm surviving tends to decrease as this gap increases. Such new suboptimal scale firms are apparently engaged in the selection process. Only those firms offering a viable product that can be produced efficiently will grow and ultimately approach or attain the MES level of output. The remainder will stagnate, and depending upon the severity of the other selection mechanism -- the extent of scale economies -- may ultimately be forced to exit out of the industry. Thus, the persistence of an asymmetric firm-size distribution biased towards small-scale enterprise reflects the continuing process of the entry of new firms into industries and not necessarily the permanence of such small and sub-optimal enterprises over the long run. Although the skewed size distribution of firms persists with remarkable stability over long periods of time, a constant set of small and suboptimal scale firms does not appear to be responsible for this skewed distribution.

8 Conclusions

Each of the topics addressed in this paper has provided a snapshot of an important aspect of the process of industry evolution, and particular, the role that innovation plays in shaping that process. These dynamic aspects involve the startup of new firms, survival, growth, the development of a strategy of compensating factor differentials, and the extent to which new firms displace incumbent enterprises.

The fundamental theory common to all of these themes is that that the dynamic process through which industries evolve is shaped, at least to some extent, by three major factors -- technology, scale economies and demand. There is, in fact, substantial empirical evidence supporting the notion of distinct technological regimes. It can be inferred from this evidence that under the routinized regime there tends to be convergence regarding the expected value of new ideas, or potential innovations, across agents and decisionmaking hierarchies within the industry. By contrast, under the entrepreneurial regime there tends to be much more divergence regarding the expected value of new ideas, or potential innovations across agents. And it is differences in the extent to which new economic knowledge tends to converge or diverge across agents that, to a considerable degree, shapes the patterns of firm demography observed across industries.

As Frank Knight (1921, p. 199) pointed out, uncertainty is the result of possessing only partial or bounded knowledge: "The essence of the situation is action according to opinion, of greater or less foundation and value, neither entire ignorance nor complete and perfect information, but partial knowledge." In fact, it is the fundamental condition of incomplete knowledge that leads Arrow (1974 and 1985) to focus on the firm as an organization whose main distinction is processing information. As March and Simon (1993, p. 299) argue, "Organizations process and channel information." But as Arrow (1985, p. 303) emphasizes, "The elements of a firm are *agents* among whom both decision making and knowledge dispersed...Each agent observes a random variable, sometimes termed a *signal*...Each agent has a set of actions from which choice is to be made...We may call the assignment of signals to agents the *information structure* and the choice of decision rules the *decision structure*." Arrow goes on to note that the cost of acquiring that signal or information is nontrivial.

How will economic agents, and ultimately hierarchical organizations, respond when confronted by incomplete knowledge? Knight's (1921, p. 241) answer was "differently," because agents differ "in their capacity by perception and inference to form correct judgments as to the future course of events in the environment." Which is to say that different economic agents confronted by the same signal, in Arrow's terms (1985), or simply incomplete information, in Knight's terms, will respond differently because they have a different set of experiences from which to evaluate that incomplete information.

March and Simon (1993) argue that one of the main functions of an organization is to filter both the signal, or information, and the response in a way that is not only efficient, but also unique to that organization. They do this by shaping the goals and loyalties of those agents participating in the organization; for example, "They create shared stories -- an organization ethos that includes common beliefs and standard practices" (March and Simon, 1993, p. 300). And they offer incentives for conduct that is consistent with the organizational goals.

Like Nelson and Winter (1982), March and Simon (1993, p. 309) emphasize the role of established routines in the functioning of organizations: "Organizations turn their own experience as well as the experience and knowledge of others into rules that are maintained and implemented despite turnover in personnel and without necessary comprehension of their bases. As a result, the processes for generating, changing, evoking, and forgetting rules become essential in analyzing and understanding organizations."

As long as new information is consistent with the routines established in an organization, it will be processed by economic agents and a decision-making hierarchy in a manner that is familiar. New information under the routinized regime is familiar turf for organizations. A more fundamental problem arises, however, when the nature of that new information is such that it can no longer be processed by the familiar routines. Under these circumstances the organizational routines for searching out new relevant information and making (correct) decisions on the basis of that information break down. And it is under such knowledge conditions that divergences tend to arise not only among economic agents in evaluating that information, but between agents and organizational hierarchies.

If each economic agent were identical, such divergences in beliefs would not arise. The greater the degree of heterogeneity among agents, the greater the tendency will be for beliefs in evaluating uncertain information to converge. But individuals are not homogeneous. Rather, agents have varied personal characteristics and different experiences that shape the lens through which each agent evaluates where to get new information and how to assess it. That is, reasonable people confronted by the same information may evaluate it very differently, not just because they have different abilities, but because each has had a different set of life experiences which shapes the decisionmaking process.

Thus, to some extent, the phenomenon of a new firm being established represents not just imperfect information, but a diverse population of economic agents. That is, diversity in the population of economic agents may ultimately lead to diversity in the types of firms populating the industrial structure. And to some extent, these diverse firms represent experiments based on differing visions about what should be produced and how it should be produced.

Diversity, however, may also be the source of the high degree of turbulence that is also apparently characteristic of at least the United States, if not of all leading developed nations.[18] That is industrial markets are characterized by a high degree of churning. It should, however, be emphasized that there is to date no evidence that the industrial structure has actually become more turbulent over time, even if that may be true. Without undertaking the painstaking statistical research to compare the degree to which the structure of industries is characterized by turbulence has changed over long periods of time, such conjectures remain

[18] For a direct analysis of the degree of turbulence in industrial markets, see Acs and Audretsch (1990 and 1993) for the United States, Invernizzi and Revelli (1993) for Italy, and Beesley and Hamilton (1984) for Great Britain.

just that -- conjectures. After all, the observation that the structure of industries, at least in the United States, tends to be remarkably fluid and turbulent is not new. Before the country was even half a century old, Alexis de Tocqueville, in 1835, reported, "What astonishes me in the United States is not so much the marvelous grandeur of some undertakings as the innumerable multitude of small ones."[19]

The new learning on technological regimes and industry demography suggests that, with respect to the dynamic patterns of firms over time, there is, in fact, no tendency that can be generalized. Rather, the dynamic nature in which firms and industries tend to evolve over time varies substantially from industry to industry. And it is apparently differences in the knowledge conditions and technology underlying the specific industry, that is the nature of innovative activity, that account for variations in industry evolution across markets.

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[19] Quoted from *Business Week*, Bonus Issue, 1993, p. 12.

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