1 INNOVATION VERSUS PRODUCTIVITY: A FUNDAMENTAL DILEMMA

Innovation in the United States automobile industry has visibly waned over years of mass production and concentration on productivity. In 1964, Donald Frey, vice-president of the Ford Motor Company, stated publicly that the last significant innovation in the auto industry was the automatic transmission, which went into mass production in the late 1930s.[1] The giant strides in productivity taken by the industry since its beginnings are not questioned by critics, but since the 1960s, concern has been voiced on many fronts over the slow pace of significant technological change.

In the early years, rapid technological progress was spurred by fierce competition among many companies, each championing its own unique contrivance, like the Stanley Steamer or Pope's electric car. Over the years, however, radical innovation has given way to standardization and to the efficiency of highly complex mass-production methods. The question is why? Is it the age of the industry? Or its commitment to mass production? What are the management processes or historical events that have led to this change? Have long-term gains in productivity exhausted the ability to innovate? Can, or should, this trend be reversed, and what might the consequences be? For so important an industry something more than an emotional response is needed! A careful historical analysis of technological change in the automobile industry helps to provide important insight about the forces that cause industrial changes. Beyond the particulars of the automobile industry, however, such analysis helps to indicate whether the same course of events can or should be avoided in other industries where increased productivity is also urgently sought.

THE MODEL IN BRIEF

Technological change, as Joseph Schumpeter has said, has proved to be a "gale of creative destruction," wrecking industrial lethargy and leading to improvements in productivity for the benefit of society.[2] But in many cases, lo! as productivity increased, significant technological change became more difficult to achieve. In the refining of gasoline or the making of steel, as well as in the production of automobiles, we see that many years of high rates of productivity have come at a cost—a declining capacity for major innovation.

Major innovations change the functions of the product in application or the basic way it is made. Such innovations are prevalent in the early stages of development of a product. Progress in this mode gives way to incremental change as the means of improvement, however, in the later stages of development.

This fact of industrial life deserves closer examination than it has usually received. The subject is full of unanswered questions, despite many good studies of particular aspects of technology. We need an integrative framework—a model—that can help to clarify the relationships of technological progress to changes in other factors: productivity, innovation, production organization, work-force skills, advances in production equipment, and new material sources. If it is to be well handled by business managers and properly encouraged by governments, technological change must be acknowledged as more than merely a matter of scientific and engineering interest.

My purpose in this book is to present a model and to illustrate and refine it through an account of technological change in the automobile industry. I developed the main ideas, largely as presented in Chapter 4, before this study was begun. Refinements and extensions of the model, as detailed in subsequent chapters, came later as I did the historical research and gained insights about the actual course of technological developments.

The model captures important milestones of change in the development of a product and its manufacturing process, from inception to maturity, over an economic life cycle, as it were. A common pattern seems to be evident in important instances for different products, firms, and industries. As the product and the manufacturing process develop over time, costs decrease, product designs become more standardized, and change becomes less fluid. At the same time, production processes, designed increasingly for efficiency, offer higher levels of productivity, but they also become mechanistic, rigid, less reliant on skilled workers, and more dependent on elaborate and specialized equipment. Perhaps of greater importance, the nature and sources of technological innovation shift with these structural changes in product and process. Innovation becomes more incremental. Major innovations, with potential to reshape the product or greatly improve productivity, originate more frequently outside the firm and the industry. Development in productivity continues until the industry reaches stagnation. Stated generally, to achieve gains in productivity, there must be attendant losses in innovative capability; or, conversely, the conditions needed for rapid innovative change are much different from those that support high levels of production efficiency.

In this book the model is developed in application to the automobile industry. But it represents a much more general pattern of change, focusing on the nature of innovation in industrial organizations, but with respect to questions that have not often been addressed in other research.

Can innovations be well understood as an independent event or do they interact with one another and with other characteristics of the business unit in which they occur so that interactions need to be jointly considered?

Does the unit of analysis make a difference? Are the traits of the firm or the industry or of individual incidents of innovation most important in systematically analyzing innovation? Would some other unit of analysis yield new insight?

Is innovation a good indicator of technological progress within the firm or business unit where it occurs? How does innovation tie in with such other aspects of technological change, as the maturity of a technology, productivity improvement, the movement toward mass production, experience (learning) curve concepts, or systematic technology improvement trends? Does change in one of these encourage or retard improvement along another dimension?

How does innovation relate to competition in a particular product? Why are organizations that stand out as most successful in a competitive sense often less innovative than their competitors?

THE BACKDROP OF PRIOR RESEARCH

A growing body of knowledge about technological innovation and industry characteristics is now emerging in several fields. As evidence accumulates, there is increased confidence that many findings represent common phenomena rather than isolated occurrences. As might be expected, the lines of inquiry in different disciplines have focused on different issues and offer different insights, as suggested by the following four areas that provide an underpinning for the present study.

Industry Differences

One perspective on the innovation process is provided by economists' studies of research and development (R&D) investment and industry structure.[3] When industries that support a high rate of major product innovation are contrasted with others, interesting variations become apparent, suggesting that totally different environments may support innovation. At the forefront of the innovative category are industrial segments like scientific instruments, electronics, pharmaceuticals, and chemicals. In these so-called "science-based industries," product technologies are rooted in active scientific fields, production processes tend to be labor- rather than capital-intensive, employees include a high ratio of engineers and scientists, and there is a high rate of new business creation based on new products that offer improved performance. Basic mass-production industries like steel, nonferrous metal production, railroads, and oil refining are in an opposing category. Here product innovation is typically incremental in nature. Firms are capital-, rather than labor-intensive, the technology is well established or "mature," and competition frequently hinges on price, economies of scale, and evolutionary advances in production processes. Studies of major innovaton in such industries suggest that they frequently originate from without the industry and diffuse slowly in established firms.[4]

Intrafirm Environment

Descriptive studies of major innovations offer consistent findings about particular conditions within the firm that support innovations, such as the organizational setting,[5] the traits of individual contributors,[6] and types of information linkages. Whereas large, highly structured organizations with well-developed lines of authority and control may be needed to amass and direct resources for large research and development programs, evidence suggests that they do not offer the right environment for radical innovation. Major innovations would seem to occur more frequently in loosely structured "organic" organizations with an entrepreneurial environment that provides large incentives to champions of successful innovation.

Process of Innovation

Historical analyses of the chain of events from scientific advance to invention, to innovation, and ultimately to broad commercialization, reveal the delays in the entire linear sequence from science to commercialization. The vast majority of scientific advances are in place long before the innovation occurs—in one study 90 percent came as early as ten years before the innovation.[7] They are typically drawn by market incentives into an industrial application that was usually unforeseen at the time of the scientific advance. The potential economic benefit to the nation as a whole from accelerating the time lags in the linked sequence is emphasized by this perspective.

Perfecting Innovations and Cost Reduction

A common picture of technological change in established products and production processes is one of evolutionary progress through a stream of incremental innovations and minor improvements. Independent studies of products as diverse as rocket engines,[8] computers,[9] and electric light bulbs[10] show that the cumulative effects of minor changes can be as important as radical innovation in reducing costs and improving product performance.[11] The same picture emerges for production processes. Progress in this mode is apparently related to the "experience" or "learning curve" phenomenon, frequently used in business planning. This phenomenon anticipates a rate of improvement proportional to the cumulative manufacturing volume of a given product—the more volume, the greater the improvement.

Central tendencies and systematic variations in the innovative process are shown by the wealth of prior studies in particular areas like the four briefly outlined here. However, they offer no higher-level explanation of why these tendencies or variations are observed or how one relates to another.[12] How, for example, does the knowledge about organizational conditions for major innovations relate to findings about experience-curve phenomenon or the environment for such systematic progress in established products? Specifically, will an organizational climate that is right for creating radical innovation also sustain high rates of productivity improvement? Can the rate of innovation be increased by applying insight gained from studying industry differences—say by breaking up large firms in concentrated, mature industries so that industry characteristics better match the profile for the innovative case? Why is the R&D investment rate higher in large firms within concentrated industries even though innovation arises more frequently from without such established firms? An explanation of differences is needed, especially one focused on characteristics of the innovative process, which is malleable or can be manipulated by decision makers. The present model of technological progress within the firm is a step in this direction. It offers a view of technological innovation that is consistent with many prior findings, but that at the same time leads to different interpretations and implications.

My approach departs from other studies in several ways. Productivity improvement has traditionally been favored as wholly beneficial, to be pursued without constraint or concern. My proposed model views productivity improvement as a phenomenon that has costs as well as benefits. It is beneficial when losses in innovative capability are recognized and balanced against potential gains. Similarly, a rapid rate of novel change has attendant costs in lost productivity. These distinctions about innovation and productivity lead to the second point of departure. Since both innovation in the product and cost ramifications are of interest, a special unit of analysis (called a "productive unit") is applied, encompassing both product and manufacturing characteristics. In this respect the model departs from product life-cycle studies[13] and learning-curve studies,[14] where either product or process may be of concern, but not both.

A course of industrial development that will lead to stagnation need not be followed to its ultimate conclusion. The purpose in studying a normal course of development is to understand how it might be altered or reversed when further advance is not desirable. In industries producing automobiles or steel or some appliances, development may have gone too far. In these cases, managers or government policy makers would benefit by understanding how development might be better directed in future. In other instances development has not yet been achieved, but is desired. In home construction, for example, the benefits of productivity gains would be welcomed by many buyers even though product variety was somewhat reduced. In these cases, a model that promises to clarify barriers to development would be helpful to those planning to encourage development.

The means whereby the course of technological development can be identified and intentionally controlled through government regulation or by the managers of firms are suggested in subsequent chapters by the findings about the automobile industry. The forces at play are complex, and great foresight is needed to direct technological progress in a competitive industry. For, under highly competitive conditions and pressures for productivity improvement, the course of progress leads naturally toward an extreme state of development. The analysis of technological change within the automobile industry suggests that development may be altered or reversed. Managers may have the means to control and renew their technologies by supporting and channeling their research and development programs in paths that promise significant technological innovations. Through programs that seek long-run technological advances, the forces of efficiency that drive an industry toward maturity can be kept in balance. The recent experience of the industry with massive government regulation would suggest, however, that this form of intervention has had the most direct influence on innovation. But the increased rate of innovation has not been realized without attendant cost increases and implications for industry structure.

APPLICATION IN THE AUTOMOBILE INDUSTRY

Technological change in the automobile industry deserves close study on three counts.

First, this industry plays a major role in the economy. One job in six within the private sector relates to automobiles.

Second, right or wrong, the lessons learned from the automobile industry are an important part of United States industrial culture. Past lessons still subtly shape attitudes and even current policy. For example, the basic concept of mass production—that great productivity gains can be realized by standardizing a custom product and then mass producing it—is accepted as an article of faith, partly because Henry Ford did it a long time ago. Since World War II, repeated attempts to apply this concept in building construction have failed. In his book on construction, Richard Bender concludes: "We have seen that much of the problem of industrializing the building industry has grown out of the mistaken image of the automobile industry as a model."[15]

Third, and of primary importance to me, the industry affords an unparalleled opportunity to study technological change over the full range of its development. Few products other than the automobile have left such a highly visible record of their development through a complete course from birth to apparent maturity. Two of the surviving major firms, Ford and General Motors, have been the major participants over most of this period. Because they have been essentially single-product firms, whose characteristics are uniquely associated with automobile production, technological change in the industry as a whole can be studied by analyzing these two.

From the standpoint of analysis, the Ford Motor Company is the most useful. Ford has the longest and best-documented history of the surviving automobile firms. Incorporated in 1903, it virtually created the U.S. automobile industry and has been a major figure ever since. For these reasons, disproportionate attention is given to Ford in the material that follows. The disadvantages of this bias are more than offset by the benefits. In a study of technological change it is more useful to have continuity in tracing changes in one major firm than to piece together a fragmented overview of the entire industry.

My method of study takes full advantage of the industry's size and diversity by comparatively analyzing two very different products and processes that coexist in each major firm: the automotive engine plant and the assembly plant. The engine plant is the most highly automated and advanced manufacturing process in any U.S. industry that makes products as complex as engines. But in reaching this state of development the industry lost the ability to accommodate change, as recent controversies over pollution control and fuel economy vividly illustrate. On the other hand, the automobile assembly plant has developed quite differently. Options for product change have been maintained in the assembly plant, where half of the labor used in making a car is employed. Flexibility is provided by the use of manual labor, light-process equipment, and an organizational orientation that anticipates change. A comparative analysis of these two types of plants, in terms of the model, reveals much about technological change in general and the automobile industry in particular.