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# Policy Uncertainty and Technological Innovation[1,2]

ALFRED A. MARCUS
Battelle Science and Government Study Center

*Without certainty about government policies, business decision makers are unable to assess risk and opportunity and make the trade-offs necessary for investment in new technologies. Different policies (R&D, health and safety, economic regulation) have different effects, depending on type of industry and size of firm. Because there are no established standards for judging industry performance, it is difficult to know whether policy uncertainty is simply a rationalization for not innovating or whether there is a cause-and-effect relationship between policy uncertainty and technological change.*

There is abundant anecdotal evidence about the relationship between policy uncertainty and technological innovation in energy and energy-related industries. Cogeneration, a process whereby industrial waste heat is used to generate electricity, is both technologically and economically feasible, but one of the barriers standing in the way of its wider adoption has been uncertainty about state public utility commission rate and licensing regulation [Hatsopolous, Gyftopolous, & Widmer, 1978; Senate Subcommittee on Energy Conservation & Regulation, 1977]. Similarly, the use of composite fuels made of pulverized coal has been held back because of uncertainty over interpretation of clean air laws [Leonardi, 1978]. Conversion of industrial boilers from oil to coal has been delayed for the same reason [Senate Committee on Interior & Insular Affairs, 1975].

William A. Johnson [1976] goes so far as to argue that policy uncertainty was the main reason the energy crisis began: the petroleum companies did not invest in new refinery capacity because of uncertainty about federal energy policy—in particular, the possibility that Congress might enact punitive legislation and the Department of Energy might issue inconsistent and poorly conceived regulations. The oil companies have argued that the prevention-of-significant-deterioration (PSD) policy in the 1977 Clean Air Amendment has jeopardized synthetic fuel developments, and that oil shale and pipeline developments have been delayed because of uncertainties over interpretation of the 1970 National Environment Policy Act (NEPA) [Nandini, 1978].

The anecdotal evidence provides many examples that energy companies are concerned about policy uncertainty. In the same vein, the Carnegie—Mellon Institute Regional Energy Policy Study [1977] found that many firms in Allegheny County did not go beyond energy-saving housekeeping conservation changes because of uncertainty about government policy. Likewise, the work of Knight, Kozmetsky,

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and Baca shows that industry in general views uncertainty about government regulation as a barrier to technological change [1976].

The evidence from these sources suggests that without certainty about government policies, business decision makers are unable to assess risk and opportunity and make the trade-offs necessary for investment in new technologies. However, more research is needed to determine whether uncertainty impedes business with respect to all government policy or only some government policy; whether uncertainty impedes all firms and industries or only some firms and industries; and, particularly, whether it is simply a rationalization for decisions not to innovate or whether there is, in fact, a simple cause-and-effect relationship between policy uncertainty and technological change.

In the remainder of this article, I will deal with these issues. First, I review the literature linking policy and innovation. Then I place the policy uncertainty/innovation relationship in the context of the "ecology of innovation" literature.

## Policy and Innovation

Many studies have stressed the importance of government policy as a determinant of technological change. The specific findings of these studies have differed, however, owing to different definitions of innovation. Innovation is a slippery concept. For instance, it has been defined by economists as the application of an invention, or the adoption of a new tool or concept; but patent attorneys consider it to be the *discovery* of a tool or concept and not its eventual application [Kelley & Kranzberg, 1975].

In this article, innovation will be viewed as the introduction of new practices and methods, as the replacement of similar but less efficient inputs in the production process or outputs in the product mix [Rosenblum, 1975; Warner, 1974]. Innovation can be either a hardware change (a change in product, plant, or equipment) or a software change (a change in ideas, processes, or systems). Points to consider with respect to such changes are percentage of relevant firms adopting, rate of adoption, and efficiency of use. (Adoption is frequently accompanied by diffuse minor changes that are largely unrecognizable, as well as by specific, identifiable large-scale changes.)

Different government policies will affect innovation differently, depending on whether it entails input or output, software or hardware, how many firms have adopted it, and so on. Unclear interpretation of provisions in laws, such as the Clean Air Act or the National Environmental Policy Act, can be expected to delay the adoption of innovation because of the difficulty firms will have assessing risk and opportunity. Braeutigam [1979] posits that higher discount rates and procedural cost lead to decreased innovation. The discounted present value of future revenues must exceed the discounted present value of future costs [Eads, 1980, p. 52]. Regulatory uncertainty makes this calculation difficult.

### Different Policies, Different Effects

Akel and Doctors [1973] studied the effects of federal space and defense R & D policy, and found that effects were selective, "being highly concentrated in just a few industries and among the largest firms in those industries." The effects of R & D policy were likely to vary according to the type of industry and size of firm.

Studies of the effects of patent policy on innovation examine what can be considered another aspect of R & D policy [Noll, 1974; Trozzo & Kitti, 1976]; other studies envision government policy in terms of *regulation*. Utterback, Allen, Holloman, and Sirlou [1976], for instance, make the distinction between regulatory constraints on the innovation-making decisions of the auto, textile, and chemical industries, and on the innovation-making decisions of the computer and consumer electronics industries. They find the constraints greater on the auto, textile, and chemical industries. Again, we find that regulation affects some industries differently from others.

"Regulation" has two meanings. It implies health, safety, and environmental controls as well as traditional economic regulation. One view, such as that found in studies like Wardell's on the FDA [1974], is that health and safety regulations stand in the way of innovation. Wardell observed that the FDA's increasingly stringent regulations on drug development contributed to a decline in the number of new drugs available on the U.S. market relative to the number available in some other countries. This finding that regulation is a constraint for the drug industry is consistent with that of Utterback et al. for the chemical industry. In contrast, Gerstenfeld [1977], who studied a different sample of environmental and safety regulations, concluded that they were a stimulant to innovation. Thus, whether health, safety, and environmental regulations stimulate or retard technological change appears to depend on the industry and the specific regulations. Another factor, and an important one, is the definition of technological change.

The practices and methods that Wardell considers innovations are not the practices and methods that Gerstenfeld considers innovations. Wardell means new products, Gerstenfeld means new processes. Environmental, health, and safety regulations may impede the introduction of new products, but stimulate the use of new processes. Magat [1980] holds that environmental regulations bias a firm's overall technological advance toward abatement technology. He also holds that they may cause a reduction in the firm's output technology innovations, although they "need not have this effect."

In the early 1970s, the Brookings Institution sponsored a series of studies on innovation that dealt with economic regulation, or as Brookings defined it, the regulation of competition [Capron, 1971]. These studies examined the effect on innovation of regulating industry structure, prices, and competitive practices. The overall conclusion was that performance of regulated industries fell "far short of the ideal and even of a reasonable target for public policy." But the Brookings studies introduced a significant caveat "that only in a few exceptional instances" can the inadequacy of performance be clearly documented. Evidence on how a firm or industry could be more innovative if unhampered by regulation was hard to come by, for there were few cases of no regulation or alternative forms of regulation to compare with existing practice in the case of the regulated industry [Capron, 1971]. When scholars hold that regulation stimulates or retards innovation, they have not resolved with consistency what standard should be used in judging industry performance.

The Brookings findings were confirmed in other studies of economic regulation by Klein [1975] and Leibenstein [1969], who found that because economic regulation eliminated business risk and restricted the freedom of firms to change operating methods, it encouraged a corporate laxity that was inconsistent with innovative behavior. However, Capron argued that reducing risk actually promoted innovation. Other studies detailed selective effects [Gellman, 1971]. Montgomery and Noll, for example, after examining the available evidence on the transportation industry, concluded that there was "too much innovation in air transportation, technologies using the highways and, perhaps, pipelines, and too little innovation with respect to rails" [1974].

The National Science Foundation, in a report on innovation and government policy, maintains:

> Hypotheses about the influence of regulation on innovation tend to be isolated, are sometimes in conflict, and do not form a coherent theory with predictive validity. This fact is not surprising, given the wide range of market structure and technological conditions in the industries that are regulated in the United States, the wide variety of regulations affecting these industries, and the numerous influences on technological innovation apart from the actions of regulatory bodies. [1976 pp. 19-20]

NSF advises not to expect general conclusions to emerge on the effects of government regulation on technological innovation, but to aim for "limited conclusions at lower levels of aggregation, such as within industries, areas of technology, or types of regulation" [p. 23].

## The Ecology of Innovation

Policy, however defined—either as R & D, or regulation—is only one factor among several affecting innovation. Scholars from different fields have tried to explain innovation through the perspectives of their disciplines. Economists, for instance, have depicted the influence of economic factors, particularly the role of market prices, relative factor costs, and limitations of supply. Mansfield [1968] argues that the rate of adoption is a linear function of the profitability of employing the innovation, the size of the investment required to use it, and other unspecified variables; Schmookler [1966] shows that intensity of technological development is directly related to growth in demand; Nelson, Peck, & Kalachek [1967] suggest that the speed of diffusion is positively related to the competitiveness of the industry or market.

At least one economist [Arrow, 1969] has also pointed out that non-economic variables affect technological change. Arrow argues that efficiency in the use or production of a novel item or technique increases with experience within the firm; moreover, the development of science, the education of engineers, and the availability of particular problem-solving skills interact with economic determinants of technological change to produce results significantly different from what one might expect from purely economic causes.

Behavioral scientists have applied a different framework to the examination of technological change. Because they look at the "innovativeness" (potential for innovation) of firms or industries, they require more dynamic and complex measures than economists, who usually seek to explain innovation that has actually occurred [Rosenblum, 1975; Warner, 1974]. Some behavioral scientists have examined the effects of characteristics of top and middle management, such as personality attributes, interest, and training [Coleman, Katz, & Menzel, 1966; Mohr, 1969]. Others have examined relationships among innovators and imitators and the relative importance of different channels of communication [Gray, 1973; Walker, 1969]. Still others have looked at the relationship between technology and the design of organizational systems or the influence of structure [Wilson, 1966]. And some behavioral scientists have investigated whether the potential adopters of an innovation perceive its significant characteristics as profitable, prestigious, compatible with needs and values, and so forth [Rogers & Shoemaker, 1971; Zaltman, Duncan, & Holbek, 1973].

The diversity of perspectives for studying innovation has led some scholars to call for an integrative framework. Warner, for instance, argues that:

> Researchers . . . have made significant contributions to the understanding of the dynamics of processes of change; yet the state of the art in diffusion research is not equal to the sum of the parts. This is due in large measure to disciplinary parochialism: Scholars have concentrated on those innovations, diffusion environments, explanatory variables, and analytical methodologies which are most compatible with their particular disciplines despite the fact that diffusion is not a discipline-specific phenomenon. [1974, p.30]

The phenomenon of disciplinary parochialism leads Rosenblum [1975] to call for "a policy-oriented synthesis, one built on a conceptual framework that would interlink current disparate traditions of inquiry" [p. 117]. A Georgia Tech group advocates an "ecology of innovation" approach, which would highlight the role of social, cultural, economic, and political factors, stress interrelatedness and interactiveness, and seek a holistic view of the innovation process.

The National Science Foundation has supported multidisciplinary studies that use what could be labelled the ecology-of-innovation approach. For instance, an NSF-sponsored study by Greenberg, Hill, and Newburger [1977] looks at the economic, technical, and legal factors involved in ammonia production. Greenberg, an economist, Hill, an engineer, and Newburger, a lawyer, make separate contributions. Policy considerations are included, as are economic and technological factors.

## Suggestions for Research

Although policy considerations may not be the critical factor affecting innovation, they play an important role. Public policies shape the environment of the firm, and they affect other crucial variables: (1) economic factors, such as prices, factor costs, availability, growth in demand, and the competitiveness of an industry or market; (2) the progress of research and development; and (3) channels of communication. They also influence social and cultural factors. In accord with recent NSF-sponsored research, there is a need to combine policy considerations with other perspectives to gain a more holistic view of innovation. It is also clear that these factors are not independent of each other and their relative interaction and interdependence need to be better defined and quantified.

Most studies view regulation as affecting the rate or intensity of innovation. A few have shown that regulation also affects the *substance* of innovation. Government-set airline prices, argues Caves [1962], have resulted in service-improving innovations. Similarly, Averch and Johnson [1962] argued, in a classic paper, that there is a propensity among regulated firms to develop capital-intensive innovations when regulation is based on return on investment. These studies indicate that the character of innovation as well as its rate have to be investigated.

Research is also needed to determine whether regulators are more effective in fostering innovation as a by-product of one type of policy as opposed to another — specifically, whether *economic* regulation—(which controls profit, price, and structure) or *health and safety* regulation (which controls qualitative performance) is more conducive to innovation. Another important question is how both types of regulation can be used to stimulate and not retard technological development.

A Georgia Institute of Technology study that reviews the current literature proposes making a "map" of institutions and public policies affecting innovation:

> This map would indicate the effect of *each* institution and policy on innovation and overlaps and conflicts among them. Such information would help locate specific areas where information is lacking and which need further study. [Kelly & Kranzberg, 1975, Vol. 1, pg. 117]

Institutional mapping could be used to track the effect of policy on critical decision-making variables, such as price, industry structure, demand, the state of knowledge in the area, the existence of communications channels, and the attitudes and opinions of managers.

## Concluding Remarks

Further study of the effects of policy uncertainty on innovation could make a significant contribution to policy development and ultimately to innovation. Decision makers need more than case descriptions if they are to cope effectively with policy uncertainty. Presently we know that uncertainty has selective effects, and that it affects the substance as well as the timing of innovation, but we are unable to judge how fast or in what way new products or techniques should be introduced. There is need for an analytical framework that will provide a taxonomy of the significant barriers to innovation that policy uncertainty imposes and of the incentives to innovation that come from policies crafted so as not to be misconstrued.

Three policy areas could be studied: R & D policy (including patent policy), health and safety regulation, and economic regulation. Examining the relationship between policy uncertainty and innovation may shed light on the continuing controversy over whether regulation stimulates or retards innovation. Further investigations will probably confirm that regulations have different effects, depending on a number of industry and firm characteristics and policy attributes.

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Alfred A. Marcus is an analyst at the Battelle Science and Government Study Center, Seattle, and an Affiliate Assistant Professor in the School of Business Administration, University of Washington, Seattle.

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