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WHY SHOULD MANAGERS BE THINKING ABOUT TECHNOLOGY POLICY?

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Courses on the management of innovation and technology seldom treat government technology policies, and the issues they pose for business management. This is unfortunate. In many fields business has a big stake in government technology policies. They can help business, be a waste of money, or actually hurt business. This essay considers three broad issues in contemporary technology policy, that are of significant consequence to business: government support of applied research, the question of how to deal with the decline in business-funded basic research, and the complex questions about intellectual property rights.

MOTIVATION

This essay originally was presented in an address to the Technology and Innovation Management Division of the Academy of Management. The topic might seem, at first thought, an odd one for that audience. The central interests of a group of scholars generally are reflected in the subject matter of the basic courses they teach. The courses that I know about in this field focus mostly on how to manage innovation and technology within a firm, and how to exploit or respond to technological developments originating outside the firm, and very seldom get into issues of government technology policy. Still more rarely do they see government technology policy as something that management ought to be concerned about and perhaps even 'try to manage.' However, my basic message is that government technology policy often matters importantly to firms, managers of innovation and technology should pay attention to what is going on on the technology policy front, and business in fact has a considerable say about what those policies turn out to be.

To make my argument concrete, let me point here to a few salient examples. Later I will discuss the issues these cases raise in more detail.

Thus consider the recent government initiative providing public funding for firms to develop their capabilities in flat panel displays (see for example, Davis and Zachary, 1994). This initiative is complemented by policies that hinder the ability of foreign firms to sell flat panel displays on the American market. The policies of subsidizing American firms, and hindering foreign firms, would seem to provide a real bonus to American firms who are now or intend to work in this area, but perhaps this is an illusion. If you were such an American firm would you support this policy? What if one of your competitors got a grant but not you? What should American firms that do not produce flat panel displays but who use them in the systems they put together think about all this? If you were to testify before Congress on this program, what would you say?

Since the middle 1980s Congress, in a series of Bills, has encouraged and pushed the National Laboratories to establish cooperative R&D agree-

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ments with private business organizations (CRADAs) (see for example, Cohen and Noll, 1994). Some of the new arrangements are between national labs and collections of firms—the textile program and the clean automobile program are cases in point. Many of the arrangements are between a lab and an individual business firm. To date, little public monies have been expressly assigned for work under CRADAs; the operant theory, for what it is worth, is that CRADAs do not represent a deviation from ongoing laboratory work, but rather are a vehicle whereby private industry can draw from and participate in such work. Currently it is being proposed that significant public funds go directly and explicitly into the CRADAs. What should be the attitude of business towards CRADAs in general, and towards the proposed policy of explicitly subsidizing them? What kind of constraints, if any, should be put on the nature of publicly subsidized applied R&D done for the benefit of industry?

At the same time that government programs to fund applied R&D with the direct aim of helping business are on the upswing, government support of basic research is under pressure. Partly the problem stems from the end of the Cold War, and budgetary pressures on the Department of Defense (DOD). It is not widely recognized that the DOD currently supports more than half of U.S. basic research in electrical engineering, computer science, materials science, and related fields. This support may soon slip away. What should be the position of business on this?

Also,Congress is pushing hard to have the NSF orient its research support more explicitly to fields and projects that have clear promise of helping U.S. industry. Should business support this pressure?

It is evident that over the last decade a number of the great American electronics companies that in the past have undertaken substantial basic research efforts have been drawing back from these programs (see Rosenbloom and Spencer, 1995). Some observers see the same developments occurring in the American chemical products industry. The reasons for these changes put forth by company executives is that their companies have been able to appropriate only a small fraction of the new technology enabled by central corporate research. On the other hand, scholars of technical change in these industries have pointed to the very important role played by corporate central research. Several knowledgeable observers see the drying up of corporate central research as seriously threatening future technical progress in these areas, and have suggested that it is urgent that the nation, and the industries involved, give serious thought to how to replace corporate central research. Should business be pushing for public policies here? What kind of policies?

There currently are a host of disputes about intellectual property rights. On the one hand, in the discussions that led up to the Uruguay Round draft agreement, American business representatives pushed very hard for other countries to agree to strengthen their intellectual property rights. But on the other hand, the American software community presently is quite divided as to whether intellectual property rights ought to be strengthened or broadened, or whether current trends in this direction represent a serious danger to the future progress in software, and at least to a portion of the industry. What happens may well be determined by Congress. How would you advise your business, or the business with whom you consult, to testify on this? The debate about whether gene fragments should be patentable or not raises similar issues. Should the American pharmaceuticals industry try to establish a unified position on this? If so, what should it be?

It seems to me that each of the cases I mentioned above are of major importance to a number of American firms and industries. Therefore, they ought to be the subject of informed and sophisticated management attention. But it is not at all clear to me that business knows how to participate in such deliberations, in large part because there has been very little thought given in business, or in business schools, to what appropriate government technology policy ought to be.

SOURCES OF FIRM AND INDUSTRY STRENGTH IN HIGH-TECHNOLOGY INDUSTRIES

Perhaps the central reason why these kinds of questions receive little attention in business schools is the perception that the principal

determinant of how well a company does in competition in high-tech industries is its own strategy and structure, the investments it makes in advancing and implementing new technologies, and how it manages these activities. In no way do I want to play down the importance of this perception. Business firms fund and undertake the lions' share of the R&D and other activities that generate technological innovation. How effectively they do this determines not only their individual fortunes, but also general economic progress. However, this perception assigns to the periphery matters that in many industries and technologies clearly ought to share the center of the stage.

Thus while the great private pharmaceutical companies have, in the post-World War II era, been by far the dominant source of new pharmaceuticals, various studies have documented the central importance of university research in enabling the companies to create the pharmaceuticals that they developed (Mansfield, 1991). Not surprisingly, the pharmaceutical industry is a strong supporter of government basic research support in fields of relevance to it. The pharmaceutical industry, more than virtually any other, depends on patent protection to enable firms to profit from their pharmaceutical R&D. Indeed, representatives of the pharmaceutical industry were by far the most vocal and active of the representatives of American industry arguing for stronger patent protection abroad in the discussions of the Uruguay Round. However, one can question whether what is good on this front for the pharmaceutical industry is good for other industries. And in fact the genome patenting issue may make the pharmaceutical industry rethink its belief that strong patents are always good. In any case perhaps because of the great importance of government 'technology policies' to the industry, pharmaceutical executives tend to be one important exception to the proposition I put forth above that, by and large, corporate R&D managers pay very little attention to 'industrial policy' issues.

The semiconductor industry also appears to be something of an exception, undoubtedly also reflecting the very major role that public 'technology policies' have played in the evolution in that industry. At least the old timers in the industry remember well that transistor technology, which was originally created at AT&T, was opened up as a result of an antitrust consent decree wherein AT&T agreed to stay out of commercial production of transistors (among other things) and to help acquaint American industry with the technology and to license it relatively freely. DOD procurement practices, which were open to new firms, induced the entry of many firms into the industry, who probably would not have entered had the military procurement market not been so open. DOD insistence on multiple sourcing has been an important reason why, up to recently at least, patents have been widely licensed in the industry. The DOD also has been the major funder of research in various scientific areas underpinning semiconductor technology, and the whole industry has drawn from that research. And, of course, recently, the DOD was the principal government agency pushing for the establishment of Sematech.

In addition to the correct perception that it is the business of firms themselves to be competitive, there is another widespread belief that militates against business executives and business school professors paying much attention to government technology policy. It is the belief that the principal role of government in 'high-tech', as well as other industries, is to set an environment that is conducive to industrial innovation, and then get out of the way. Again, I do not want to argue in any way against the position that a principal role of government policy is to establish an environment within which business firms have strong incentives to invest in industrial innovation. However, in many cases establishing that environment has involved some quite specific and directed 'technology policies'.

The National Institutes of Health (NIH) have been the principal funder of the fundamental research that has laid the basis for pharmaceutical development. It is no accident that the NIH supported certain sciences and research areas and not others, and that the areas they funded have proved fruitful in pharmaceutical development. The mandate of the NIH is to advance science related to health. The American electronics industry has drawn extensively from what has been learned through basic research in computer sciences, material science, and various fields of electrical engineering. It is no accident that the DOD supported research in these fields. They all are tied into technologies vital to the DOD. To shift away from these two industries,

the research support programs supported jointly by the Department of Agriculture and state governments have played an enormous role in technical advance in farming, and in the technologies used in industries that provide inputs to agriculture, and which process agricultural products. The old National Advisory Commission on Aeronautics, and later NASA, played important roles in the development of aircraft technology.

I want now to try to pull together and focus the above discussion by relating it to three different theories about the source of competitive advantage in high-tech industries. One of these, and as noted the most prominent one taught in business schools, sees the sources of competitive strength in the 'resources' and 'special competences' built up by the firms themselves. The influence of Alfred Chandler (1990) is clearly visible in this strand of theorizing, with his emphasis on the importance of firms' strategies, structures, and their three-pronged investments in manufacturing, marketing, and management. This body of theorizing also has been influenced profoundly in recent years by the various studies that have compared Japanese firms with American ones, identifying a number of features in the former that seem to be lending them competitive advantage. These views have been drawn together in a body of express theorizing about firm capabilities by writers prominently including Prahalad and Hamel (1990), Barney (1986), Dosi, Teece, and Winter (1992), and recently surveyed and extended in a review article by Teece, Pisano, and Shuen (1994).

Much of this writing about the sources of the competitive advantage of firms in high-tech industries is unknown in economics departments, and were this theory to be put forth it would be scoffed at. Economists traditionally have seen the sources of competitive, or as they would call it comparative, advantage in industries in characteristics of the national economic environment. Nearly two centuries ago David Ricardo pointed to the climate of Portugal on the one hand and the U.K. on the other as providing the major explanation why Portugal had comparative advantage in the production of wine and the U.K. in textiles. That theory gradually evolved over the years into what came to be called Heckscher–Ohlin trade theory, which posited that nations differed in relative factor endowments and, hence, in relative factor prices, and that these relative price differences provided the sources of competitive advantage. Nations tended to specialize in those industries whose production stressed the factors most plentiful, and hence most cheap, in that country. In the simplest version of that theory, the firm's discretion regarding strategy, structure, and investments, that are the focus of the theories discussed earlier, are nowhere in view. Firms in a country compete effectively in world markets in certain industries because of the factor market environment in which they live.

There are two amendments to this theory that are relevant here (See Dosi, Pavitt, and Soete, 1990). One is what came to be called product cycle international trade theory. Under that theory nations endowed with particular kinds of markets, for example those demanding especially high-performance products, and possessing certain kinds of resources, for example plentiful highly trained scientists and engineers, tend to have a comparative advantage in 'new products' or 'new technologies'. Firms in these countries naturally are induced to create these products and technologies first. As the technologies mature, firms in other countries begin to pick them up. Another, but related, strand stresses national institutions. Thus economic historians, like Landes (1970), have argued that the reason why Germany (and the U.S.A.) took the lead toward the end of the nineteenth century in the new chemical products and electrical equipment industries was that the German (and American) university systems were much more responsive to the needs of these new industries for trained scientists and engineers, than was the university system of Great Britain.

However, note that these extensions of the economist's theory of comparative advantage, like the pure vanilla version, stress broad-gauged national characteristics. The theory admits, indeed presumes, that a nation's factor endowments and institutions may be more beneficial for some industries than for others, but does not see these national endowments as coming about 'because of' an interest in supporting these industries.

The arguments I presented earlier invoke still a third theory of the sources of competitive or comparative advantage. Without denying the importance of firm-specific investments and

decisions, or the broad national economic environment, this third body of theorizing focuses on particular national activities and investments that are, usually by intention, aimed to help particuar industries or to advance particular technologies. Thus Alfred Marshall's concept of industrial districts has been picked up in recent scholarship, for example by Michael Porter (1990) and Paul Krugman (1991). While both of these authors focus on the self-organizing features of a system involving firms in an industry, suppliers, users, and the supply of skills and connections that these interactions naturally induce, both writers acknowledge that government policies can help or hinder in this process. Other writers, for example Bennett Harrison (1992), have stressed the public investment aspects.

The arguments I put forth above are in the spirit of this third kind of theorizing. They are focused on governmental activities and investments that are aimed to help particular industries, or further the advance of particular technologies. The general theoretical proposition is that the environment within which firms in a particular industry operate must be seen as including a wide variety of institutions, ranging from regulatory authorities to universities to government departments, who have an explicit interest and involvement in the industry in question, and whose policies can make a big difference to the competitive advantage of the firms in that industry.

THREE BASIC QUESTIONS ABOUT TECHNOLOGY POLICY

I intend now to use the examples I described at the start of this essay to raise three basic questions about technology policy. First, should public support of applied R&D go to individual firms, or to industries collectively, and how should such applied R&D programs be governed? Second, how should industry-focused basic research programs be structured, and governed? Third, what should be proprietary, and what should be public, about what emanates from such publicly supported programs? I will present my own views on these questions, but not in strong advocacy. Rather, my intention is to get a discussion started.

The structure and governance of industry-oriented applied R&D support programs

The new flat panel display support program, the advanced technology program of NIST, Sematech, and the policy of arranging CRADAs between national laboratories and private firms or groups of them, are all new policies involving the use of public monies, or public resources more generally, to support applied R&D to help individual firms, and industries. I believe that there are two connected questions that should be asked about such programs. Should they provide support for individual firms, or should the objective be to help an industry as a whole, or to develop a technology of particular interest to an industry or group of industries, with funding not going to individual firms, but rather to some collective or outside organization? Second, how should such programs be governed? In particular, what role should industry play in determining how the funds are allocated?

It seems to me that it is important to recognize that there are signficant differences in these programs in terms of whether they are oriented to supporting projects of particular firms or, whether they support projects aimed to benefit the whole industry. The flat panel display program, at least as it has been articulated thus far, and the general philosophy about the CRADAs, suggests an orientation to projects proposed by and benefitting individual firms. On the other hand, Sematech, the textile and automobile research programs linked to the National Laboratories, and the various programs in support of high-temperature superconductivity seem to be oriented to help broader industries, rather than particular firms.

While to my knowledge this issue has not been posed sharply, I think it is important to think through whether government programs in support of applied research to help industry should have a broad industry focus, or whether they should deal with firms on an individual basis. I believe relatively strongly that government technology policies supporting applied R&D ought to have a broad industry focus, and that it is important to stay away from programs that fund research on a firm-by-firm basis. I have two reasons for this position. One involves the question of how to structure effective governance for such programs. My second reason is in terms of the politics involved.

Programs that are aimed to support R&D for a broad industry, or to support technological development that will aid a broad industry or collection of them, can without awkwardness involve industry people centrally in the processes that select what projects will be funded, and how the overall program should be governed. The Sematech structure is a good example. Textile industry representatives are prominent in the governing structure of the National Laboratories program to support the development of appropriate broad-gauged technology for the American textile industry. I believe industry presence on the allocation and governing structure is essential. On the one hand, as a general rule it is important to guard against government programs that fund research that already is being done in industry, or which industry is ready to do in any case. On the other hand, if these programs are to be effective, industry must welcome them, and lend its expertise in providing guidance for allocation, and be sufficiently well connected so that, when research yields results, industry can pick up on them. Where such programs are conducted without strong industry representation in their direction, there is a good chance that government programs will duplicate what is already going on in industry, or will undertake efforts that industry does not regard as helpful, or both. I believe that sophisticated industry representation in the governing body of government programs probably requires that the programs be directed at broad industry questions, or at broad technologies. If the programs involve competition among different companies for government funds, I think it implausible that one can have unbiased industry representation in making decisions as to what companies get funds, and what companies don't.

I also have some misgivings as to whether government applied research support programs that provide monies, or other government resources, to particular companies will prove politically viable over the long run, unless an implicit rule evolves to share the money around, which is not a prescription for good science. There have been several occasions, already, in which a movement to finance a particular project of benefit to a particular company has, when the wind of what was going on got around, been effectively resisted politically by other companies who felt that their interests were jeopardized. My belief is that government programs funding applied R&D which benefit one or one group of companies against another group in the same industry will prove politically unviable.

So, regarding this class of 'technology policies,' my suggestion is that industry push for industry-wide programs, and that industry insist on significant representation in the governing structures. But then there also need to be mechanisms built into the programs to prevent simple 'sharing around'. My belief is that, to guard against this, matching industry funds ought to be required and the work conducted outside of industry.

Strong industry influence on the allocation of funds under a program has its pluses, and also its minuses. The experience under Sematech suggests that an industry group will not, if their own funds are at stake, support long-run basic research. If one believes, as I do, that an important task of government policies these days is to shore up long-run basic research of relevance to industry, one must develop particular instrumentalities to do that. To this issue I now turn.

The 'basic research' problem

I think the following positions are quite consistent with each other. A program whose direction is largely set by a board in which industry people play a dominant role, or have veto power, and where a large share of the funds are coming voluntarily from individual business companies, will tend to shy away from funding long-run basic research. On the other hand, if those same industry people were to step away from the particulars of the decision problems they face, most of them would agree that it is highly important for their industry that certain areas of long-run basic research be supported. I want to again stress that 'basic research' can be, and in fact largely is, highly targeted to the problems and opportunities of particular industries, and to particular technologies that are largely employed in certain industries. I also would like to propose that the industries that have experienced the most rapid technical progress over the last half century—industries like pharmaceuticals and electronics—have benefitted from a large amount of 'basic research' that was targeted in their direction.

The current problem is that support for such

basic research is eroding. As noted earlier, much of the support of basic research relevant to electronics has been supported through the DOD, and the end of the Cold War seriously threatens that support. NSF support of basic research is being looked at skeptically by Congress. At the same time, the great electronics companies who had been supporting and undertaking such basic research in their own laboratories are drawing away, not because such research has not proved productive, but rather because the fruits of such research have been widely shared across the industry, rather than being largely concentrated in the company that funded the research.

The policy design problem, it seems to me, contains several elements. First, industries who benefit from university basic research need to establish mechanisms to strongly lobby Congress, and the Executive, to provide significant public funding to support that research. One special problem resides in fields that, up to the present, have been funded largely through the DOD. I think a good case can be made for moving these programs, and the funding for them, over to the National Science Foundation. I also think that industry people ought to testify strongly against pressures to move the NSF towards applied and away from basic research. Industry needs to articulate its strong interest in university basic research, and its concerns that applied research not be permitted to drive out basic.

The issue of finding institutional replacements for corporate central research in various industries is different. The problem here is not adequately met simply by funding a number of research projects scattered around at different universities, but would sem to require relatively large-scale coordinated efforts. In my view this problem is one of the most challenging ones in the technology policy area. My bet is that university-affiliated labs are the place for this activity. Industry funds should go into it, but with significant public monies as well. And industry scientists should be among those working in the labs. But all this is quite controversial.

Proprietary or public results?

The issue about 'patenting the human genome' raises an important set of issues in a particularly dramatic form, but the issues are also cropping up outside the genome project. The research findings under controversy refer to the genetic code for particular gene fragments. Knowledge of this code facilitates further research which, ultimately, may result in a commercial product, but the main use of such knowledge is in research. In a very basic sense such knowledge is part of the domain of science. It has been traditional in science to publish findings, and to allow all scientists to have free access to them in their own research. While the biotechnology industry gave mixed testimony on the matter, a considerable portion of that testimony expressed concerns that, if portions of the genetic code were patented, that would seriusly complicate the doing of research in biotechnology. This raises two questions. First, should research findings whose principal use is in further research be patentable at all? And second, if the answer to this question is affirmative, should there be a 'research exemption' to allow the use of those findings in further research in corporate as well as university laboratories? In biotechnology industry, and in a number of others, questions like this are becoming increasingly important.

The debate about intellectual property rights on 'software' raises a somewhat different issue. Almost all operant software programs involve a combination of subprograms that fit together. Software is a 'systems' technology. A number of studies have shown that strong intellectual property rights cause significant difficulties in systems technologies, because different parties tend to accrete property rights on different parts of the system, and therefore putting together a 'state of the art' system and using it may require a considerable amount of licensing, which often has proved difficult to obtain. The patent codes of several other countries contain a provision for compulsory licensing of technology when it is needed to enable a company to exploit its own invention. Should something like this be considered in the U.S.A.?

But this essay is not intended to address policy issues like those involving intellectual property rights, or basic research, or government support of industry-oriented applied research programs, in a detailed way. Rather, my purpose is to argue that issues of this sort are of major importance to high-tech business, and thus important topics that ought to be considered under the rubric of the management of technology and innovation.

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