INCREASING INNOVATORS' RETURNS FROM INNOVATION

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ABSTRACT

Innovators appear unable to capture as much benefit from their innovations as they--and society--might wish. This paper explores the problem by identifying and examining the mechanisms used by innovators to capture innovation benefit for themselves and to allocate innovation-related costs to others. Only a few weakly and unevenly functioning mechanisms are found serving these purposes in the U.S. economy. Improvements are proposed which government and innovating firms could undertake to increase innovators' returns from innovation.

INTRODUCTION

Firms find it worthwhile to develop new products and processes when their benefits exceed their costs by a margin they find attractive. But attractive cost benefit ratios are not immutable characteristics of particular innovations: they are created by an innovating firm's energetic strivings to capture innovation-related benefits for itself and to allocate innovated-related costs to others.

Innovating firms are not as successful at creating attractive innovation cost benefit ratios as society might wish. As recent research by Mansfield et al. (1) and two others (2,3) finds (see Table 1), firms' "private" rates of return from innovation (net return to the innovating firm) are much lower than "social" rates of return from innovation (net return to the innovator plus net return to all other private parties--innovation users, suppliers, imitators, etc.--affected by the innovation).

INSERT TABLE 1 HERE

This result suggests the unfortunate possibility that many innovations which would pay handsome social returns are not being carried out because the private rates of return to the innovating firm are unattractive. It would thus behoove us to identify and explore the nature of the mechanisms which firms currently use to capture innovation benefit and allocate innovation costs, and to consider how these might be improved by industry and government. To my knowledge, such an exploration has not been carried out before, and we will often find ourselves treading new ground.

Table 1

SOCIAL AND PRIVATE RATES OF RETURN*
FROM INVESTMENT IN INNOVATION

Study:	Mansfield et al. (1)		Tewksbury et al. (2)		Nathan Associates (3)	
	Social	Private	Social	Private	Social	Private
Median %;	56	25	99	27	70	36
Range %:	Neg-307	Neg-214	Neg-472	Neg-148	Neg-371	Neg-157
Sample n:	17		20		20	

*Note: All three studies utilize Mansfield's definitions of private and social rates of return. In brief, Mansfield defines private returns as net pretax profit of the innovating company minus R&D costs and other innovation-related investment minus profits (such as profits from sales of products displaced by the innovative product) lost as a result of the innovation. Social returns are defined as private returns plus innovation-related benefits and costs incurred by all innovation users and firms which compete with the innovator plus the impact, if any, of the innovation on public goods such as water quality. Note that Mansfield's measure of social return is incomplete, since it excludes innovation-related returns experienced by suppliers, independent inventors and others. These omissions have an appropriately conservative effect given the direction of his findings.

A TAXONOMY OF INNOVATION BENEFIT CAPTURE MECHANISMS

Many means exist by which firms may gain competitive advantage, ranging from superior management, marketing, or production skills to favorable access to financial and other resources. Almost all of these means are innovation independent, however: they will serve innovators and imitators equally. The only mechanisms which will give an innovator advantage over imitators are those which give him some degree of monopoly control over his innovation, control which he can use to charge license fees or to exclude would-be imitators and produce in-house under favorable market conditions, thus recouping his innovation investment. Without such control, part of the costs incurred by an innovator can be avoided by an imitator because he can freely learn what the innovator has spent money to learn. And under such conditions it would pay firms to imitate rather than innovate--obviously not a socially desirable result.

It is a rather difficult to devise mechanisms which allow innovators some effective degree of monopoly control over their innovations, because at bottom one is trying to control the diffusion of innovation-related knowledge. I have been able to identify three such mechanisms currently extant in our economy: patents, trade secrets (also called "know-how"), and lead time.* Interestingly, while the patent grant and trade secrecy may be discussed as conscious social inventions, the lead time mechanism may best be described as an aspect of our economic system which innovators have learned to turn to advantage. As I will describe, each of the mechanisms operates according to a different principle, allows protection of different types of innovation knowledge, and provides the innovator with a greater or lesser degree of freedom with respect to converting innovation control into innovation benefit.

*Copyright protection, extended to computer software by Congress in December, 1980 via an amendment to the 1976 Copyright Act, is not considered here.

The Federal patent system grants a patentee temporary legal property rights to publicly available knowledge--normally a free good. In essence, it stipulates that, if the inventor will make knowledge of his invention generally available by publishing it in a patent, society will grant him the temporary legal right to prevent others from using that knowledge and/or allow him to charge fees for its use.

The type of innovation-related knowledge which a patent grant is designed to protect is severely limited. Protection is offered only to explicitly described technical means to achieving a useful end--given that the means is of sufficient novelty and usefulness to be legally deemed an invention. Thus, patents cannot be used to protect valuable technical know-how not deemed sufficiently novel to constitute invention. Nor can they be used to prevent free access by imitators to the very valuable non-technical developments which an innovator must often invest in, such as proving the existence of a market for a functionally new device and educating potential customers.

In contrast to the patent system's protection of publicly available knowledge, innovators can protect their innovation-related trade secrets from would-be imitators by keeping that knowledge secret. The possessor of such a trade secret has an indefinite period of exclusive use of his invention or discovery. State trade secret legislation allows him to keep the information entirely secret or to make legally binding contracts with others in which the secret is revealed in exchange for a fee or other consideration and a commitment to keep the information secret. A trade secret possessor may take legal steps to prevent its use by others if they can be shown to have discovered the secret through unfair and dishonest means such as theft or breach of a contract promising to keep it secret. Note, however, that the possessor has no property rights in the secret knowledge itself. If an imitator discovers the secret by legal means such as reverse engineering, the innovator has no recourse.

A legally protectable monopoly of indefinite duration is obviously a very attractive mechanism for capturing innovation benefit. It is, however, an option only for innovations which can in fact be kept secret. In practice, therefore, trade secrets have proven to be effective only with regard to product innovations incorporating various technological barriers to analysis, or with regard to process innovations which can be hidden from public view.

There are, in the first instance, certain innovations embodied in products which, while sold in the open market and thus available for detailed inspection by would-be imitators, manage nevertheless to defy analysis for some technological reason and which cannot therefore be reverse engineered. Complex chemical formulations sometimes fall into this category, the classic case being the formula for Coca-Cola. Such barriers to analysis need not be inherent in the product--they can sometimes be added on by design. Thus, some electronic products gain some protection from analysis via use of a packaging method ("potting") and packaging materials which cannot easily be removed without destroying the proprietary circuit contained within. (4) Methods for protecting trade secrets embodied in products accessible to competitors need not be foolproof to be effective--they simply have to raise enough of a barrier in a given case to create an unattractive cost benefit equation for would-be imitators in that case.

In the second instance, process innovations such as novel catalysts or process equipment can be protected effectively as trade secrets, whether or not they could be "reversed engineered" by a would-be imitator allowed to examine them, simply because they can be exploited commercially while shielded from such examination behind factory walls.

Finally, an innovator can use the lead time mechanism to temporarily protect his innovation property rights. Lead time is the period which starts when an innovator begins to make economic use of his innovation and ends when the first imitator begins to compete. Even when an innovator cannot protect himself via patent or secrecy, some lead time is always present due to the response time of imitators, and lead time protection is therefore potentially applicable to all innovators. It simply takes time to decide to imitate and then to tool for production, develop marketing plans, and do the other myriad things which must be done before any product, even an imitative one, can be brought to the marketplace.

Although some amount of lead time is always available to an innovator, the level of effective monopoly control it can provide him is heavily dependent on several situation-specific factors. One such factor is the length of lead time divided by length of customer purchase decision cycle. A high value of this factor favors the innovator over imitators. Consider one extreme example: a consumer "fad" item (very short purchase decision time) which sells in high volume for six months only. Assume that the item can be readily imitated--but can only be produced economically by mass-production tooling requiring six months to build. Obviously, lead time here allows the innovator to monopolize the entire market if he can supply it with his initial tooling. At another extreme is an expensive capital equipment innovation which customers typically take two years to decide to buy, budget for, etc.--and which competitors can imitate in one year. Obviously, lead time in this instance affords an innovator little protection. A second situation-specific factor involves the slope of the learning curve. The steeper the curve, the greater the production cost advantage an innovator can accrue relative to potential imitators per unit of lead time enjoyed.

While innovators are trying to protect their innovations via the mechanisms described above, would-be imitators are trying to defeat these and gain free access. The actual protection an innovator achieves depends on the outcome of this contest. Since numerous, often effective strategies are known for attacking each mechanism, protection afforded is often low--and always uncertain.

Imitators who wish to use an innovator's patented knowledge against his will have several time-tested options. First, knowing that the patent law places the considerable burden of detecting and prosecuting infringers on the patentee, imitators can simply infringe if they judge a particular patentee unable or unwilling to defend his rights. If brought to court, they may try to convince a court that the patent is invalid, and studies of court statistics (5) show they often succeed in this even though under the U.S. patent system claims are studied by employees of the Patent Office and judged to be valid before a patent is granted. Second, imitators can try to "invent around" a patent by modifying the invention in such a way as to skirt the material specifically protected by the patent. Such inventing around may well cost considerably less than the investment the innovator--and society--is trying to protect via the patent mechanism.

Empirical and anecdotal evidence (6) shows that that patent grant is not a very effective innovation benefit capture mechanism in most fields of technical endeavor, with pharmaceuticals and chemicals being the primary exceptions. Data shows innovators do not rely much on patent protection (7) and gain little financial return from patents they attempt to license. (8)

Would-be imitators use several means to gain access to innovator's secret know-how. Products on the marketplace are the most vulnerable because methods of analysis are getting more sophisticated. In some industries, notably semiconductors, certain companies specialize in circumventing the technical barriers erected by innovators, analyzing and reverse engineering the innovative product and selling the innovator's hard-won knowledge at a low price to interested imitators. Sometimes secret process innovations will also be discoverable by analyzing the chemical or mechanical traces left in the manufactured product output. (We find traces of x solvent in the plastic so they must have developed x process; the mold marks left on the product indicate a novel mold was used of construction z) or by noticing unusual inputs to the factory containing the secret process (why are they buying so much platinum?). More often, however, such process secrets are eventually revealed by people who shared in the secret of the innovating company and then left. If such breaches of confidence can be traced and proven, the innovating company can sue and enjoin the resulting imitation, but often the evidence is not so clear.

Finally, an innovation's lead time is also potentially vulnerable to the efforts of would-be imitators. Such firms can attempt to shorten an innovator's lead time by being alert to early signs of an innovator's plans such as orders of special parts from suppliers and test market experiments. In the consumer product field, some firms even make a business of observing innovator's test markets and reporting the results to interested competitors for a fee.

Conversion of Control into Benefit

An innovator who has succeeded in thwarting the attacks of would-be imitators and has established some degree of monopoly control over his innovation has another task to perform--the conversion of control into innovation benefit. As in the case of establishing control, this is not an orderly process--and not all types of innovators find themselves created equal with respect to it.

As was observed earlier, an innovator can in principle capture benefit from his innovation either by licensing it or by producing the innovative product (using the innovative process) in his own firm. In the former case, the innovator uses his monopoly power to exact a fee from those he licenses--and to exclude those he does not license. In the latter case, he uses his monopoly power to exclude all competitors and thereby increases the innovation-related sales and/or profits of his own firm above what would otherwise be attainable. Since, for a given innovation, maximum private innovation return may come from a policy of in-house exploitation by the innovator only, licensing to other firms only, or a combination of these, the perfect innovation benefit capture mechanism would provide monopoly control effective for either strategy. In fact, only the patent mechanism approaches this ideal--for the type of knowledge protected by a patent. Know-how and lead time protect in-house exploitation of an innovation far more effectively than they protect the innovation property rights of an innovator who wishes to license. The reason for this difference is clear--and the consequences are significant.

In order to license innovation knowledge, an innovator must be able to display it to potential licensees without thereby losing his innovation property rights. If his protection comes via a patent grant, he can publicize his innovation with impunity: The patent protects <u>public</u> knowledge. In contrast, his ability to display trade secrets to potential licensees is sharply limited because, as the reader will recall, the trade secret mechanism protects only secret knowledge--and a secret cannot be shared very widely and remain a secret. Finally, the leadtime mechanism cannot be used at all for licensing because it involves no proprietary control of knowledge. It can only protect an innovator's own direct, in-house exploitation of his innovation.

The relative lack of protection for innovators who wish to license their innovations creates a bias in favor of direct in-house exploitation of an innovation by an innovator. Since all would-be innovators are not equally _able_ to exploit a given innovation in-house, the significant consequence is that some innovators are better positioned to convert their monopoly control of a given innovation into a private innovation benefit than are others.

For example, firms with more resources to invest would be better positioned than poorer firms to exploit innovations which require high investment. So too would firms who find they already have some of the needed resources--such as special production facilities or distribution channels or reputation in the market--in place.

On the other end of the scale, independent inventors will be uniquely _poorly_ positioned to convert monopoly control to innovation benefit when that monopoly control applies to protection of in-house use only.

Note that in many industries, especially fragmented ones, all existing firms may have a relatively poor ability to capture benefit via in-house exploitation of an innovation. And in such industries, one can expect the industry's incentive to innovate--and innovation record--to suffer from the relative inability of existing innovation benefit capture mechanisms to protect innovators who wish to license.

A TAXONOMY OF COST ALLOCATION MECHANISMS

To this point I have examined mechanisms by which innovators can capture innovation benefit--but private rates of return on innovation investment can be increased by improving the ability of the innovating firm to allocate its innovation costs to others as well, and I now turn briefly to a taxonomy of mechanisms to achieve this end. I will consider first the mechanisms which innovators use to allocate innovation costs to users and suppliers, then those applied to allocate costs to competitors, and finally those applied to government.

Innovating firms gain their power to allocate innovation costs to some suppliers and users through their power to choose whom to buy from and their power to set some conditions of sale. An innovating firm's allocation of innovation costs to high benefit users usually takes the form of requests for innovation-related payments of various types such as payments for "tooling" and for "development." In contrast, cost sharing with suppliers usually involves the supplier shouldering some of the development work involved in the innovation project. Thus, suppliers are often asked to do some or all of the design work on components they will supply to the innovating firm, and are sometimes asked to design other components as well or to provide other "technical assistance."

Cost sharing agreements are made between innovating firms and individual users and suppliers. An innovator is most likely to be able to make such agreements if his innovation is one which brings high benefit to individual user or supplier firms--as opposed, for example, to bringing a little benefit to each of many firms in a fragmented market. Further, such high benefit users and suppliers are most likely to cost share if they gain some commensurate advantage from it which is not available to their free-riding competitors. Thus, user's willingness to cost share may be contingent upon receiving favored treatment with respect to delivery times while a supplier may expect to receive production orders for a part in exchange for designing it. Such expectations are often not legally enforceable--for example, a supplier usually has no legal means of preventing an innovating firm from placing production orders for the part he has designed with others. Indeed, the only pragmatic constraint on such behavior is usually an innovating firm's fear that not giving preferential treatment to cost-sharing users and suppliers will result in less help being offered on their next project.

Innovators sometimes share development costs and/or work with their competitors via joint agreements. Such agreements can be limited to a specific project but are often for an open-ended program of industry-relevant research to be conducted by a jointly funded "Industrial Research Association." The recent, reportedly fruitful, joint research effort by a group of Japanese semiconductor firms in the area of VLSI Processing technology appears to have triggered some interest in the concept in the U.S., and the Justice Department has recently responded by issuing guidelines indicating that, under many conditions, research sharing between competitors would not violate existing antitrust laws. Such research sharing is not new, however, and the historical record does not show the concept very vital. Despite long-term government funding and support, for example, the proportion of a given industry's R&D performed in British Industrial Research associations was only 1-3% of total industrial R&D effort in such research intensive industries as electrical engineering and chemicals (9) and tended to be focused on matters such as standards setting rather than novel products or processes. The proportion of industry R&D expenditure performed in Industry Associations was also relatively small in other European countries (10) and also felt to be unimportant in Japan (11).

Research cost and/or work sharing between potential competitors is unlikely to prove a more vital innovation cost allocation mechanism in the future for a simple reason: As was not the case when one shares costs with users or suppliers, the quid pro quo for sharing innovation cost with one's direct competitors is that one shares innovation knowledge. Thus competitors are prevented from using that knowledge to competitive advantage--which is usually its main source of benefit. Joint research can and does flourish when providers of the same good or service are not direct competitors for some reason, however. Thus, the electric utilities, each a geographic monopoly, logically cooperate in the Edison Electric Institute. Similarly, patent pools on such technologies as the manufacture of petrochemicals often thrive when there are strong barriers, such as control of feedstocks, which prevent one firm from using innovation to invade another's market.

Government shares innovation costs in several ways--and via myriad specific programs. First, it is a buyer and user of many innovative goods and services, and it will often share the cost of developing these much as buyers in the private sector do. Thus, the Defense Department has paid for the development of military aircraft, electronics, etc. Second, the government implicitly recognizes that the ability of would-be innovators to capture private return from basic research is low, and therefore undertakes to fund research in university and industry laboratories, and to perform research in government laboratories. Third, the government attempts to diffuse research results to potential users via general data banks such as the National Technical Information Service (NTIS) as well as programs targeted to specific user groups such as the Agricultural Extension Service. Fourth, it reduces the cost of R&D through special tax treatment for R&D expenditures. Periodically, the government will decide that a particular area--energy is a good current example--needs special stimulus and it may then shoulder a greater than usual amount of innovation costs in that area by, for example, funding "demonstration plants" embodying a new technology. Obviously, the pattern and level of government innovation cost sharing is set and reset as part of the political process.

DISCUSSION

As a result of the examination of innovation benefit capture and cost allocation mechanisms discussed, one can begin to appreciate the possibility that benefit capture by innovators is not only in general too low, as is suggested by the data collected by Mansfield and others, but that it varies strongly from case to case and from industry to industry and causes related--and not necessarily desirable--variations in the types and levels of innovation undertaken in the U.S.

Given the importance of the issue, it would seem useful to explore the area further. One research approach which seems promising in several regards involves empirical studies of what I have termed the "functional locus of innovation." I have summarized the findings of a few such studies in Table 2 and as the table shows, such studies have shown strong variations in the sources of innovation. These are arguably (12) caused by major variations

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Table 2

EMPIRICAL DATA ON THE FUNCTIONAL SOURCE OF INDUSTRIAL INNOVATIONS

Study	Nature of Innovations and Sample Selection Criteria	n	Innovation Developed[a] by: User%	Mfr%
Knight[13]	Computer innovations 1944-62:			
	- systems reaching new performance high	143	25	75
	- systems with radical structural innovations	18	33	67
Berger[14]	All engineering polymers developed in U.S. after 1955 with >10mm pounds produced in 1975	6	0	100
Boyden[15]	Chemical activities for plastics: All plasticizers and UV stabilizers developed post World War II for use with 4 major polymers	16	0	100
von Hippel[16]	Scientific instrument innovations:			
	- first of type (e.g., first NMR)	4	100	0
	- major functional improvements	44	82	18
	- minor functional improvements	63	70	30
von Hippel[17]	Semiconductor and electronic subassembly manufacturing equipment:			
	- first of type used in commercial production	7	100	0
	- major functional improvements	22	63[b]	21[b]
	- minor functional improvements	20	59[b]	29[b]

Notes

[a]Attribution of an innovation to a user or manufacturer "developer" is determined by which of these first builds and utilizes the innovation in conformance with his economic function. Thus, attribution to a user source is made if a user builds and uses an innovation before a manufacturer builds and sells a commercial version. And conversely, attribution to a manufacturer source is made if a manufacturer builds and sells a commercial version of an innovation before a user builds and uses a home-made version; NA data excluded from percentage.

[b]Attribute missing percentage to joint user-manufacturer innovation projects.

in the abilities of firms holding different functional relationships (e.g., user, supplier) to a given innovation to apply the different benefit capture mechanisms which have been discussed to capture benefit from it (for example, a user who develops an innovative process machine can protect it or a trade secret while using it behind his factory walls. In contrast, a process machine manufacturer who developed the same machine could not avail himself of this form of protection from imitators: he must display the machine in order to sell it). These differences can be used to empirically explore the real-world effectiveness of extant benefit capture and cost allocation mechanisms, and work on this topic is in process.

All corrective action need not wait on further research, however, and I now turn to consider some implications of what is currently known for government and industry.

Implications for Government

Government is in the fortunate position of being able to devise and improve mechanisms for innovation cost allocation and benefit capture. To this point, it has focused almost exclusively on cost allocation mechanisms, and I suggest that it is now time to devote effort to exploring and improving benefit capture mechanisms.

In my view it is particularly important to make efforts to improve the level of real world protection offered by the patent grant because, as we observed earlier, it is in principle the most flexible of existing benefit capture mechanisms, offering, as it does, protection for publicly available innovation-related knowledge. Indeed, if a "perfect" patent mechanism could be devised which gave an innovator "perfect," costlessly enforceable property rights to his innovation, i.e., if, without cost to himself, he could totally control its diffusion and capture benefit from innovation users, manufacturers, and others to the point where adoption becomes a matter of indifference to these, then two very interesting things happen. First, <u>any</u> innovator could reap the same amount of benefit from a given innovation* and, second, the innovator could increase his private rate of return above the social rate of return.** Since perfection is elusive in this as in all spheres, the

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* The reasoning behind the above conclusion is that costless enforcement of property rights would allow any innovator to set the fees charged to each innovation beneficiary, and each class of beneficiaries, so as to attain the maximum return. The role which the innovator himself happens to play with regard to the innovation--user, manufacturer, etc.--does not influence his fee-setting decision because he is equally able to capture innovation returns from his own company and other companies. This being so, he has no incentive to concentrate benefits in his own company. For this to strictly hold, the assumption of costless enforcement of property rights is required for the following reason: Since marketing of an innovation and enforcement of payment can be reasonably assumed to be costless for an innovating firm when it captures output-embodied benefit by utilizing the innovation knowledge in its own processes and/or products, <u>non</u>-costless marketing of and enforcement of payments for use of innovation knowledge by other firms would create a differential between benefit attainable from in-house and external use of the innovation and generate a preference for the former. This in turn would allow an incremental benefit from the same innovation to accrue to those innovators with a larger in-house use for it.

Note that, with perfect, costlessly enforceable innovation property rights, an innovator has no reason to give preference to his own firm's in-house use of the innovation even if the direct return from the particular innovation can be "leveraged" by its user. Suppose, for example, that a minor cost-reducing process innovation were made available to one of several manufacturers of a commodity with previously equal manufacturing costs, financial resources, etc. If further innovations or other changes did not intervene, the commodity producer benefiting from the innovation could in principle increase his market share as a consequence of innovation and thus "leverage" the direct benefits of the innovation, perhaps many fold. But note that, even under such a set of circumstances, the innovator has no incentive to prefer to increase or decrease the market share of his own company relative to that of his competitors because he can, given perfect information, also charge the benefiting company for such second (and nth) order benefits arising from the innovation up to the point of indifference.

** Recall that the social return from an innovation is the innovator's net private return plus the net innovation-related return of all other affected parties. If perfect, costlessly enforceable innovation property rights allow the innovator to reduce the returns of all other affected parties to their indifference point, the private rate of return will be above the social rate of return (given, of course, that the weighted indifference rate of these others lies below the private rate of return of the innovation at issue).

important point is that improving the patent mechanism will have an effect in the desired direction on the private rate of return and will also reduce the discrepancy which currently exists between the ability of different innovators to capture private benefit from a given innovation.

As we have discussed, the effectiveness of the patent mechanism is currently low for two types of reason: First, because the type of knowledge it protects is narrowly restricted to technical invention and, second, because protection of granted patent rights is uncertain and expensive. I suggest that solutions be sought for both of these patent problems. With respect to the first we should experiment with expanding the protection offered by patents to other forms of knowledge which are currently free to imitators, but which innovators must invest in so as to obtain innovation benefit. Consider, for example, the cost involved in defining the market for a new-function product. Why should that innovation-related knowledge not be protected directly rather than indirectly via the (possible) technical novelty of the means by which the effect is achieved? Similarly, why should one not extend patent protection to the invention of a new means of doing business and other subject matters now not covered? (18) Second, the government should make the assertion of one's patent grant rights less costly and uncertain than it currently is. The recent revised patent law promises some help in this direction by allowing the patent office to reexamine initial challenges to a patent's validity administratively, rather than requiring that challengers pursue the matter in court. This should allow some questions of patent validity to be resolved more quickly and economically than heretofore. Many other problems, such as judges' apparent bias against the monopolies afforded by patents (19), still have to be addressed however.

Innovation benefit capture mechanisms can be designed to protect a broad range of innovators, as in the case of the patent grant, or to reward only a specified few. As an example of the latter type, consider a mechanism in which the government offers a prize to the first to achieve a specified innovation and make the knowledge freely available. Economists are fond of this concept because, as they point out, innovation-related knowledge, once created, has a very low reproduction cost and social returns from it would be highest if all were given free access to it. (Note that the patent mechanism insures less than optimal use because it arranges that the innovator will obtain his return by charging a fee for use of his knowledge, thus making otherwise marginally attractive uses of that knowledge uneconomic.) Clearly a prize can call forth enormous effort--as the recent Kramer prize offered for the achievement man-powered flight around a specified course shows. On the other hand, this mechanism requires that some individual or group set the specifications for individual desired innovations, and appropriate levels of reward--not a trivial task.

Next the government should strive to avoid taking actions which weaken the effect of existing benefit capture mechanisms. For example, it should review current policies regarding requirements for second sourcing for products if it can economically meet its needs for security against interruption of supply by, for example, carrying an inventory large enough to tide it over until a new source can be initiated. The effect of demanding a second source is to eliminate the lead time advantage of the first firm--and any lead time-related incentive which that firm might have to innovate. As a second example, it should be careful about demanding access to innovator's trade secrets--as it has demanded of chemical firms under the Toxic Substances Control Act (TSCA). Given the central role played by know-how in many industries, the companies' pleadings that crucial trade secrets are at risk is not to be taken lightly. (20)

Finally, government should understand that innovation costs, benefits--and work--are distributed differently in different industries, and should develop an input-output table type of measure of R&D expenditures versus innovation sources to reflect this reality appropriately. Such a measure would, for example, allow one to display the reality that scientists usually resident in universities develop novel scientific instruments which instrument manufacturers then produce. (16) Simpler measures which compare only the R&D expenditures versus innovation output of a given firm result in significant distortion (for example, use of that measure in NSF's Science Indicators 1976 gave rise to the predictable but misleading observation that producers of professional and scientific instruments were relatively efficient converters of R&D dollars into scientific instrument innovations). (21) Similarly, an input-output type measure would demonstrate the often-voiced concern that the U.S. machine tool industry is too fragmented to support the process machinery innovation needed to improve U.S. productivity is at least partly wrongly framed by showing that much process machinery innovation is carried out by machine tool users. (17)

Implications for Industry

In this paper we have seen that innovation-related costs and benefits are distributed over users, manufacturers, suppliers, and others, and that the level of private return achieved by the innovator depends on the outcome of a struggle between the participants, waged with combinations of imperfect benefit capture and cost allocation mechanisms. In principle, innovating firms can enhance their private returns by discovering and exploiting new mechanisms--as was done in the instance of lead time and cost allocation to users and suppliers--or, more routinely, they may seek to improve the efficiency with which they use existing mechanisms.

Currently no hard information exists as to how firms might improve their use of existing benefit capture mechanims. Anecdotal evidence of two sorts suggests, however, that improvement is possible. First, while most firms clearly understand their overall competitive strengths and weaknesses with respect to other firms, and can articulate the strategies they have developed to enhance the former and minimize the latter--almost no firm, in my experience, can articulate precisely how--or whether--it benefits to utilize available innovation benefit capture mechanisms. Second, the behavior of many firms seems puzzling when viewed in terms of innovation benefit capture. For example, some firms will openly display apparently valuable innovative process know-how to competitors, while other firms will be quite secret about what, upon inspection, seem to be rather generally known processing techniques. Clearly, more research in this area would be interesting and useful.

The anecdotal evidence is slightly stronger with respect to the efficiency with which innovating firms use existing cost allocation mechanisms. On the one hand, firms appear to routinely use the mechanism of allocating innovation costs to benefiting users and suppliers. Indeed, evidence of this activity can sometimes be found in the public record--especially with respect to major projects (for a recent example see (22)). On the other hand, firms have not installed the analytical tools needed to routinize such cost allocations, and this suggests that their efficiency in the area could be significantly improved. Consider, for example, the fact that an innovating firm's R&D staff seldom makes an analysis to identify the benefits which a contemplated project might bring to potential suppliers of components and materials. As a result, it is not in a position to identify portions of the development work which competent suppliers might be induced to undertake if asked. In the absence of such data, present practice appears to be to simply assume that all relevant R&D which can be done in-house will be, and that outside cost and/or work sharing with suppliers will only be sought when in-house resources or expertise is lacking. Obviously, opportunities to allocate costs to suppliers are missed under such a regime, and obviously improvement should be possible.

References and Notes

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