4

The Functional Source of Innovation as an Economic Phenomenon

We have now seen that striking variations do exist in the functional sources of innovation. Next, we must understand the causes of such variations. Success at this task will allow us to convert the functional source of innovation variable from a "mere" phenomenon into a powerful tool that can be used to explore and manage the innovation process.

I begin this chapter by proposing an economic explanation for variation in the functional source of innovation. Next, I propose two preconditions that must exist in the real world if this hypothesis is to be tenable. A review of the available evidence suggests that the needed preconditions do commonly exist, and this opens the way to a test of the hypothesis in chapter 5.

The Hypothesis

Variation in the functional source of innovation may have many contributing causes. However, we need not necessarily explore all of these to gain a useful ability to predict such variation. I propose that a straightforward economic model will allow us to predict that source "usefully often."

Schumpeter[1] argued that those who succeed at innovating are rewarded by having temporary monopoly control over what they have created. This control, in turn, is the lever that allows innovators to gain an enhanced position in the market and related temporary profits or "economic rents" from their innovations.

Suppose that every firm was aware of the opportunity to develop each of the innovations that I studied in chapters 2 and 3. And suppose every firm analyzed each of these opportunities and said, in effect, "If I respond to this opportunity and develop an innovation, I may expect a rent of x amount over y years." Then my hypothesis, a familiar one to economists, is simply that innovating firms will

TABLE 4–1. Summary of Functional Source of Innovation Data

Innovation Type Sampled	*Innovation Developed by* *User*	*Manufacturer*	*Supplier*	*Other*	*NA*[a] *(n)*	*Total (n)*
Scientific instruments	77%	23%	0%	0%	17	111
Semiconductor and printed circuit board process	67	21	0	12	6	49
Pultrusion process	90	10	0	0	0	10
Tractor shovel–related	6	94	0	0	0	11
Engineering plastics	10	90	0	0	0	5
Plastics additives	8	92	0	0	4	16
Industrial gas–using	42	17	33	8	0	12
Thermoplastics–using	43	14	36	7	0	14
Wire termination equipment	11	33	56	0	2	20

[a]NA = number of cases for which data item coded in this table is not available. (NA cases exluded from calculations of percentages in table.)

be found among those whose analyses lead them to expect a rent they consider attractive.

This hypothesis will allow us to predict the functional source of innovation only if all or most firms expecting an attractive rent from a given innovation opportunity are of one functional type. There are reasons for supposing that this may often be the case, but let me defer discussion until the end of chapter 5 when we will have seen more data. At the moment, I will simply point out that a summary of the empirical evidence we have collected on the functional source of innovation (Table 4–1) does show that innovations of a specific type are often developed by a single functional type of firm.

Necessary Preconditions

An ability to predict the functional sources of innovation on the basis of firms' preinnovation expectations of rents requires that correlations exist between such expectations and the functional role of innovating firms. More specifically, two conditions must hold:

1. It must be difficult (expensive) for innovators to adopt new functional relationships to their innovations.
2. Innovators must have a poor ability to capture rent by licensing their innovation-related knowledge to others.

In the remainder of this chapter I will explain the necessity for each condition and consider whether each is likely to be commonly present in the real world. Significant empirical data on this matter only exist in the instance of the second condition. However, indirect proof that both conditions at least sometimes hold in the real world is provided in chapter 5 in the form of tests of the hypothesis itself.

Condition 1: Difficulty of Switching Functional Roles

The first condition states that one can only expect to predict the functional source of innovation on the basis of related variations in expected rents if firms do not frequently switch or adopt new functional roles. If role switching were frequent or inexpensively accomplished, innovators might switch to the functional role that offered them the best innovation-related return. And, under such conditions, we would only be able to predict the functional locus of innovation in a weak sense, that is, "the developer of *x* innovation will *become* a user" rather than able to make the stronger statement that "the developer of *x* innovation will be a firm or individual that currently is a member of the user community."

I have no hard data on the general frequency of functional role switching in the U.S. economy. However, I have two reasons for thinking that it is not common. First, as can be seen in the case data contained in the appendix, role switching occurred in only a few instances in the samples we examined. (Typically, in those instances a user firm employee would spin off to form a new equipment manufacturing company based on a user innovation.) Second, the switching of functional roles appears to be often both difficult and expensive.

Consider, as an example, the barriers that face a firm that is a member of an industry characterized by a given functional relationship to an innovation (e.g., an industry using semiconductor process equipment to make semiconductors) and that wishes to join an industry characterized by another functional relationship to that innovation (e.g., the industry manufacturing semiconductor process equipment). These two types of firms are in very different businesses. Each has a great deal of know-how, organizational arrangements, and capital equipment that is quite specialized to build its existing products and to serve its existing customer base. Thus, the semiconductor manufacturer has a sales force that specializes in serving semiconductor buyers. This force would be entirely inappropriate for selling semiconductor process equipment: The customers are different; the sales techniques are different (samples of semiconductor devices can be given out as a selling technique but not samples of semiconductor process equipment); and the specialized knowledge the salesman must have is completely different (a salesman with an electrical engineering background can help customers with problems in selecting and using semiconductor devices whereas a background in solid-state physics would be considerably more appropriate for a salesman trying to sell the semiconductor process equipment used to grow the ultrapure single silicon crystals used in semiconductor device manufacture).

If the sales, organizational, and production infrastructure that a company uses to serve one functional role relationship to a given innovation cannot effectively be used in the service of a different functional relationship, then it follows that a firm wishing to change such relationships must also set up a new infrastructure appropriate to this new role. Further, since the costs of the infrastructures of competitors already having the role relationships the innovator wishes to acquire are typically allocated across many products (e.g., a line of process equipment or a line of semiconductor devices), the would-be new entrant must develop, adopt, or buy a similar line of product to sell if he wishes to be economically competitive. All these requirements, I suggest, can indeed represent significant barriers to the switching of functional roles, although the height of the barriers will, of course, differ from case to case.

Condition 2: Inability to Capture Rent by Licensing Innovation-Related Knowledge

The second condition that must be in place if the hypothesis is to be useful is that innovators must have a poor ability to capture rent by licensing their innovation-related knowledge to others. The reasoning behind this requirement starts with the observation that, barring special situations such as when prizes are awarded for successful innovation, an innovator has only two routes toward capturing rents from an innovation: (1) exploiting the innovation himself while preventing others from doing so; (2) licensing others to use his innovation-related knowledge for a fee.

From the innovator's point of view, it probably does not matter much which of these courses he chooses: Whichever promises the most rent will do. But from our point of view, it matters a great deal. Indeed, the hypothesis must fail if innovators can capture rents efficiently through licensing because it contains the implicit assumption that innovators in different loci have significantly different abilities to capture rent from a given innovation. An ability to license efficiently, however, allows an innovator in any functional locus to (in a sense) tax licensees in different functional loci according to their differing abilities to benefit, thus diminishing this crucial difference.

We can see the problem clearly by means of an extreme example. Suppose that an innovator had a perfect ability to license his innovation-related knowledge without risk or cost. Under these conditions an innovator could license users, manufacturers, or others as he wished. He could set the fee he charged to each innovation beneficiary and each class of beneficiaries so as to maximize his return. Therefore—and this is the crucial point—the functional role that the innovator himself happened to play with regard to the innovation—user, manufacturer, or other—would not influence his expectations of rent because he would be equally able to capture innovation returns from his own company or other companies.

If an innovator is to expect to capture rents from licensing efficiently, he must be able to achieve two things. First, he must have some form of property rights in his innovation-related knowledge that can be used to protect a licensee against those who would want to use the licensed knowledge without paying. Second, he must expect to be able to license others and obtain rent from them at a low risk and cost. In the remainder of this chapter I will focus on the first of these two matters only because an inability to achieve the first makes the second irrelevant. However, when rights to an innovation *can* be protected, then efficiency in licensing becomes very interesting indeed. Since licensing to oneself is costless, any costs or risks incurred in licensing to others will create a preference for in-house use of an innovation and tend to favor those potential innovators who have the largest in-house use for it. (I will return to this matter in chapter 5 when considering the case of engineering plastics innovations.)

Licensing conveys an innovator's rights to innovation-related nonembodied knowledge to another. (Nonembodied knowledge is "pure" knowledge, not incorporated or embodied in physical property such as a product or a process machine.) Currently, only two mechanisms exist in the United States that potentially give an innovator property rights in the nonembodied knowledge he may develop, rights that he may then choose to transfer to another by means of licensing. First, patent law gives an innovator property rights in publicly known information that he has published in his patent. Second, trade secret legislation allows an innovator to license secret knowledge to a user(s) and put the recipient under the legal duty of maintaining the secrecy of that information so that it will not become a free good on the marketplace.

A useful amount of data exists on the real-world effectiveness of these two mechanisms, and I will review it in the remainder of this chapter. If we find that both mechanisms are generally ineffective at protecting innovators' rights to nonembodied knowledge, then the preconditions for licensing that knowledge effectively do not exist and I will have shown that the second condition required for my hypothesis to be useful does often exist in the real world.

Patents and Licensing

A patent grants an inventor the right to exclude others from use of his invention for a limited period. In return for the right to exclude not only those who copy the invention but also those who independently discover the same thing, the inventor must disclose the invention to the public at the time of the patent's issue. This disclosure, contained in the patent itself, must be sufficiently detailed so that those "ordinarily skilled in the art" may copy and utilize the invention after the patent's expiration. While the patent is in force, however, the inventor is given the right to control the use of "his" knowledge.

The real-world value of patent protection to innovators is a much-examined question. A series of studies conducted by several authors over a span of nearly 30 years (1957 to 1984) have asked whether inventors find patents useful for excluding imitators and/or capturing royalty income. The answer uniformly found: The patent grant is not useful for either purpose in most industries. In the next few pages I will briefly review the several studies that came to this conclusion. Then I will explain some of the mechanics of the patent grant and its enforcement that lie at the root of its general ineffectiveness.

Levin et al.[2] conducted a survey of 650 R & D executives in 130 different industries. Several of the questions explored opinions regarding the effectiveness of patents as a means of capturing and protecting the competitive advantages of new and improved production processes and products. The results were that all except respondents from the chemical and pharmaceutical industries judged patents to be "relatively ineffective."[3]

Taylor and Silberston[4] examined the impact of British and foreign patents in a very rich study of 44 British and multinational firms. These firms were selected from five broad classes of industrial activity: chemicals (including pharmaceuticals and petrochemicals), oil refining, electrical engineering (including electronics), mechanical engineering, and man-made fibers.[5]

The upper bound of rents innovators obtain from licensing their patented knowledge can be approximately represented by licensing fees and/or other considerations received, minus patenting and licensing costs incurred by the innovating firm. Taylor and Silberston present such data (Table 4–2) for 30 firms and find these gained little benefit from licensing.

Wilson[6] also studied benefits that corporations reap from licensing their patents. He explored data on royalty payments submitted by some U.S. corporations to the U.S. Securities and Exchange Commission (SEC) in 1971 on Form 10K.[7] Wilson's data for the SIC categories he studied that are most similar to the industrial activity classes examined by Taylor and Silberston are compared in Table 4–3. Here too, corporate returns from licensing appear generally low.[8]

The low returns from licensing patented knowledge found by Taylor and Silberston and by Wilson could be caused by weakness in patent protection or have some other cause. A second type of finding, however, suggests that, whatever the cause, protection afforded by the patent system is in fact generally weak and that innovators in most fields probably could not expect to benefit from licensing their patented knowledge even if they wanted to.

Taylor and Silberston reasoned that, if the patent system does in fact help innovators protect and benefit from their innovations, the presence of patent protection should increase innovators' willingness to invest in R & D. Therefore they asked the companies in their sample: "Approximately what proportion of your R & D in recent years would not have been carried out if you had not been able to patent any resulting discoveries?"[9] The data derived from this question are shown in Table 4–4. Note that 24 of the 32 returns indicate that only 5% or less of recent R & D expenditures would not have been undertaken if patent protection had not been available.[10] This suggests that the patent system is *not* seen by innovators as very effective in general and, by implication, that it is not seen as effective in protecting innovators' rights to knowledge they might wish to license.

A study by Scherer et al.[11] shows a similar result. Only 8 of 37 respondents ("executives responsible for technical change") reported that patents were "very important" to their companies. Fourteen reported that patents had "some importance," and 15 said they were "not very important" to their firms.[12] This result is especially interesting because Scherer selected his sample only from the firms that presumably valued patents most highly—those that held a large number of patents.[13]

In sum, empirical data seem to suggest that the patent grant has little value

TABLE 4–2. Relationship of 1968 Patent Expenditures to 1968 Patent-Related Receipts in Taylor and Silberston's Thirty-Firm Sample

Industry	1 *1968 U.K. license and royalty receipts £ (million)*[a]	2 *1968 U.K. patenting and licensing expenditures £ (million)*[b]	3 *1968 R & D expenditures in U.K. £ (million)*[c]	4 *1968 license receipts as percentage of R & D expenditures plus patenting and licensing expenditures (cols. 1−[2+3])*	5 *1968 license receipts as percentage of 1968 U.K. sales* *col. 1 / note d*
Chemicals					
Pharmaceuticals	£3.7	NA	£7.1	NA	6.00
Other finished and speciality	0.2	NA	10.1	NA	0.04
Basic	2.4	NA	3.3	NA	1.00
TOTAL CHEMICALS	6.3	0.99	20.5	29	1.10
Mechanical engineering	1.4		7.3	18	0.40
Man-made fibers	0.7	0.37	7.6	9	0.20
Electrical engineering	2.3	0.65	50.5	4	0.30

Source: Adapted from *The Economic Impact of the Patent System: A Study of the British Experience* by C. T. Taylor and Z. A. Silberston. Except as noted in a to d, data in all columns are derived from the same set of companies, NB: Taylor and Silberston have *not* logged patent and R & D expenditure data relative to receipt data on licensing, royalty, and sales.

[a]Taylor and Silberston, Table 8.7, p. 164. (Taylor and Silberst on note that data from oil companies in sample and one large electrical group are excluded from Table 8.7.)

[b]Taylor and Silberston, Table 6.4, p. 109. (Taylor and Silberston note that data from oil companies are excluded from Table 6.4.)

[c]Taylor and Silberston, Table 8.1, col. 2, p. 145. (I have excluded oil company data from basic chemical category to make this data base more compatible with Table 6.4. Taylor and Silberston offer more aggregated R & D expenditure data in Table 6.4, whose magnitudes deviate from those shown in Table 8.1 by 20% to 40%. These discrepancies are unexplained, but my uses of that data are not sensitive to corrections of this magnitude.)

[d]Taylor and Silberston, Table 8.1, col. 4, p. 145.

TABLE 4–3. Wilson and Taylor-Silberston Royalty Data Compared

	Wilson (1971 U.S. data)		*Taylor and Silberston (1968 U.K. data)*	
Industry	*Percentage of U.S. sales by firms in sample*[a]	*Royalties paid as percentage of firm 1971 sales*[a]	*Royalties paid as percentage of firm 1968 sales*[b]	*Industrial activity*
Chemicals				Chemicals
Industrial	76.4%	0.244%	0.042%	Basic
Drug	72.8	0.745	0.635	Pharmaceuticals
Other	51.4	0.034	0.044	Other finished and speciality
Machinery	40.2	0.051	0.255	Mechanical engineering
Electrical	40.5	0.130	0.182	Electrical engineering

Sources: Adapted from R. W. Wilson, "The Sale of Technology through Licensing" (Ph.D. diss., Yale University, New Haven, Conn., 1975) © 1975 Robert W. Wilson; and from *The Economic Impact of the Patent System: A Study of the British Experience* by C. T. Taylor and Z. A. Silberston. Copyright © 1973 Cambridge University Press.

[a]Wilson, Table 12, p. 169. Note that the data presented here are computed from Wilson's sample of 350 royalty reports, *not* his larger sample comprised of these reports plus estimated data.

[b]Royalty and license-fee expenditures data from Taylor and Silberston, Table 8.7, col. 3, p. 164; sales data from Table 8.1, col. 4, p. 145. Petrochemicals have been removed from the basic chemicals category of Table 8.1 to make this category compatible with the equivalent category of Table 8.7.

TABLE 4–4. Estimated Proportions of R & D Expenditure Dependent on Patent Protection: Twenty-seven Respondent Firms

	Estimate of R & D affected[a]				
Industry	*None or Negligible (number of returns)*	*Very little (less than 5%)*	*Some (5–20%)*	*Sub-stantial (over 20%)*	*Total Returns*
Chemicals					
Finished and speciality	1	2	1	4	8
Basic	1	2	1	0	4
TOTAL CHEMICALS	2	4	2	4	12
Mechanical engineering	7	1	0	2	10
Man-made fibers	1	1	0	0	2
Electrical engineering	7	1	0	0	8
TOTAL	17	7	2	6	32[b]
Percentage of returns	53%	22%	6%	19%	100%

Source: From *The Economic Impact of the Patent System: A Study of the British Experience* by C. T. Taylor and Z. A. Silberston. Copyright © 1973 Cambridge University Press. Reprinted with permission. Table 9.1, p. 197.
[a]Percentages refer to the estimated reduction in annual R & D expenditure in recent years that would have been experienced had patent monopolies not been available.
[b]Some companies made returns for more than one activity.

to innovators in most fields. Are these data congruent with tests of reason? Let us explore.

First, does it make economic sense that firms would take out patents if these do not, on average, yield much economic benefit? The answer is yes, because the cost of applying for patents is also low. The cost of the average patent application prosecuted by a corporation is on the order of $5000 today.[14] Even this small cost is often not very visible to corporate personnel deciding whether to pursue a patent application because it is typically subsumed within the overall cost of operating a corporate patent department.

Second, what do we know about the nature of the patent grant and of the real-world workings of the patent office and the courts? And, is it reasonable in the light of what is known to conclude that the patent grant is likely to offer little benefit to its holder? Consider the following points:

1. A patent, if valid, gives a patentee the right to exclude others from using his invention, but it does *not* give him the right to use it himself if such a use would infringe the patents of others. For example, Fairchild Semiconductor has a patent on the so-called planar process, an important process invention used in the manufacture of integrated circuits. If firm *B* invents and patents an improvement on that process, it may not use its improvement invention without licensing the planar process from Fairchild and in turn that firm may not use the improvement either without licensing it from firm *B*. Thus, in rapidly developing technologies where many patents have been issued and have not yet expired, it is likely that any new patent cannot be exercised without infringing the claims of numerous other extant patents. Given this

eventuality, the benefit of a particular patent to an inventor would very probably be diminished because the patentee might be prevented from using his own invention or might be forced to cross-license competitors holding related patents in order to practice his invention.

2. The patent system places the burden on the patentee of detecting an infringer and suing for redress. Such suits are notoriously long and expensive, and both defendants and plaintiffs tend to avoid them assiduously. For the defendant the best outcome in recompense for all his time and expense is judicial sanction to continue his alleged infringement, whereas the worst outcome would involve the payment of possibly considerable penalties. For the plaintiff the likelihood that a court will hold a patent valid and infringed—as opposed to invalid and/or not infringed—is on the order of one to three.[15] If a patentee has licensees already signed up for a patent at issue, he has a high incentive to avoid litigation: If he loses—and the odds are that he will—he loses payments from all licensees, not just the potential payments from the particular infringer sued.
3. The patent grant covers a particular means of achieving a given end but not the end itself, even if the end and perhaps the market it identifies are also novel. A would-be imitator can invent around a patent if he can invent a means not specified in the original inventor's patent. In the instance of the Polaroid and xerography processes (and a few other notable cases), determined competitors could not in fact invent around the means patented by the inventor. In most instances and most fields, however, inventing around is relatively easy because there are many known means by which one might achieve an effect equivalent to the patented one, given the incentive to do so. Where inventing around is possible, the practical effect is to make the *upper* bound value of an inventor's patent grant equal to the estimated cost to a potential licensee of such inventing around.

Taken in combination, the observations presented above provide a very reasonable explanation for the typical ineffectiveness of the patent grant. However, the data given in Tables 4–2 and 4–3 show clearly that patents are more effective in some fields than in others. This is because the factors mentioned above are more salient in some fields than others, as the following two examples illustrate. First, I will spell out the situation in semiconductors where the patent grant is quite ineffective, and then I will describe the situation in pharmaceuticals where patents have historically been quite effective.

The semiconductor field is a very fast-moving one that contains many unexpired patents with closely related subject matter and claims. The possible consequence—confirmed as actual by corporate patent attorneys for several U.S. semiconductor firms whom I interviewed—is that many patentees are unable to use their own inventions without the likelihood of infringing the patents of others.

Since patents challenged in court are unlikely to be held valid, the result of the high likelihood of infringement accompanying use of one's own patented—or unpatented—technology is not paralysis of the field. Rather, firms in most instances simply ignore the possibility that their activities might be infringing the patents of others. The result is what Taylor and Silberston's interviewees in the electronic components field termed "a jungle" and what one of my interviewees termed a "Mexican standoff."

Firm *A*'s corporate patent department will wait to be notified by attorneys from firm *B* that it is suspected that *A*'s activities are infringing *B*'s patents. Because possibly germane patents and their associated claims are so numerous, it is in practice usually impossible for firm *A*—or firm *B*—to evaluate firm *B*'s claims on their merits. Firm *A* therefore responds—and this is the true defensive value of patents in the industry—by sending firm *B* copies of "a pound or two" of its possible germane patents with the suggestion that, although it is quite sure it is not infringing *B*, its examination shows that *B* is in fact probably infringing *A*. The usual result is cross-licensing, with a modest fee possibly being paid by one side or the other. Who pays, it is important to note, is determined at least as much by the contenders' relative willingness to pay to avoid the expense and bother of a court fight as it is by the merits of the particular case.

Thus in the semiconductor field—except for a very few patent packages that have been litigated, that have been held valid, and that most firms license without protest—the patent grant is worth very little to inventors who obtain it. Indeed, the one value noted to me—defense against the infringement suits of others—suggests that perhaps the true net value of the patent system to firms in the semiconductor industry is negative because it requires all to assume the overhead burden of defensive patenting.

In sharp contrast to the situation pertaining in most other industries and the electronics field in particular, the patent grant often confers significant benefit to innovators in the pharmaceutical field. My discussions with patent attorneys working for pharmaceutical firms brought out two likely reasons for this situation. First, unusually strong patents are obtainable in the chemical field, of which pharmaceuticals is a part. Second, it is often difficult to invent around a pharmaceutical patent.

Pharmaceutical patents can be unusually strong because one may patent an actual molecule found to have useful medical properties *and* its analogs. One need not make each analog claimed but can simply refer to lists of recognized functional equivalents for each component of the molecule at issue. For example, if a molecule has 10 important component parts, one patent application might claim x plus 10 recognized functional equivalents of x for each part. Obviously, by this means an inventor may claim millions of specific molecules without actually having to synthesize more than a few. Furthermore, demonstration that any of the analogs so claimed does not display the medical properties claimed does not invalidate the patent.

Many pharmaceutical patents are difficult to invent around today because the mechanisms by which pharmaceuticals achieve their medical effects are often not well understood. When this is so, potential imitators cannot gain much helpful insight from examining a competitor's patented product. (Interestingly, as biochemists' understanding of the biological basis of the effects achieved by pharmaceuticals improves, one side effect may be to weaken the protection the patent grant affords to inventors of pharmaceuticals.)

Trade Secrets and Licensing

Trade secrets, like patents, can be used as a basis for licensing nonembodied innovation knowledge. A trade secret, also sometimes called know-how, is typically knowledge that can be kept secret even *after* development is completed and commercial exploitation begun. Trade secret legislation allows one who possesses a trade secret to keep the information entirely secret or to make legally binding contracts with others in which the know-how is revealed in exchange for a fee or other consideration and a commitment to keep the information secret. The possessor of a trade secret has an indefinite period of exclusive use of his invention or discovery. He may take legal steps to prevent its use by others *if* he can show that those others have discovered the secret through unfair and dishonest means such as theft or breach of a contract promising to keep it secret.

A legally protectable monopoly of indefinite duration would appear to make trade secrecy a very attractive mechanism for capturing rents from innovation. It is, however, an option only for innovations that can in fact be kept secret: The holder of a trade secret cannot exclude anyone who independently discovers it or who legally acquires the secret by such means as accidental disclosure or reverse engineering. In practice, trade secrets have proven to be effective only with regard to (1) product innovations that incorporate various technological barriers to analysis or (2) process innovations that can be hidden from public view.

There are, in the first instance, certain innovations embodied in products that, 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 that therefore cannot 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 through use of a packaging method (potting) and packaging materials that cannot easily be removed without destroying the proprietary circuit contained within.[16] 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 reverse 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.

Few empirical data exist on the information protected as trade secrets: There is no central registry for such material analogous to the U.S. Patent Office; even those trade secrets that are licensed to others, the subset of interest to us here, do not usually appear on any public record unless litigated.

Although some examples exist of major rents from nonembodied knowledge being reaped by innovators by means of licensing of trade secrets,[17] I argue that the typical effectiveness of this mechanism is severely limited for two reasons. First, the mechanism is clearly not applicable to product or process innovations that are not commercially exploitable while concealed behind factory walls and that are amenable to reverse engineering if accessible to inspection by imitators—considerations that apply to many industries and many innovations. Second, a trade secret licensor can only gain redress under trade secret legislation if he can document the *specific* illegal act that diffused his innovation to unlicensed parties. A licensor finds such specificity difficult to achieve if he seeks to license nonembodied knowledge to many licensees.

To conclude, it appears likely that both conditions that must exist for my hypothesis to be useful are in fact frequently present in the real world. Therefore, it is appropriate to proceed on to test that hypothesis.

Notes

1. Joseph A. Schumpeter, *Capitalism, Socialism and Democracy,* 3rd ed. (New York: Harper & Row, 1950).

2. Richard C. Levin and Richard R. Nelson, "Survey Research on R & D Appropriability and Technological Opportunity. Part I: Appropriability" (Working Paper, Yale University) (New Haven, Conn., July 1984).

3. Richard C. Levin, "A New Look at the Patent System," *American Economic Review* 76, no. 2 (1 May 1986): 200.

4. C. T. Taylor and Z. A. Silberston, *The Economic Impact of the Patent System: A Study of the British Experience* (Cambridge: Cambridge University Press, 1973).

5. Taylor and Silberston's sample was selected as follows: First, approximately 150 firms selected from a "comprehensive list of U.K. quoted companies" were invited to join the study on the basis of their net assets in 1960. In each of the five classes studied, all companies showing net assets in excess of £10 million in 1960 were selected, and every seventh company of the remainder was selected from a list tabulated in ascending order of net assets in 1960. Finally, "some additions were made to take account of mergers and acquisitions and to include unquoted companies." Eventually, "just over 100" firms responded to the letter of invitation. Sixty-five expressed interest, but "some twenty of these indicated that patents were a very minor aspect of their operations and were firmly believed to have no significance on the business . . . this left 44 firms which agreed to participate in the inquiry" (Taylor and Silberston, *The Economic Impact of the Patent System,* 371).

6. R. W. Wilson, "The Sale of Technology Through Licensing" (Ph.D. diss., Yale University, New Haven, Conn., 1975).

7. In 1971 firms were required to report royalty payments if they were "material" with the precise interpretation of that term being left up to individual firms. Focusing on the *Fortune* listing of the largest manufacturing corporations in 1971, Wilson found that 518 had considered their royalty receipts "material" enough to report to the SEC. Since he was interested only in royalty payments for "technology licenses," he used various means to detect and winnow from the sample firms that reported royalty payments for such things as trademarks, copyrights, and mineral rights (Wilson, "The

Sale of Technology Through Licensing," 152 ff., provides a detailed description of his data collection methods). The end result of this process was a sample of 350 royalty figures for 1971 Wilson felt were largely or entirely payments for "technical agreements," a term that he does not define, but that presumably includes both patent and technical know-how–related payments. The responses of these 350 firms were then aggregated under appropriate "2 and 3 digit SIC codes" (not given) and displayed in tabular form. Wilson used the 350 reports of corporate royalty payments to develop estimates of royalty payments to all members of the industries he studied and then compared these estimates with industry-level data on corporate R & D expenditures collected by the National Science Foundation (NSF). As I find Wilson's estimating procedures inappropriate for my purposes here, I use only the direct company report data he provides.

8. The data reported by Wilson are for royalty payments rather than receipts. But it is likely that the bulk of technical agreements would be between firms in the same industry. If so, it would follow that the low magnitude of royalty payments in the Wilson data implies that royalty receipts would also be found low in the industries sampled.

9. Taylor and Silberston, *The Economic Impact of the Patent System,* 396.

10. Ibid., 30.

11. F. M. Scherer et al., *Patents and the Corporation,* 2nd ed. (Boston: James Galvin and Associates, 1959).

12. Ibid., 117.

13. Scherer sent a questionnaire to a sample of 266 firms shown in P. J. Federico (*Distribution of Patents Issued to Corporations [1939–44]*, Study No. 3 of the Subcommittee on Patents, Trademarks, and Copyrights [Washington, D.C.: U.S. Government Printing Office, 1957], 19–34) to be corporate assignees for a relatively large number of patents. Sixty-nine of the questionnaires (26%) were completed and returned in time to be included in the study's analysis phase. All but 4 of these respondents held more than 100 patents and collectively they "held approximately 45,500 patents, or about 13.5% of all the unexpired U.S. patents held by domestic corporations at the end of 1956" (Scherer et al., *Patents and the Corporation,* 107).

14. In 1961 the commissioner of patents reported the cost of an average patent application prosecuted by a corporation to be $1000 to $2500, and the cost of a single application prosecuted by an attorney for an individual to be $680 (Hon. David Ladd, Commissioner of Patents, Statement Before the Patents, Trademarks, and Copyrights Subcommittee of the Judiciary Committee, U.S. Senate, September 4, 1962, re: S.2225, quoted in Elmer J. Gorn, *Economic Value of Patents, Practice and Invention Management* [New York: Reinhold, 1964]). My own recent conversations with several corporation patent attorneys yielded an estimate that the average patent application prosecuted by a corporation currently costs on the order of $5000.

15. For references to, and discussion of, several such studies, see Carole Kitti, "Patent Invalidity Studies: A Survey" (National Science Foundation, Division of Policy Research and Analysis) (Washington, D.C., January 1976).

16. Deborah Shapley, "Electronic Industry Takes to 'Potting' Its Products for Market," *Science* 202, no. 4370 (24 November 1978): 848–49.

17. John Lawrence Enos, *Petroleum Progress and Profits: A History of Process Innovation* (Cambridge, Mass.: MIT Press, 1962).