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PATENTS AND INNOVATION: AN EMPIRICAL STUDY*

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To what extent would the rate of development and introduction of inventions decline in the absence of patent protection? To what extent do firms make use of the patent system, and what differences exist among firms and industries and over time in the propensity to patent? These questions are in need of much more study. This paper, which reports the results of an empirical investigation based on data obtained from a random sample of 100 U.S. manufacturing firms, provides new findings bearing on each of these questions.
(RESEARCH AND DEVELOPMENT; ECONOMICS)

1. Introduction

The patent system is at the heart of our nation's policies toward technological innovation. Consequently, it is of widespread interest to managers, management scientists, and economists, among others. Two of the most important questions concerning the patent system and its effects are: (1) To what extent would the rate of development and commercialization of inventions decline in the absence of patent protection? (2) To what extent do firms make use of the patent system, and what differences exist among firms and industries and over time in the propensity to patent? Despite the considerable advances that have occurred recently in our understanding of the patent system,[1] these questions are in need of much more study. The present paper, which reports the results of an empirical investigation based on data obtained from a random sample of 100 U.S. manufacturing firms, should be of interest because it extends both the nature and quantity of information bearing on both of the above questions.

2. Effects of Patent Protection on the Development and Commercialization of Inventions

Given the age and prominence of the patent system, it is surprising how little is known about its effects on the rate of innovation. To throw new light on this topic, it would be useful to obtain information concerning the proportion of developed or commercially introduced inventions that would have been developed or commercially introduced in the absence of the patent system. Obviously, there are many problems that arise in carrying out such a study, since it is difficult to obtain a representative list of inventions and to determine whether each invention would have been developed or commercially introduced without patent protection. However, the work of Taylor and Silberston (1973) and Mansfield, Schwartz and Wagner (1981) suggest that it may be possible to carry out such a study based on a detailed investigation of a sample of firms.

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[1] For a summary of some of this work, see *APLA Quart. J.*, 1 and 2 (1982), as well as the references at the end of the present paper. Early work was done by F. M. Scherer and Klaus Grefermann, in particular. More recent studies include Mansfield, Schwartz, and Wagner (1981) and Taylor and Silberston (1973).

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Following this direction, we chose a random sample of 100 firms from twelve industries (excluding very small firms) in the United States.[2] From each firm, we obtained an estimate of the proportion of its inventions[3] developed in 1981–83 that would not have been developed if it could not have obtained patent protection. Also, an estimate was obtained of the proportion of the firm's inventions commercially introduced in 1981–83 that would not have been commercially introduced if it could not have obtained patent protection.[4] These estimates were prepared under the direction of the firms' leading R and D executives. Although they should be treated with caution, they appear to have been prepared with considerable care.

When the estimates for individual firms are combined to produce industry-wide estimates, the results indicate that patent protection was judged to be essential for the development or introduction of 30 percent or more of the inventions in only two industries—pharmaceuticals and chemicals (Table 1). In another three industries (petroleum, machinery, and fabricated metal products), patent protection was estimated to be essential for the development and introduction of about 10–20 percent of their inventions. In the remaining seven industries (electrical equipment, office equipment, motor vehicles, instruments, primary metals, rubber, and textiles), patent protection was estimated to be of much more limited importance in this regard. Indeed, in office equipment, motor vehicles, rubber, and textiles, the firms were unanimous in reporting that patent protection was not essential for the development or introduction of any of their inventions during this period.[5]

Earlier studies focused on a relatively few industries. For example, Taylor and Silberston (1973), using data from 27 firms, found that about 60 percent of pharmaceutical R and D, about 15 percent of chemical R and D, about 5 percent of mechanical engineering R and D, and a negligible amount of electronics R and D were dependent on patent protection. Mansfield, Schwartz, and Wagner (1981), using data for 48 product innovations, found that about 90 percent of the pharmaceutical innovations and about 20 percent of the chemical, electronics, and machinery innovations would not have been introduced without patents. The results in Table 1 (which, in contrast to earlier studies, are based on a random sample of firms) are quite consistent with the finding of these earlier studies that the pharmaceutical industry regards patents as much more important in this sense than the chemical, electrical equipment, and machinery industries. In addition, Table 1 provides data of this sort regarding a wide variety of other manufacturing industries.

[2]This sample of firms was chosen at random from a list of all firms in these industries spending over $1 million (or 1 percent of sales, if sales were at least $35 million) on R and D in 1981 (see *Business Week*, July 5, 1982), as well as a group of smaller firms listed in *Poor's Register*. Thus, the emphasis here is on firms with about $25 million or more in sales, not very small ones. The information was obtained through interviews and correspondence. Practically all firms filled out a detailed questionnaire. In addition, major executives of about 25 of the firms were interviewed. There was very little problem with nonresponse. Only 4 out of the 100 firms felt that they could not respond, largely for lack of information.

[3]An invention is defined here as a prescription for a new or improved product or process (or one or more components or facets thereof) that is prospectively useful and that is not obvious to one skilled in the relevant art at the time the idea is generated. See Mansfield (1968).

[4]Of course, there is also a question of timing. Under some circumstances, an invention might be developed or commercially introduced more slowly or later if the firm could not obtain patent protection. However, according to the firms in the interviews, this is not an important caveat.

[5]The percentage for each industry in Table 1 is the unweighted mean of the percentages for the firms in this industry in the sample. Had a firm's percentage been weighted by its sales, the results would have been much the same as in Table 1. With regard to the percent that would not have been introduced, the only major change is that the chemicals figure would have been higher (and closer to the figure for the pharmaceutical industry). However, it is not obvious that the weighted figures are to be preferred to the unweighted ones, since the number of inventions made by a firm is not proportional to its size. In any event, there is relatively little difference between the weighted and unweighted figures.

TABLE 1

Percent of Developed or Commercially Introduced Inventions That Would Not Have Been Developed or Commercially Introduced if Patent Protection Could Not Have Been Obtained, Twelve Industries, 1981–83.[a]

Industry	Percent That Would Not Have Been Introduced	Percent That Would Not Have Been Developed
Pharmaceuticals	65	60
Chemicals	30	38
Petroleum	18	25
Machinery	15	17
Fabricated metal products	12	12
Primary metals	8	1
Electrical equipment	4	11
Instruments	1	1
Office equipment	0	0
Motor vehicles	0	0
Rubber	0	0
Textiles	0	0

Source: see §2.

[a]Some inventions that were developed in this time period were not introduced then, and some inventions that were introduced then were not developed then. Thus, the left-hand column of the table refers to somewhat different inventions than does the right-hand column.

Many economists seem to believe that patent protection tends to be more important to smaller firms than to larger ones.[6] However, although this proposition sounds reasonable, the existing evidence on this score is weak and sometimes contradictory. To test this proposition, we correlated a firm's size (as measured by its 1982 sales) with the proportion of its inventions (developed in 1981–83) that would not have been developed if it could not have obtained patent protection. In only one industry (fabricated metal products) is the correlation coefficient negative and statistically significant. In two industries (instruments and machinery), it is positive and statistically significant. In the remaining seven industries, it is not statistically significant. Thus, this proposition receives very little support. However, it is worth recalling that this study is not concerned with very small firms (sales below $25 million). If such firms were included, the results might be different.[7]

Within each industry, there is considerable variation among firms in the importance of patents, as measured by the proportion of developed or commercially introduced inventions that would not have been developed or commercially introduced without patent protection. In pharmaceuticals and chemicals, the industries where patents are most important, one would expect the more R and D-intensive firms to regard patents as much more important than the less R and D-intensive firms because their inventions are more likely than those of the less R and D-intensive firms to be of the type that patents are relatively effective in protecting. On the other hand, in industries where patents are not so important, such as electrical equipment and office equipment, one would expect a smaller difference of this sort between more and less R and D-intensive firms. In fact, these hypotheses are borne out by the data.[8]

[6]For some discussion of this point, see Mansfield, Romeo, Schwartz, Teece, Wagner, and Brach (1982).

[7]Mansfield, Schwartz, and Wagner (1981) also found no evidence that patent protection was more likely to be deemed essential for innovations carried out by smaller firms than for those carried out by larger ones.

[8]In the pharmaceutical and chemical industries, the percentage of inventions that would not have been introduced without patent protection averages about 75 percent among firms where R and D expenditures were at least 4 percent of sales in 1981 and about 25 percent among firms where they were less than 4 percent. The difference between these averages is significant at the 0.025 probability level. On the other hand, in the electrical equipment and office equipment industries, the percentage averages about 10 percent

3. The Propensity to Patent: Interindustry and Interfirm Differences

Not all patentable inventions are patented.[9] In some cases, firms rely instead on trade secrets, because technology is progressing so rapidly that it may be obsolete before a patent issues, because it is very difficult to police the relevant subject matter, or for other reasons. Also, in cases where technological advances are very difficult and costly to copy, patent protection may not seem worthwhile. To achieve a better understanding of the extent to which various industries and types of firms make use of the patent system, we would like to know the percentage of patentable inventions that are patented. Unfortunately, no data exist on this score.

To help shed some light on this matter, we obtained estimates from each of the firms in the sample concerning the percentage of its patentable inventions in 1981–83 that were patented.[10] If we divide the sample into two parts, one consisting of firms in the five industries (pharmaceuticals, chemicals, petroleum, machinery, and fabricated metal products) where, according to Table 1, patents seem more important, and the other consisting of firms in the seven industries (primary metals, electrical equipment, instruments, office equipment, motor vehicles, rubber, and textiles) where patents seem less important, the results indicate that over 80 percent of the patentable inventions in the former group of firms were patented and that over 60 percent of those in the latter group of firms were patented.[11]

Thus, even though firms in the latter seven industries seldom regard patent protection (or the prospect of such protection) as necessary to the development or commercial introduction of an invention, this does not mean that they do not take out patents. On the contrary, in each of these industries in Table 2, at least half of the patentable inventions were patented.[12] The reason seems to be that the prospective benefits of patent protection, including (besides royalties) whatever delay is caused prospective imitators and the use of patents as bargaining chips, are judged to exceed its costs. If this is true, it is perfectly reasonable, of course, for the firm to take out a patent, whether or not the invention would have been introduced without patent protection.

In most of the industries included here, there is a positive correlation between a firm's size (measured by 1982 sales) and the percentage of its patentable inventions

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among firms where R and D expenditures were at least 4 percent of sales and about 5 percent among those where they were less than 4 percent. The difference between these averages is far from statistically significant.

[9]The three essential statutory requirements of novelty, utility, and nonobviousness of the subject matter over the prior art must be met if an invention is to be patentable. ("Novelty," with some exceptions, means being the first to invent.) In addition, there are other legal requirements for patentability. See L. J. Harris's paper in National Science Foundation (1979).

[10]Like the data in the previous section, these estimates were obtained in interviews and correspondence. Firms often have records of the proportion of disclosures that have been regarded as patentable and the proportion that have been patented. However, the proportion of patentable inventions that is disclosed is more difficult to estimate. Also, unless the firm actually files, it may not be absolutely certain that a particular invention is patentable. Thus, the data are rough, but accurate enough for present purposes. Of course, firms with no patentable inventions during this period could be excluded.

[11]The difference between the unweighted means in the two groups is statistically significant at about the 7 percent level.

[12]Separate figures are not given for all individual industries, for the reason given in note c of Table 2. If a very large percentage of a firm's or industry's inventions were not patentable, the firm or industry might patent a high percentage of its patentable inventions; yet the proportion of all of its inventions (patentable and nonpatentable) where patent protection is necessary for their introduction might be small. In such a situation, the firm or industry might not be patenting a larger share of its inventions than the percentage required to bring about their introduction. But this does not seem to be the case in these seven industries where patents are relatively unimportant. On the contrary, in each of these industries, the percentage of inventions that were patented far exceeded the industry's percentage in Table 1. For example, the former percentage was about 10 times the latter percentage in the electrical equipment industry.

TABLE 2

Percentage of Patentable Inventions That Were Patented, Twelve Industries, 1981–83[a]

Industry Group or Industry	All Firms	Firms with 1982 Sales Exceeding $1 Billion
Industry groups:		
Industries (Pharmaceutical, Chemical Petroleum, Machinery and Fabricated Metal Products) where patents are relatively important	84	86
Industries (Primary Metals, Electrical Equipment, Office Equipment, Instruments, Motor Vehicles, Rubber, and Textiles) where patents are relatively unimportant	66	66
Individual industries:		
Pharmaceuticals	82	83
Chemicals	81	84
Petroleum	86	87
Machinery	86	97
Primary Metals	50	49
Electrical Equipment	83	83
Office Equipment and Instruments[b]	75	77
Motor Vehicles	65	65
Other[c]	85	d

Source: see §3.

[a]Each firm's percentage is weighted by its sales. While this is rough, it is the best feasible procedure. If R and D expenditures were used instead, the results would not differ appreciably.

[b]Office equipment and instruments are combined to increase the number of firms on which the percentage is based.

[c]The figure given here is the unweighted mean of the percentages for the fabricated metal products, rubber, and textile industries, each of which has relatively few firms in the sample.

[d]So few firms in the sample are in this category that this figure would not be very meaningful.

that were patented. In each of the three industries (pharmaceuticals, chemicals, and petroleum) where patents seem to be most important, this correlation is statistically significant.[13] Apparently, the very large firms in these industries tend to be even more convinced than their smaller rivals that patent protection is worthwhile. Thus, the frequently-observed tendency for the number of patents per dollar of R and D to be lower among the largest firms than among smaller ones does not seem to be due to differences in the percentage of patentable inventions that are patented.[14] Instead, it seems to be attributable to differences between the largest firms and their smaller rivals in the number of patentable inventions per dollar of R and D.

[13]In seven of the ten industries (for which more than a very few observations are available), the sample correlation coefficient is positive. Focusing on the pharmaceutical, chemical, and petroleum firms, a billion-dollar increase in sales seems to be associated with about a 7 percentage-point (pharmaceuticals), 4 percentage-point (chemicals), or 1 percentage-point (petroleum) increase in the percentage of patentable inventions that were patented. The correlation coefficient is significant at about the 0.025 level (pharmaceuticals), 0.05 level (petroleum), and 0.10 level (chemicals). Finally, note that the differences in Table 2 between the percentages for all firms and those for firms exceeding $1 billion in sales are quite small because the largest firms dominate both sets of percentages.

[14]For some discussion of this tendency, see Keith Pavitt's paper in National Science Foundation (1979).

Many analysts have called attention to the very large differences among industries in the number of patents per dollar of R and D. Scherer (1982) has suggested that they may be due in part to interindustry differences in the percentage of patentable inventions that are patented. Using our data together with Scherer's estimates of the number of patents per dollar of R and D in each of the industries in Table 1, it is possible for the first time to test this hypothesis. The results indicate that the number of patentable inventions per dollar of R and D varies less among industries than the number of patents per dollar of R and D, which supports the hypothesis. However, it appears that only about 12 percent of the interindustry variation in the number of patents per dollar of R and D can be explained this way. The principal cause of this interindustry variation is the variation among industries in the yield of patentable inventions per dollar of R and D.[15]

4. The Propensity to Patent: Differences over Time

The percentage of inventions that is patented can vary over time as well as among industries and firms. According to one influential hypothesis, this percentage has tended to decline over the past decade or two, as firms have become more disillusioned with the patent system and as they have devised other ways of protecting their technology that are more cost-effective than patents. Proponents of this hypothesis often argue that this decline in the propensity to patent is at least partly responsible for the well-known drop from the late 1960s and early 1970s to the late 1970s and early

TABLE 3

Percentage of Firms that Patented a Larger, Smaller, and Equivalent Percentage of Inventions in 1980–82 *than in* 1965–69, *Ten Industries*

Industry	Larger	Smaller	Equivalent	Total[a]
		(percent of firms)		
Pharmaceuticals	11	11	78	100
Chemicals	50	17	33	100
Petroleum	20	30	50	100
Machinery	25	25	50	100
Primary metals	20	40	40	100
Electrical equipment	30	10	60	100
Instruments	27	18	55	100
Office equipment	12	12	75	100
Transportation equipment[b]	25	25	50	100
Other[c]	33	29	38	100
Total	28	21	51	100

Source: see §4.

[a] Because of rounding errors, figures do not always sum to total.

[b] Since all firms in the transportation equipment industry included in the sample in Tables 1 and 2 produced motor vehicles, the industry was called "motor vehicles" in those tables. This is not the case here, so the industry is called "transportation equipment."

[c] The rubber, stone, clay, and glass, food, paper, and communications industries are included in the "other" category. See note 17.

[15] The coefficient of variation of the number of patents per dollar of R and D for the 12 industries in Table 1 is 41 percent. The coefficient of variation of the number of patentable inventions per dollar of R and D for these same industries is 36 percent. Thus, the latter coefficient of variation is only about 12 percent less than the former. However, some of the variation in the number of patentable inventions per dollar of R and D is probably due to the sampling errors in the percentage of patentable inventions that are patented. Thus, this factor may turn out to explain a somewhat larger percent of the interindustry variation in the number of patents per dollar of R and D, if more precise data can be obtained.

1980s in the annual number of patents granted to U.S. inventors (as well as for the decline in the patent rate in many other major countries at that time).[16]

Because no data have been available concerning the changes over time in the percentage of inventions that have been patented, it has been impossible to test this hypothesis directly. To help shed some light on this score, we obtained information from a sample of 100 firms concerning the percentage of their inventions in 1965–69 and 1980–82 that were patented. (See Table 3.) These data were provided generally by the firm's vice-president of research and development.[17]

The results provide no evidence supporting the hypothesized decline in the propensity to patent in the United States. One-half of the firms reported that there was essentially no difference between 1965–69 and 1980–82 in the percentage of inventions that were patented. Of the remaining half of the firms, more reported an increase than a decrease from 1965–69 to 1980–82 in the percentage patented. Even in the electrical equipment industry, which is often cited as a case where the propensity to patent has declined, more firms reported an increase than a decrease.[18]

To understand better why so many of the firms increased the percentage of inventions patented, we chose a random sample of the firms that reported such an increase, and asked them why it had occurred. The most frequently-cited reason was that the firm's product mix had changed; there was a shift toward more sophisticated product lines where inventions are more likely to be patented. Other reasons were increases in perceived competition, greater sophistication with regard to patents, and technical developments that reduced some of the disadvantages of patenting. (For example, one chemical firm reported that, with improvements in analytical equipment, rivals can analyze and duplicate the firm's products more easily; thus, the firm is less concerned that patents will reveal what it is doing.)

If it is true that there has been no substantial decline in the propensity to patent, the drop in the annual number of patents granted to U.S. inventors during the 1970s must reflect a real decrease in the number of inventions. The extent to which such a decrease in the number of inventions resulted in a decrease in the rate of technological change depended, of course, on whether the average economic importance of an invention changed during this period. It is quite possible that firms, confronted with considerable increases in the costs of carrying out R and D during this period, found it profitable to develop fewer inventions of minor or marginal importance, and that the decrease in the number of inventions exaggerates the reduction in the rate of technological change. More information is needed on this score.

[16] For example, see Milnamow (1982), National Science Foundation (1983), and Shapley (1978).

[17] This sample, while it is of the same size, covers much the same industries, and was chosen at random from essentially the same frame as that used in previous sections, is different from the one used there. To maintain high response rates and accurate estimates by firms, it seemed worthwhile to choose two separate samples, thus enabling us to reduce the number of questions asked each firm to a very small number. Only 1 out of the 100 firms did not respond (after follow-ups in many cases). There is every indication that the estimates provided here were prepared with considerable care. The difference in industrial coverage is that communications, stone, clay, and glass, food, and paper were included, but fabricated metal products and textiles were excluded. As in the previous sample, the frame came from the list of firms in *Business Week*, July 5, 1982, and *Poor's Register*. (See note 2.)

[18] In addition, data of this sort were obtained in interviews with 35 non-U.S. firms, their location being Canada (18 firms), Sweden (9 firms), Switzerland (5 firms), the United Kingdom (2 firms), and Germany (1 firm). The number of firms that patented a larger, smaller, and equivalent percentage of patentable inventions in 1980–82 than in 1965–69 was calculated. Although more firms reported a decrease in the percentage than reported an increase in it, the difference is not statistically significant at the 0.05 probability level. This result is relevant but it should be interpreted with great caution, because the sample of non-U.S. firms was, strictly speaking, not a random one. (Some of the firms were included because colleagues of mine in these countries suggested them.) In the case of Canada, DeMelto, McMullen, and Wills (1980) also report a decrease in this percentage during 1960–79.

5. Conclusions

Despite the fact that the patent system generally is defended at least partly on the grounds that it increases the rate of innovation, the present study indicates that its effects in this regard are very small in most of the industries we studied. In primary metals, electrical equipment, instruments, office equipment, motor vehicles, rubber, and textiles, very few additional inventions were commercially introduced because of patent protection, according to the firms themselves. (In many of these industries, patent protection was reported to have not been essential for the introduction of *any* of their inventions during this period.) However, in a few industries, particularly pharmaceuticals and chemicals, the effects of the patent system were reported to be very substantial.

Although the patent system seems to have a relatively small effect of this sort in most industries, this does not mean that firms make little use of the patent system. On the contrary, even in those industries where practically all inventions would be introduced without patent protection, the bulk of the patentable inventions are patented. And in industries like pharmaceuticals and chemicals, where patents seem to be important, over 80 percent of the patentable inventions are patented. Clearly, firms generally do not prefer to rely on trade secret protection when patent protection is possible. Even in industries like motor vehicles, where patents are frequently said to be relatively unimportant, about 60 percent of the patentable inventions seem to be patented.[19]

Moreover, despite the frequent assertions that firms are making less use of the patent system than in the past, the evidence does not seem to bear this out. Even in electronics (where "potting"—i.e., block boxing, such as the encapsulation of products in epoxy resin to deter imitation—is said to have come into prominence, and patents are claimed to be less important), the firms in the sample report no such trend. This is important because it is the first systematic evidence concerning the extent to which the reduction in the patent rate during the 1970s was due to a shift away from patents and towards trade secrets and other forms of protection. If, as some responsible observers have claimed, "the so-called patent decline may be merely a patent bypass,"[20] it is important that policy makers be aware that this is the case. Based on our results, there is no indication that this is true.[21]

[19] It is well known that the standards for patentability are met by many inventions that are of little or no economic consequence. Thus, the fact that firms patent such a large percentage of their patentable inventions suggests that the bulk of their patented inventions must be of minor importance, which is consistent with previous studies.

[20] Shapley (1978, p. 848).

[21] The research on which this paper is based was supported by a grant from the National Science Foundation, which, of course, is not responsible for the views expressed here. I am also indebted to the large number of firms that provided the basic data, without which the study could not have been done.

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