NBER WORKING PAPER SERIES

# PATENTS: RECENT TRENDS AND PUZZLES

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Working Paper No. 2922

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 1989

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## ABSTRACT

This paper reviews the historical data on patenting in the United States with special reference to the last 20 years and their potential relation, if any, to the recent productivity slowdown. Two Points are made: Patents are not a "constant-yardstick" indicator of either inventive input or output. Moreover, they are "produced" by a governmental agency which goes through its own budgetary and inefficiency cycles. The paper shows that the appearance of an absolute decline in patenting in the 1970's is an artifact of such a cycle. This leaves us still with the longer run puzzle of a slower growth in patenting, especially by U.S. residents, relative to R&D expenditures. It is conjectured that this reflects more the changing character of patents and R&D than an indication of diminishing returns to R&D and an exhaustion of technological opportunities.

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Among the various explanations of the worldwide productivity slowdown in the 1970s, the exhaustion of inventive and technological opportunities remains one of the major suspects in the case. (See Baily and Chakrabarti, 1988, among others.) This suspicion is fed by one of the more visible statistical facts: the total number of patents granted peaked in the U.S. around 1970 and then declined through most of the 1970s (see Figure 1). Similar trends could also be observed in patenting worldwide, except in Japan (see Evenson, 1984 and Englander et al, 1988). This same kind of data also fed the idea that the United States had lost its competitive inventive edge. If one looks at the data on patents granted to U.S. corporations they peaked in the mid-sixties and have not really recovered since (see Figure 2). A related notion is diminishing returns to inventive activity, to investments in R&D. Looking at Figure 2 one notices the much more rapid rate of growth in national R&D expenditures than in total patenting and the implicit suggestion of diminishing returns.

In what follows, I shall argue that one cannot reach such conclusions without first examining the meaning and construction of patent data. Two points will be made: Patents are not a "constant-yardstick" indicator of either inventive input or output. Moreover, they are "produced" by a govermental agency which goes through its own budgetary and inefficiency cycles. These considerations will effectively dispose of the appearance of absolute declines in such data, leaving us still with the longer run puzzle of potential diminishing returns to R&D. The paper will close with some meditations on this theme.

I

Figure 1 points out two important aspects of these data: the trends in patent grants do not always follow those of patent applications and there have been cycles before. An application for a patent is filed when, presumably, the expected value of receiving the patent exceeds the cost of applying for it. The expected value of a patent equals the probability that it will be granted, times the expected economic value of the rights associated with the particular patented item or idea, minus the potentially negative effects arising from its disclosure. A patent is granted if it passes certain minimal standards of novelty and potential utility. These standards can change over time, both as a result of changes in perception of what is an innovation and as the result of changing "applications" pressure on a relatively fixed number of patent office workers. (It might be useful here to think of an anology to articles and journals, the publication rate being limited both by the available number of pages and the limited number of referees.) Moreover, a change in the resources of the patent office or in its efficiency will introduce changes in the lag strucure of grants behind applications, and may produce a rather misleading picture of the underlying trends. In particular, I will show below that the decline in the number of patents granted in the 1970s is almost entirely an artifact, induced by fluctuations in the Patent Office, culminating in the sharp dip in 1979 due to the absence of budget for printing the approved patents.[1]

The last point can be made in several ways. Perhaps the simplest way is shown in Figure 3 which plots the number of grants that would be predicted by a "constant" Patent Office policy and performance, i.e., a 65 percent approval rate and a constant lag structure. The graph of such a "prediction" is essentially flat throughout the 1970s, reflecting the rough constancy of total applications during this period. Table 1 shows, at the same time, that the lag structure of the granting process changed markedly during the last twenty years. In the late 1960s it took more than three years for half of the eventual grants to be issued. A campaign to reduce these lags and eliminate the accumulating backlog was begun in 1971 and brought down the fraction taking more than three year to about 10 percent by the late 1970s. But by the early 1980s the Patent Office ran into another budgetary crisis and the backlog began to grow again.

Another way of looking at the granting process is via an estimated Patent Office "production function," which looks at the number of patents granted as a function of two major "inputs": the internal resources available to it, the average number of patent examiners over the previous three years (AVEXAM), and the "materials" it has to work with, lagged past applications (in the form of the PRGRNT variable). Table 2 presents a number of such regressions for the 1924-1987 and later periods (examiner data are not available before 1920). The major determinant of the number of patents granted is the number of patent examiners employed by the Patent Office. Their estimated coefficient is approximately one. The supply of applications is important but it works largely through the examiner variable. Examiners are employed, in part, in response to application pressure and the state of the accumulating backlog. There appears to be a negative trend in the "efficiency" of patent examiners, perhaps as the result of the rising complexity of applications and the increasing size of the literature that needs to be searched.[2] This trend is largely over by 1960. It changes sign in the mid 1970s and is not statistically significant in the post-WWII period by itself.

Similar conclusions can be reached by looking at Figure 3 which focuses on the post-war period and plots the original data. What is clear from this figure is that the shorter run fluctuations in the total number of patents granted are much more closely associated with the number of examiners than with the inflow of patent applications ("Predicted grants" being just a scaled moving average of recent applications). It is also clear that the decline in patents granted in the 1970s came not from a decline in applications, they declined very little, but from the contraction in the resources of the Patent Office. Thus, this particular indicator of "technological decline" was nothing more than a bureaucratic mirage!

The story for grants to domestic inventors, told in the second half of Table 1, is largely similar. Most of the variability in their numbers is again attributable to the number of examiners. But there is also evidence of a significant negative effect of the rising number of foreign applications, represented in this table by the number of "predicted" grants to foreigners or the logit transformed ratio of foreign applications. Both versions of this variable indicate a "crowding out" of domestic patents by the rising tide of foreign applications and provide a substantive interpretation for the negative trend in this equation. This does not "solve," however, all of the mystery. In the case of domestic patents there has been also a decline in applications in the 1970s which requires an interpretation of its own.

## II

Before looking at the determinants of domestic patenting and its interpretation as an indicator of inventive activity, I want to make one cautionary point: From the point of view of the measurement of technical change in the U.S., using total factor productivity measures or related indexes, it is not clear that domestic patenting is the relevant magnitude. Total patents may be a better measure of shifts in "technology," in the "production possibilities" frontier; it does not matter whence the invention came from. Foreign inventions should have a similar impact and hence from the point of view of measures of technological "opportunity" available to the U.S. economy, total patents are probably the better index. The level of domestic patenting is more relevant for studies of "competitiveness" and when thinking about rates of return to domestic R&D. Changes in measured productivity growth are also affected by changes in capacity utilization and hence, also indirectly, by the "competitiveness" of the domestic industries. It is interesting, therefore, to know what happenned to levels of inventive activity in the U.S. but there is some doubt how well we can tell it from the data on patenting by U.S. residents.

Figure 4 plots the long term data on domestic patent applications, real GNP, and gross private domestic investment, all on a common log scale. (The domestic patent application numbers are extrapolated backward, before 1940, by the number of total patent applications, foreign applications constituting less than 10 percent of the total at that point.) Several interesting facts stand out in this chart: After growing at roughly the same rate as real GNP in the late 19th and early 20th century, domestic patent applications peaked in the late 1920s and have not achieved such levels again. After a severe decline during the Great Depression and the early war years and a brief post-war recovery, they stayed essentially flat throughout the whole post-war period, while both GNP and total and corporate R&D expenditures were growing.

These facts led Schmookler (1966, p. 28-30) to declare such data not really comparable between the pre- and post-WWII periods. He gave three reasons for the "shortfall" in the more recent period: (1) The change in judicial and political climate in the late 1930s which became much more hostile to corporate patenting and the enforcement of patent rights, reducing thereby the value of applying for one. (This may have reversed itself in recent years.) (2) The growth in delays in processing patent applications at the Patent Office which reduced the ultimate value of such protection. (The length of the delay went through a number of cycles and its magnitude does not appear to be large enough to provide much of an explanation for the observed decline. See Table 1.) And (3), the rise of industries where there is less reliance on patents and more on secrecy and on first-mover advantage, and the realization by many corporations that they might be able to do without patenting. (Here too, as I will show below in Table 3, the computable effects appear to be rather small.) What Schmookler did not mention explicitly is the rise in the real wage and hence the rise in the opportunity cost of dealing with the patent system. This rise in real wages contributed to the significant decline in the number of patents issued to "independent" inventors and probably also to a higher threshold of potential value for corporations before they would file an application. If this is true, then the relative stagnation of domestic applications in the post-war period does not preclude the possibility that real inventive activity and its output were rising at the same time.[3]

Before we look at the post-war period in greater detail, we should remind ourself of the fact that the number of patent applications (and grants) grew sharply and more or less steadily from 1880 to 1920 without the help of any formal or recorded R&D expenditures and that they grew very little during the 1950s and 1960s, the period of most rapid growth in both total and corporate R&D in U.S. industry. Thus, it is unlikely that such patent numbers can be taken as a good, constant-yardstick, indicator of the "output" of R&D, unless we admit the possibility of sharply diminishing returns to such investments. This is the question that I will keep coming back to in the rest of the paper.

## III

The number of domestic patent applications hovered around 64,000 between 1955 and 1986. It peaked in 1970 at about 72,000, declined to a low of 61,000 in 1979, and then hit another low of 59,000 in 1983 before turning up in the mid-1980s (see Fig. 2). During approximately the same period, total R&D expenditures in industry grew by about 8 percent per year between 1953 and 1968 (1953 is the first date for which we have comparable R&D data), and then declined by about -2 percent per year between 1968 and 1975, before turning up again. It is plausible that some of the decline in the growth of domestic patenting (from plus .7 between 1953 and 1968 to -.6 percent per year between 1968 and 1985) is associated with this decline in the rate of growth of R&D. The turn-around in patenting starts in 1978, is interrupted by the recession of 1983, and is much slower than the contemporaneous recovery in total R&D spending.

One of the questions to ask is whether this lack of growth in domestic patent applications is due to a change in industrial mix, away from the traditionally high patenting areas (such as chemicals) and towards the faster growing, lower patenting industries such as computers. Table 3 presents some data on this point, using patents per R&D dollar intensities in 1976 (taken from Bound et al, 1984) and reweighting them with the industrial distribution of company R&D expenditures in 1957 and 1985. Computing a "predicted" average number of patents per R&D dollar from these data yields results which go in the right direction, but the total effect is rather small: a minus 3 percent adjustment for the whole 1957-1976 period. One gets similar results, not reported here in detail, using Scherer's (1984) data on 1974 patents by Lines of Business per R&D dollar. In either case, the industry mix effects are rather small both because patenting intensities are not all that different across industries and because the industrial composition of R&D did not change drastically during this period.

That the observed declines in U.S patenting are not just the result of compositional effects can be seen also from the available detail on patenting by industries and major companies. Table 4 gives industrial detail, in the form of annual growth rates between three-year averages, on patenting by U.S. residents (by year of grant) and by U.S. corporations (by year applied).These data are based on the "Concordance" constructed by OTAF (1985), which takes data on the number of patents by patent class and assigns them (patent classes), not uniquely, to potential industries of manufacture or use. The assignment rules can be and have been criticized (see Scherer 1982a and the discussion reported in OTAF 1985) but the resulting detail should still be instructive.[4] What Table 4 shows is that the decline in U.S. patenting in the 1970s was very pervasive: Almost all of the industries, except for Drugs and Agricultural Chemicals, had significant declines or no growth in patenting during the early and middle-1970s. By the late 1970sthe only recovery that was visible was in Office and Computing Machinery and Ordnance. Hence the story would not change much by a reweighting of industries. This can also be seen in Part B of Table 4, which lists the expenditures in U.S. industry on Applied R&D by product field for selected years and also the implied number of patents per AR&D dollar in 1971. The latter numbers are rather wild, indicating some of the problems with this Concordance, but the table as a whole illustrates clearly some of the conflicting trends in the data: both the strong growth in AR&D in such low patenting industries as Office and Computer Machinery and the contemporaneous declines in AR&D in even less patent intensive industries such as Aircraft and Guided Missiles.[5]

Given the difficulties of allocating specific patents to particular industries, it is perhaps simpler and much cleaner to look at the actual numbers for selected companies which are plotted, for selected industries, in the different panels of Figure 5. All the major U.S. companies depicted there show at least some decline in patents received during the early 1970s and also some recovery in the 1980s. There is also an indication of a common business cycle effect in 1973-75 and 1983 for most of the companies, including many of the foreign companies.

Having disposed of the changing industrial mix of R&D and patenting as an explanation for the decline in U.S. patent applications, we are still left with the possiblity that the deterioration in the overall economic conditions during this period may have been responsible for some of this decline.

## IV

The productivity slowdown of the 1970's is not the result of the slowdown in inventive activity, as measured by patent applications, U.S. or worldwide, but rather, and more likely, causality runs from a deterioration in economic conditions and expectations to declines in incentives for innovation. It is difficult, however, to observe the timing and to disentangle causation in such data. There is already some "softness" in demand growth to be discerned in the data for the late 1960s, visible in the various total factor productivity growth numbers (see Nordhaus 1973 and Jorgenson et al 1987, among others), arising in part from the end of the Vietnam war and the associated defense boom. This is followed by the brief but sharp recession of 1971-1972 and then the large and worldwide OPEC induced oil price shocks of 1974 and 1979 which keep the world economy operating below capacity for quite a long time (Griliches 1988). It may not be surprising, therefore, to find that inventive activity is also a depressed sector of the economy, among many others.

The notion that inventive activity is largely "demand" driven had its strongest proponent in Schmookler (1966), who used patent data from the late 19th and early 20th centuries to show that inventive activity (as measured by patents) was related to earlier movements in investment and output of the relevant industries. His work can be, and has been, criticized on several levels. In the longer run, "supply" forces, in the form of new discoveries and the steady contribution of new scientific knowledge, surely have an important role to play (Rosenberg 1974). Moreover, by current econometric standards the evidence presented by Schmookler for his conclusions does not look all that strong (though it gains conviction by the cumulative force of the various bits and pieces examined, and by observing the working of a knowledgeable and first rate mind, grappling with the problem and coming to a considered judgment). Subsequent empirical work on this topic, by Scherer (1965 and 1982b), Stoneman (1979), Wyatt (1986), Bosworth and Westaway (1984), Papachristodoulou (1986), and Kleinknecht and Verspagen (1988), have either supported his original conclusions or weakened them, but no one has really overturned them.[6] In any case, at the level of annual fluctuations that we are looking at, demand forces are likely to be more important and easier to detect than the much slower "supply" forces whose effects take longer to accumulate.[7]

It should be noted that to the extent that we are focusing on the decline in patenting relative to the growth in R&D expenditures we have already taken into account demand forces, at least to a first approximation. They are already reflected in the R&D series, which themselves represent an investment in the future, and are the main channel through which demand forces can and do affect the level of patenting. The additional fall in the "propensity to patent," in patents per R&D dollar, could also arise from demand forces, if they can affect the patenting decision more rapidly than the decision to invest in R&D because of differential adjustment costs. Other reasons for this decline may be shifts of R&D to areas where patenting is less profitable and perhaps more difficult, or an overestimation of the growth in "real" R&D due to an underestimate, by the conventional R&D "deflators," of the growth in the real cost of doing science, in finding new drugs and new compounds, and in designing new chips. Thus, allowing the "real" cost of doing R&D to rise by about 3-4 percent more per year than is indicated by the conventional deflators would eliminate most or all of this decline (Smith, 1988).[8] It is rather difficult, however, to distinguish this from various other versions of the exhaustion of the scientific frontiers hypothesis. Why is the cost of real science rising faster than a reasonably weighted index of scientific salaries and a quality adjusted price index of scientific instruments and equipment? Is it because the competition from other scientists within the country and abroad is driving up the resources neccessary to produce a unit of "visible" advance in a field? Is not this just a reflection of diminishing returns to R&D investments when they are applied to a fixed or a slower growing underlying scientific opportunities set, of crowding out and fishing out? (See also the discussion in Englander et al on this.)

Table 5 presents a number of different attempts to explain the aggregate number of total domestic patent applications in the U.S. during the last 30 years or so. Because reasonably consistent R&D data at the national level do not exist before 1953, most of the analyses is based on the 1954-87 period. I look here at several issues: How much of the decline in domestic patenting in the 1970s can be attributed to the decline in real R&D expenditures during the same period? Do domestic patents depend largely on company financed R&D expenditures or on "total" R&D in the economy, including university R&D? Did changes in the demands of the defense establishment impinge positively or negatively on domestic inventive activity? Can part of the decline in the propensity to patent be explained by the rising real cost of R&D? Because of the shortness of the period, the highly aggregated nature of all of the variables, and the rather common trendlike movement in most of them, it is not possible to answer such questions definitively, but the results summarized in This table 4 are suggestive, nevertheless.

There are a number of interesting findings in Table 5. (1) For the period as a whole (1953 to 1987) there was no significant decline in the number of patent applications in the U.S. by U.S. residents. Since there was a positive rate of growth in real R&D over this period, at least if one uses the standard deflators, any attribution of a positive influence to them will imply the finding of a negative time trend in the patents "production function." (2) Fluctuations in R&D do affect the number of patents applied for, but less than proportionately. Among the various possible measures of R&D, company expenditures on R&D "works best," as long as only one measure of R&D is to be included in the equation. (1) and (2) together imply a negative trend in the "propensity to patent" or in the "efficiency" of patent "production" of about -1 to -2 percent per year. The estimated coefficient of the company R&D variable is quite high and significant, between 0.2 and 0.4, and is consistent with earlier findings based on micro data (see Hall, Griliches, and Hausman, 1986). (3) Changes in the size of the defense establishment, in the form of current and lagged changes in real gross national product devoted to national defense, have a large and significantly negative effect on the number of domestic patents applied for and perhaps also on actual levels of inventive activity. The estimated effect is large: a decline of 5 percent in domestic patenting as the result of a 10 percent increase in defense GNP, and it is quite robust to the introduction or deletion of other variables. This finding is consistent with both the view that defense expenditures pull resources away from inventive activity and with the view that they channel inventive activityinto areas where patenting is either more difficult or less important.[9] (4) There is evidence in these data of a positive contribution of basic research in universities to the overall level of domestic inventive activity as measured by the total number of domestic patent applications. (5) There is also some evidence that the rising real cost of R&D, in the form of the ratio of the R&D to GNP price deflators, has had a negative impact on patenting, either because it reflects also the rising cost of patenting relative to other economic activities, or because it adjusts in part for the "underdeflation" of the R&D variables by the same set of deflators. All of these conclusions are very tentative. They are based on highly aggregated data, a rather short time period, and a highly multi-collinear set of examined variables. The latter point is made clear by the "insignificance" of the company R&D variable once the "real R&D deflator" variable is added to the equation and is reinforced by the fact of the very high intercorrelation between most of these variables. The simple correlation between the company R&D variable, time, and real GNP is 0.99 and 0.98 respectively, and it is on the order of 0.94 with university basic research or total R&D in industry. It would be desirable, therefore, to confirm some of these conclusions using better and more detailed data at a less aggregated level.

Earlier work with micro data on related topics is consistent with most of these conclusions. Using firm data on patents and R&D, Pakes(1985), Hall et al (1986), and Griliches et al (1988) all found that, to the extent that it is testable, "causality" runs from R&D to patents. This relationship is close to instantaneous, with some evidence of longer lags present but difficult to establish precisely. Almost all of the other economic variables that they examined, such as the stock market rate of return, sales, or investment, "work" primarily via the R&D variables and do not have a significant independent contribution of their own in the various estimated patent equations. The estimated coefficients of the R&D variables in the time dimension of such equations (in first differences or "within" firm) were between 0.2 and 0.4. The small size of such coefficients and the absence of a significant finding of direct effects of demand side macro-related variables do not make the interpretation of the patenting trends at the aggregate level any easier.

An attempt has been made also to use the industry level data already presented in Table 4. Unfortunately, the data on patents received by year applied for are not available before 1970 and are incomplete past 1983. Moreover, the AR&D data are seriously incomplete past 1979, with the NSF reporting significantly less industrial detail for this variable. Running patent-R&D equations on these data, in the first differences of logarithms format, including separate year and industry dummy variables, and limiting ourselves to the complete data years 1970-79, yields no evidence of a significant lag structure and an estimate of 0.27(0.08) for the elasticity of corporate patents received with respect to applied R&D. Adding current and three lagged values in output and/or capital growth, and lagged values of growth in AR&D, improves matters very little. In the "best" equation, changes in corporate patents received (by year applied for) depend only on current changes in AR&D, with a coefficient of 0.22 (0.07), and two periods lagged growth rate of output, with a coefficient of 0.23 (0.11). Since during this period, 1971-79, the average growth rate of output, and of "real" AR&D as measured, are both positive, the implied estimate of the trend rate on the propensity to patent is still negative, and in fact, more negative than the observed trend in the raw numbers. Thus, a positive role for such variables in the patenting relationship is inconsistent with the hope that they would contribute to an explanation of the observed negative trends in these data.

The estimated trend remains negative for all of the years, except for 1975, and for all of the industries, except for Drugs and Agricultural Chemicals. Adding post 1979 data for some of the industries, where they are available, does not change these results appreciably.

Returning to Table 5 and the associated macro data we can summarize its conclusions along the following lines: Focusing first on the peak-to-trough in domestic patenting period of 1970-79, we observe an average decline (in patents applied for by U.S. residents) of about -2 percent per year of which about a third, -0.7 percent, could be attributed to the accelerating growth i the U.S. defense establishment. At the same time, however, company financed R&D expenditure and basic research expenditures in universities grew at about 2 and 1 percent per year respectively. Using the estimated coefficients from column 4 in Table 5 would imply that this should have resulted in about 0.5 percent per year growth in patent applications, cancelling out most of the negative effect of the growth in defense and leaving almost all of the observed decline in patenting unexplained. A similar computation for the whole 1954 through 1987 period would find no actual decline in patenting to explain and also no substantive change in the rate of growth of defense in th period as a whole. But unless the R&D deflators are all wrong, the data do indicate a rather significant growth in both private company R&D expenditures in industry and basic R&D expenditures in universities, at 5 and 8 percent pe year respectively, which should have resulted in some increase in the observe rate of patenting. Thus, we are left more or less where we started, with a significant unexplained decline in U.S. patenting relative to the ongoing investment in R&D.

## V

Aggregate patent numbers (applied and granted) have fluctuated greatly in the past. They have also grown slowly in this century, much less so than investments in R&D, which has led scholarly observers to wonder repeatedly about the implied "slackening" in the growth rate of technical progress. In 1935, Robert K. Merton wrote: "In the U.S., however, the number of patents has scarcely kept pace with the growth of population since 1885 -- a fact which may lead us to suspect the possibility of a slackening in the rate of technologic advance generally" (p.454). At the same time, Gillfillan (1935), was blaming the decline in patenting on the decline in the native ability of the American people, due to immigration and dysgenics, since "the stupid have been breeding at a much higher rate" (p. 218-9). In 1952, Alfred B. Stafford wondered "Is the Rate of Invention Declining?" as he observed a declining trend in patenting, from 1916 through 1947, in two-thirds of all the patent classes, and worried about diminishing returns on one hand and the increasing complexity of invention on the other.[10] The same point was taken up by Scherer in 1959: "... the sharp decline in patenting during the depressed 1930's can be attributed to unfavorable economic conditions, while the slump during World War II is explained by the historical tendency for patenting to decline during wartime. But no such ready explanation is available for the continued record of sluggishness during the booming postwar period" (p. 130). He then attributed some of this decline, as did also Schmookler (1966) later on, to a change in the judicial climate and especially to the increase in compulsory licensing decrees. But that does not seem to explain all of the decline, or its persistance into the 1970s. And this type of worry continues to this day, as can be seen in Baily and Chakrabarti (1988), Scherer (1986), and this paper itself. One can always worry that the world is coming to an end. Someday it undoubtedly will, but it does not look as if the end is already upon us, at least not yet.

What are the facts, so far as they can be discerned? There has been no absolute decline in the rate of patenting in the U.S. Total patent grants and applications are running about 30 percent above the early 1960s, and U.S. domestic patent applications have also recovered to the levels attained in the 1960s. The question then is, do we need a growing rate of invention (if patent numbers do indeed measure it), to sustain a steady positive rate of growth in total factor productivity? Does the faster growth in real R&D expenditures indicate diminishing returns to R&D or an improvement in the quality of patented inventions? And could the, hopefully temporary, 11 percent decline in the average number of domestic patent applications, between its peak in 1968-71 to its trough in 1977-83, have been responsible for the productivity slowdown in the 1970s or have significant productivity growth implications for the future?

To the extent that an invention either reduces the cost of production or develops entirely new products, it has an aspect of increasing returns to it. The same invention could produce the same proportional effect, in different size markets or economies. The public good nature of most inventions and the "multiplicative" aspect of their impact do not require, therefore, their number grow just to sustain a positive rate of productivity growth. On the other hand, economies do not grow just by replication and expansion, they also get more complex, proliferate different products and activities, and develop in different geographical and economic environments. To that extent, the "reach" of any particular invention does not expand at the same rate as the growth of the overall economy, but only at the rate of growth of its "own" market. Therefore, I would expect that the "required" number of inventions for a steady positive rate of growth in productivity has also to grow, but at a rate which need not be as fast as that of the economy as a whole.

The paragraph above deals with the fundamentally unobservable quantum of "invention" or "an advance in knowledge." It is clear, from the previous discussion and the earlier references, that its relationship to observed patent numbers is unlikely to have stayed constant over time. The important question, however, is what does an observed decline in patent numbers imply about the underlying stream of inventions and their ultimate effect on productivity. If the decline occurs because of a rise in the real cost of patenting, or even a decline in the expected value of the marginal patent, this may still have very little effect on the aggregate contribution of inventive activity, given the great dispersion in the private and social values of the inventions associated with these patents. The dispersion in patent values has been documented and commented on in the past, by Sanders (1964), Scherer (1965), and Nordhaus (1969), among others, and more recently by Pakes (1986), Schankerman and Pakes (1986), and Griliches et al (1987). The evidence discussed there shows that the vast majority of patents is worth very little and that the bulk of the private and social total product of the inventive system is based on a relative small number of very valuable patents. If the patent value were known to the inventor in advance then a rise in the cost of patenting or a decline in the return from inventing would only deter the marginal, low value inventive activity, and would leave the total aggregate return effectively unchanged. Inventors are unlikely, however, to know the value of their inventions in advance. At the other extreme, one could assume that all of the estimated dispersion in patent values is "within," that all of it represents the uncertainty that faces each individua inventor. Then, a decline in patent numbers would imply a parallel decline i total inventive activity and results.[11] Inventors do, undoubtedly, face great uncertainty about the ultimate value of their invention, as is emphasized and documented by Pakes (1986), but probably not as extensive as would be implied by the estimated cross-sectional dispersion in patent values. The truth, I believe, is somewhere in the middle, but closer to the first case, with some definite knowledge about the potential importance of the particular invention In that case, and this is also what can be read into the numbers reported in Schankerman and Pakes (1986), a decline in patenting would be associated with an increase in the average "value" of a patent, and a much smaller impact, if any, on the aggregate valuation of this activity.

Even if there were a real decline in inventive output associated with th observed decline in patent numbers, it is unlikely that we could discern its effects in the conventional productivity numbers. There are at least three reasons for this: First, not all of productivity growth is due to invention and only some fraction of the latter arises from patented inventions. If one takes 1.5 to 2.0 percent as the approximate growth rate per year in total factor productivity, at least half of it is likely to be due to the growth in the quality of the labor force, economies of scale, and various reallocations of capital between assets and industries. Moreover, it is unlikely that patented inventions could account for more than half of all the relevant advances in knowledge. This leaves us with at most a quarter of total productivity growth, and an unknown fraction of its fluctuations, to be attributed to patented invention.[12]

Second, the effects of an invention on productivity appear with a long and variable lag and it is doubtful that the available data and current econometric techniques could identify them clearly. Moreover, the aggregation over many inventions and many lag structures is likely to smooth them out futher, beyond recognition.

Third, the great variability in the magnitude and importance of the various inventions adds another source of variance here. Given the great skewness in the value distributions one cannot take much comfort from the relatively large sample, or rather population numbers. If, for example, one were to approximate the value distribution by a spike, assuming that 999 patents are worth zero while one-in-a-thousand has a present value of $500 million and annual real flow equivalent (at a 3 percent real interest rate ) of $15 million per year, this would imply a standard deviation of $121 million for the expected total value of flows from newly patented inventions of $975 million.[13] If about one-third of the 10 percent decline in domestic patent applications between the late 1960s and and late 1970s were to translate itself into a decline in real innovative output, we would be looking to detect a $32 million decline in the expected annual flow. With a standard deviation of $121 million per year it would take us over seven years, not counting any lags, to detect it with any statistical "confidence" even if there were no other sources of variation in productivity. And in the meantime, it might have turned itself around. It is this great variability in relative importance of individual patents together with a variable lag structure which makes the detection of such phenomena so difficult, a point already noticed in the past by Nordhaus (1969) and others. To the extent that one does observe correlations between patent numbers and contemporenous productivity numbers, the causality is most likely running the other way, from productivity as a measure of the economic enviroment to patents as a measure of inventive "effort" rather than from the impact of inventive "output" on subsequent productivity.

The question of diminishing returns to R&D and the implicit forecast of a declining productivity growth rate also remains unresolved. If the relationship of patent numbers to inventive output has been changing then they cannot be used to make a judgement about this. The other evidence on this topic is also equivocal. A priori, one would expect to hit diminishing returns in any narrowly defined field, at least until the field or the product area are redefined anew by some other major breakthrough. Kuznets used detailed patent data to make this point already in 1929 (pp. 54-58). This also follows from the various theoretical models of the R&D process such as Evenson and Kislev (1975, chap. 8) and others. On the other hand, inventive effort moves from one "fishing" ground to anther, and new fishing grounds open up as the result of basic R&D and other sources of discovery. Hence, in the longer run, there is less evidence of exhaustion of opportunities and studies which have tried to look for declines in the rates of return to R&D have found very little evidence of such a decline (see Griliches 1986 and Sveikauskas 1988, among others). The same conflict appears in the various estimates of the "patent production function". Time series estimates, which presumably measure returns to movements primarily along alreday established trajectories, all tend to come out with relatively low elasticities of patents received with repect to R&D invested, on the order of .2 to .45 (see Pakes and Griliches

1982, Hausman et al 1984, and Hall et al 1986). On the other hand, cross-sectional studies, which presumably represent better the optimal migration of R&D resources across fields and the finding of new niches, yield elasticity estimates much closer to unity. (See Bound et al 1984, Scherer 1982, and the literature cited there.)

The assumption of diminishing returns is actually already contained in most R&D based models of productivity and productivity growth. In such models, with the stock of knowledge capital, proxied by a "stock" of accumulated past R&D expenditures, the estimated elasticities tend to be rather small, on the order of 0.06 to 0.2 (see, e.g., Mansfield 1984 and Griliches 1986). This, by the way, is not all that different from the time series based patent-R&D coefficients estimates in the previous section. If productivity is a measure of knowledge accretion and patents are a proxy index for it, then there may be no paradox here, after all. This is what is also implied by Figure 6, which plots (on a common logarithmic scale) the index (level) of Multi-factor productivity in the Private Business Sector of the U.S. economy (as computed by the BLS) together with a measure of the total "stock" of patent applications in the U.S. and the parallel concept of the stock of total R&D expenditures (both based on a 15 percent depreciation rate). Note the remarkably parallel behavior of the productivity series and the total patent stock series and the faster growth rate, at least during the earlier part of the period, of the total R&D stock series. The relationship would be poorer for the patent stock variable if only domestic patent applications were counted, it would have turned down significantly by the mid-1980s. This is a bit of evidence for my view that the relevant indicator for measures of technical change are total patents, not just domestic patents.

In the past I looked at such charts and thought that something was wrong with the productivity numbers. But if we were to believe the patent numbers, perhaps they are not so wrong after all. For reasons discussed above, I do think that over longer periods of time patent numbers are an imperfect index of inventive output, whose relationship to the underlying "frontier shift" has been declining over time. More will have to be learned, however, before we can fell certain about such inferences. Thus, the patent numbers leave us where we began, with a suggestive, but possibly misleading puzzle.

## Footnotes

*Supported by NSF Grants PRA85-12758 and SES82-08006. I am indebted to Bronwyn H. Hall for some of the data and for access to her unpublished paper on this same topic (Hall 1988).

1. The impact of changes in bureaucratic procedures on shorter run aspects of these data is discussed in Brunk and Demack (1987) who point out that since 1968, the Patent Office has been issuing a fixed number of patents each week, with this number changing, from time to time, as the backlog varied.

2. See Scherer (1959) p. 134, for evidence of rising complexity.

3. The only indirect evidence on this point that I know of comes from the Schankerman and Pakes (1986) study of patent renewal data in Europe which can be taken to show that the average value of a patent right rose between 1955 and 1975 in all the three countries studied by them. See also Pakes and Simpson (1988).

4. There are 42 distinct manufacturing fields in the OTAF data base which have been consolidated here to 26 to make them comparable to the AR&D data in Part B of this table. See Griliches and Lichtenberg (1984) for a discussion of the advantages and difficulties of using the AR&D data by product field. In principle, the OTAF data are available back to 1967 and earlier but the recently revised concordance based data have not been tabulated before 1970 by single years (by year of application).

5. Because of the ambiguity as to which patent classes should be assigned to which industries, many of them are assigned to several industries simultaneously, in a fractional manner. Thus, for example, the numbers for patents in the Drugs and Agricultural Chemicals industries are not really independent, since there is an overlap of almost 90 percent between the patents assigned to both industries. Similarily, the extremely high number for patents per AR&D dollar in the Metal Working Machinery industry (354), is likely to be the result of attributing a large number of patents from Fabricated Metals and other kinds of machinery also to this industry.

6. A number of studies, following Stoneman, have regressed the log of patents on the log of R&D per patent, interpreting the latter variable as a measure of the "cost" of invention, and the resulting negative coefficient as an indication of the workings of "supply" forces. But the sign of this coefficient could reflect nothing more than the spuriousnes of such a relationship, induced by the large transitory or measurement error component in patent numbers. On the latter possibility see Griliches, Hall, and Pakes, 1988.

7. Taking the longer run view and looking at periods with no R&D data, one can reproduce the main outlines of Schmookler's results. For example, for the whole 1880-1987 period (88 years), one gets (in first differences of logarithms format):

$$\underset{}{gda} = \underset{(.009)}{-.006} + \underset{(.030)}{.110}\, ggpdi + \underset{(.128)}{.299}\, ggnp(-1)$$

R = 0.15
SEE = 0.075
D-W = 1.87

where the rate of growth in domestic patent applications (gda) is related positively to the current rate of growth in gross private domestic investment (ggpdi) and the lagged rate of growth in real GNP (ggnp). Because the post-World War II period exhibits much less variance, the results are much weaker there, but not all that different. During this later period we have, however, actual direct "input" measures, such as R&D expenditures and the number of scientists and engineers engaged in R&D, and they dominate the aggregate economy indexes such as GNP or GPDI.

8. "For an institution viewed as a whole, with a constant complement of young scientists, typical weighted growth rates per scientist (in the "sophistication factor") might be 2-5 percent in constant-value terms per annum, ..." Cohen and Ivins (1967), p. 28.

9. Attempts to extend these results by adding more "demand" side variables such as changes in real GNP, capacity utilization, or stock price indexes were not successful. Almost all of the systematic short-run variability in aggregate domestic patenting is picked up by fluctuations in the R&D and national defense variables. All of the other demand variables appear to be working via these variables.

10. Stafford (1952) is a marvelous example of how easy it is to make wrong predictions about the future. See also the sharp and confused exchanges between Gillfillan, Schmookler, and Kunik in Technology and Culture in 1959.

11. This is one way to read the evidence presented in Mansfield (1986) that

major U.S. corporations have not reduced the fraction of their inventions that they patent.

12. Taking half a million dollars as the midpoint between the low and high estimates of the average present value of a patent right from Griliches et al (1986) and 65,000 as the average number of patents per year in the 1980s and a 3 percent real interest rate, yields about $1 billion as an estimate of the annual increment in private returns. Taking 1.5 percent as the growth rate of total factor productivity recently would have yielded an annual increment in Private Nonresidential GNP in 1982 of $47 billion attributable to the growth in productivity, of which a quarter, about $12 billion, could be the result of patented inventions. This would require that the social return from these inventions be at least ten times larger than the private return from the ownership of patent rights. That is clearly possible but perhaps not all that plausible.

13. With 15 as the expected value of a success, 0.001 as its probability, and $n = 65{,}000$, we have

$$E(x) = 15 \times 0.001 \times 65{,}000 = 975$$

and

$$\sigma_x = 15 \times \sqrt{65} = 121.$$

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Table 1: The Distribution of Patents Granted by Year of Application, 1966-82, and Time to Year of Grant

| Year of Application | Percent Granted Years Later: 0 | 1 | 2 | 3 | 4 | 5+ | Percent of Total Grants Granted Within 3 years of Application Date |
|---|---|---|---|---|---|---|---|
| 1966 | 1 | 13 | 36 | 35 | 12 | 3 | 50 |
| 1967 | 1 | 13 | 43 | 33 | 8 | 2 | 57 |
| 1968 | 0 | 12 | 44 | 36 | 6 | 2 | 56 |
| 1969 | 0 | 11 | 66 | 20 | 2 | 1 | 77 |
| 1970 | 0 | 18 | 62 | 17 | 2 | 1 | 80 |
| 1971 | 0 | 17 | 61 | 18 | 2 | 2 | 78 |
| 1972 | 0 | 28 | 57 | 11 | 2 | 2 | 85 |
| 1973 | 0 | 37 | 50 | 10 | 2 | 1 | 87 |
| 1974 | 1 | 42 | 48 | 6 | 2 | 1 | 91 |
| 1975 | 1 | 42 | 46 | 8 | 1 | 2 | 89 |
| 1976 | 2 | 42 | 47 | 6 | 2 | 2 | 91 |
| 1977 | 1 | 42 | 41 | 12 | 2 | 2 | 84 |
| 1978 | 1 | 24 | 57 | 15 | 2 | 1 | 82 |
| 1979 | 0 | 22 | 60 | 15 | 2 | 1 | 82 |
| 1980 | 0 | 22 | 53 | 20 | 3 | 2 | 75 |
| 1981[e] | 0 | 17 | 50 | 27 | --- | --- | 67 |
| 1982[e] | 0 | 15 | 52 | --- | --- | --- | 67 |

1966-68 based on a special unpublished OTAF (Office of Technology Assessment and Forecast, Patents and Trademarks Office, U.S. Department of Commerce) tabulat 1969-79 based on a sample of 100,000 patents from the 1969-79 OTAF tape on patents granted. 1971-82 based on the complete 1984 OTAF tape.

[e]estimated

Table 2: The Patent Office "Production Function"

| Variables | Log total grants 1925-87 | Log total grants 1945-87 | Log domestic grants 1945-87 | | |
|---|---|---|---|---|---|
| | Coefficients (standard errors) | | | | |
| **Inputs** | | | | | |
| Log Ave. Examiner | .916 (.145) | .879 (.129) | .938 (.153) | .957 (.146) | .899 (.130) |
| Log Pred. Grant | .479 (.188) | .419 (.129) | | | |
| Time | -.026 (.008) | | | -.010 (.003) | |
| Time Sq. | .00025 (.00010) | | | | |
| Log domestic Pred. Gr. | | | .625 (.325) | .400 (.301) | .333 (.311) |
| Log foreign Pred. Gr. | | | -.195 (.071) | | |
| Logit for. appl. ratio | | | | | -.102 (.031) |
| $\bar{R}^2$ | .890 | .950 | .788 | .796 | .800 |
| SEE | .107 | .115 | .119 | .117 | .116 |
| AR(1) | .427 (.121) | .273 (.153) | .286 (.160) | .273 (.158) | .273 (.159) |

Average Examiner = [Examiners (-1) + Examiners (-2) + Examiners (-3)]/3

Predicted Grants = .65[.1 Appl (-1) + .61 Appl (-2) + .24 App (-3) + .04 Appl (-4)

Same formula for predicted domestic and foreign grants as a function of domestic and foreign applications.

AR(1) -- First order autoregressive serial correlation adjustment.

SEE -- Standard error of estimate (standard deviation of estimated residuals).

Logit foreign applications ratio -- log[(Fr. Appl/Tot. Appl)/(1-(Fr. Appl./Tot. Appl))

Table 2 (continued)

<u>Sources:</u>

From <u>Historical Statistics of the U.S.</u>, Chapter W and U.S. Dept of Commerce, Patents and Trademarks Office, <u>Technology Assessment and Forecasts</u>, 7th Report, March 1977, Appendix A. Updated from National Science Board, <u>Science and Engineering Indicators - 1987</u>, Washington, D.C.: Government Printing Office, and Patent Office releases (TAF, April 1988). Number of applications by residence of inventor for 1940-1959 from an unpublished Patent Office memo by P.F. Fredrico, dated 1-18-1961. 1960 numbers are taken from the <u>Journal of the Patent Office Society</u>, 44(2), February 1964, p. 168; 1961-2 from the 1966 <u>Annual Report</u> of the Commissioner of Patents, p. 26; 1963-1987 from the Patent Office releases (TAF April 1988). Number of examiners: 1927-78 -- private communication from the Patent Office. 1924-26 from B.H. Hall (1988); 1970-87 from the Annual Reports of the patent Office.

Table 3: The Industrial Distribution of Company Financed R&D and Patent Intensity per R&D Dollar

| Industry | Number of Patents per million $s of Company Financed R&D[1] | Percent of total company financed R&D in specific industry 1957[2] | 1976[3] | 1985[3] |
|---|---|---|---|---|
| Food | 1.25 | 2.2 | 2.1 | 2.1 |
| Textiles & Apparell | 2.09 | .4 | .4 | .3 |
| Lumber and paper | 1.89 | 1.5 | 2.3 | 2.0 |
| Chemicals, exc. drugs | 1.53 | 15.3 | 9.8 | 9.6 |
| Drugs | 1.31 | 3.1 | 6.4 | 7.0 |
| Petroleum refining | 1.98 | 6.1 | 4.4 | 4.2 |
| Rubber | 1.23 | 2.1 | 2.0 | 1.7 |
| Stone, clay, glass | 2.68 | 2.1 | 1.4 | 1.0 |
| Primary metals | 2.14 | 3.1 | 2.9 | 1.5 |
| Fabricated metals | 2.26 | 3.0 | 1.8 | 1.2 |
| Machinery, incl. computers | 1.16 | 12.1 | 17.4 | 18.5 |
| Electric equipment | 2.22 | 11.5 | 9.6 | 9.5 |
| Communication equipment | 2.16 | 7.1 | 8.5 | 10.8 |
| Motor vehicles | .41 | 15.7 | 14.8 | 12.4 |
| Aircraft | .78 | 9.1 | 8.2 | 8.3 |
| Instruments | 1.10 | 4.3 | 6.7 | 9.4 |
| Other | 1.50 | 1.1 | 1.3 | .7 |
| | Estimated average number of patents per million R&D $s using 1976 intensities | 1.43 | 1.38 | 1.39 |

1. Computed from Table 2.3 of Bound et al (1984) as the total number of patents divided by the total R&D of the firms in the particular industry, in 1976.

2. From National Science Foundation, Basic Research, Applied Research, and Development in Industry, 1962, Washington, D.C., NSF 65-18. Some small industries estimates based on later year data.

3. From National Science Foundation, Research and Development in Industry, 1985, Washington, D.C., NSF 88-305.

Table 4: Part A

Growth Rates (in percent): U.S. Patents Granted by Potential Industry of Manufacture or Use, 3 year Averages*

| Total U.S. by date granted | 1968-71 | 1971-74 | 1974-77 | | | Average Annual No of Patent 1970-72 |
|---|---|---|---|---|---|---|
| U.S. Corps. by date applied | | | 1971-74 | 1974-77 | 1977-80 | |
| Industry (SIC)[1] | | | | | | |
| Food 20 | 9.6 | -2.1 | -6.8 | | | 483 |
| | | | -2.1 | -5.7 | 0.8 | 312 |
| Textiles 22 | 8.2 | -7.0 | -1.7 | | | 365 |
| | | | -4.3 | 0.1 | -3.0 | 233 |
| Industrial Chemicals 281,6 | -1.1 | 0.1 | -2.8 | | | 3922 |
| | | | 0.5 | -3.5 | -5.1 | 3064 |
| Plastics 282 | -5.6 | -5.8 | 0.6 | | | 731 |
| | | | 0.4 | -1.7 | 0.6 | 528 |
| Drugs 283 | 8.9 | 8.0 | 12.3 | | | 395 |
| | | | 13.6 | 6.3 | 0.2 | 350 |
| Agr. Chem. 287 | 0.6 | 9.7 | 15.0 | | | 305 |
| | | | 18.6 | 9.3 | -2.6 | 257 |
| Petroleum Ref. 13, 29 | 0.3 | 0.0 | -4.1 | | | 716 |
| | | | -2.2 | 4.1 | -2.4 | 584 |
| Rubber 30 | -1.1 | -0.5 | -0.9 | | | 1931 |
| | | | 0.5 | -1.6 | -0.7 | 1358 |
| Stone, Clay & Glass 32 | 4.3 | -1.5 | -3.7 | | | 956 |
| | | | -0.8 | -1.1 | 1.1 | 622 |
| Ferrous Metals 331-2 | 1.6 | 3.7 | -9.2 | | | 227 |
| | | | 1.4 | -8.2 | -1.8 | 163 |
| Non-Ferrous Metals 333-6, 9 | 4.5 | 0.8 | -2.8 | | | 243 |
| | | | -3.0 | -1.5 | -4.5 | 183 |
| Fabricated | -1.9 | 0.8 | -5.7 | | | 4498 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Metals 34 | | | -3.0 | -1.9 | -3.6 | 2601 |
| Engines 351 | -1.4 | 9.4 | -1.0 | | | 315 |
| | | | 6.1 | -7.6 | -0.4 | 233 |
| Farm Mach. 352 | 2.9 | -0.5 | -6.8 | | | 838 |
| | | | -0.9 | -1.6 | -3.6 | 383 |
| Construction | -1.4 | -0.0 | -7.4 | | | 1651 |
| Machinery 353 | | | -2.8 | -3.6 | -1.2 | 1008 |
| Metal Working | 1.9 | -2.0 | -9.8 | | | 1644 |
| Machinery 354 | | | -6.0 | -4.1 | -5.2 | 967 |
| Office and | 7.6 | -4.6 | -2.9 | | | 1254 |
| Computing 357 | | | -1.2 | 1.0 | 3.4 | 844 |
| Elect. Trans. | 2.7 | -6.8 | -6.3 | | | 1200 |
| Eq. 361 | | | -6.8 | -4.5 | -2.6 | 867 |
| Elect. Industry | 1.0 | -9.7 | -6.3 | | | 1433 |
| Apparatus 362 | | | -3.7 | -5.9 | -0.2 | 850 |
| Other Elect. | 0.0 | 0.0 | 6.1 | | | 1208 |
| Equip. 363-4,9 | | | -1.9 | -0.5 | -3.7 | 789 |
| Communication | 5.5 | -3.2 | -5.0 | | | 5992 |
| Equipment 365-7 | | | -1.3 | -1.6 | 0.7 | 3618 |
| Motor Vehicles & | -1.1 | 6.2 | -7.3 | | | 883 |
| Equipment 371 | | | -1.3 | -3.9 | -5.0 | 568 |
| Aircraft and | -3.7 | 0.3 | -3.9 | | | 447 |
| Parts 372 | | | -0.9 | -1.1 | -4.7 | 287 |
| Guided Missiles | -8.5 | -5.3 | -9.9 | | | 55 |
| 376 | | | -10.4 | 1.5 | -3.6 | 21 |
| Ordnance 348,379 | 0.4 | 9.5 | -7.3 | | | 283 |
| | | | -9.2 | -1.8 | 3.8 | 111 |
| Instruments 38 | 8.7 | -1.5 | -5.4 | | | 6199 |
| | | | -1.1 | -2.0 | 0.5 | 3668 |
| U.S. Total | 1.6 | -1.2 | -4.9 | | | 56528 |
| | | -0.9 | -1.8 | -2.1 | -1.6 | 32103 |

Table 4, Part B

Applied R&D Expenditures by Product Field in 1972 Dollars (millions)

| Industry | Year 1967 | 1971 | 1975 | 1981 | Implied Annual Average Number of U.S. Corporate Patents (1970-72) Per Million of Applied R&D in 1971 |
|---|---|---|---|---|---|
| 20 | 174 | 217 | 212 | 245 | .70 |
| 22 | 72 | 63 | 57 | | .27 |
| 281,6 | 719 | 707 | 672 | 856 | 4.33 |
| 282 | 617 | 535 | 458 | 527 | 1.01 |
| 283 | 451 | 560 | 609 | 914 | .63 |
| 287 | 120 | 136 | 137 | 242 | 1.89 |
| 29 | 230 | 278 | 318 | 485 | 2.10 |
| 30 | 172 | 279 | 252 | | 4.86 |
| 32 | 158 | 134 | 117 | 119 | 4.64 |
| 331-2 | 152 | 119 | 112 | 133 | 1.37 |
| 333-6,9 | 118 | 121 | 114 | 206 | 1.51 |
| 34 | 265 | 733 | 712 | 804 | 2.75 |
| 351 | 250 | 257 | 361 | 450 | .91 |
| 352 | 133 | 94 | 107 | 138 | 4.07 |
| 353 | 155 | 205 | 222 | 283 | 4.92 |
| 354 | 87 | 88 | 60 | 113 | 10.99 |
| 357 | 799 | 945 | 1215 | 1602 | .89 |
| 361,3,8 | 139 | 163 | 110 | | 5.31 |
| 362 | 178 | 196 | 202 | | 4.34 |
| 363-4.9 | 309 | 313 | 240 | 325 | 2.72 |
| 365-7 | 3353 | 3062 | 3042 | | 1.18 |

| | | | | | |
|---|---|---|---|---|---|
| 371 | 983 | 1284 | 1339 | | .44 |
| 372 | 2823 | 2600 | 1763 | 2450 | .11 |
| 376 | 4871 | 2962 | 2276 | 2395 | .01 |
| 379,348 | 284 | 201 | 145 | 225 | .55 |
| 38 | 697 | 682 | 780 | 739 | 5.38 |
| Total U.S. Industry | 20515 | 18546 | 18254 | 24973 | 1.41 |
| Total U.S. Corporate Patents, by date applied 3 year centered average | 32512 | 32103 | 29878 | 26848 | |

Source: Data on patents by SIC from Patenting Trends in the United States, 1963-1986, Office of Documentation, U.S. Patent and Trademark Office, unpublished report to the NSF, 1987, microfiche, and earlier OTAF tabulations. Data on Applied R&D by product field from NSF, R&D in Industry annuals, adjusted and interpolated as described in Appendix of Griliches and Lichtenberg (1984). Deflated by R&D price index from Griliches (1984) and Hall et al (1988).

***The growth rates are based on three year averages, that is, the entry for 1968-71 is**

$$\left[\frac{P(70) + P(71) + P(72)}{P(67) + P(68) + P(69)} - 1\right] \frac{100}{3}$$

**, where the notation 1968-71 signifies the mid-points of the two periods. First line for each industry is based on all patents granted to U.S. residents by date of issue; second line is based on patents issued to U.S. residents and assigned to U.S. corporations, by date applied for.**

[1] **The SIC detail is more complex than is indicated in this table. E.g., "Ferrous Metals" include 331, 332, 3399, and 3462. See Table 29 in OTAF (1985) for details.**

Table 5: Determinants of Applications for U.S. Patents by U.S. Residents, 1953-1987.
Dependent variable: log of domestic patent applications

| Variables | Regression coefficients (standard errors) and period | | | | |
|---|---|---|---|---|---|
| | 1953-87 | 1954-87 | | | | |

| Variables | 1953-87 | 1954-87 | | | | |
|---|---|---|---|---|---|---|
| Time | -.000 (.001) | -.017 (.005) | -.018 (.004) | -.013 (.003) | -.007 (.004) | -.007 (.001) |
| DLNTDF | | | -.279 (.097) | -.317 (.084) | -.314 .(074) | -.314 (.077) |
| DLNTDF(-1) | | | -.257 (.098) | -.203 (.081) | -.155 (.084) | -.155 (.076) |
| LCRD(-1) | | .338 (.094) | .410 (.075) | .203 (.090) | .000 (.125) | |
| LRUNBR(-1) | | | | .064 (.019) | .121 (.032) | .121 (.015) |
| LRRDDF | | | | | -.775 (.352) | -.776 (.233) |
| SEE | .0507 | .0425 | .0326 | .0281 | .0264 | .0259 |
| $\bar{R}^2$ | -.029 | .256 | .561 | .674 | .713 | .724 |
| D-W | .72 | 1.21 | 1.74 | 2.00 | 2.04 | 2.02 |

SEE - standard deviation of the estimated residuals. D-W Durbin-Watson statistic.

DLNTDF - the rate of growth in the national defense component of real GNP.

LCRD - logarithm of company financed R&D expenditures in industry, deflated.

LRUNBR - logarithm of total "real" basic research expenditures in universities, deflated.

LRRDDF - logarithm of the ratio of the R&D to the implicit GNP deflators.

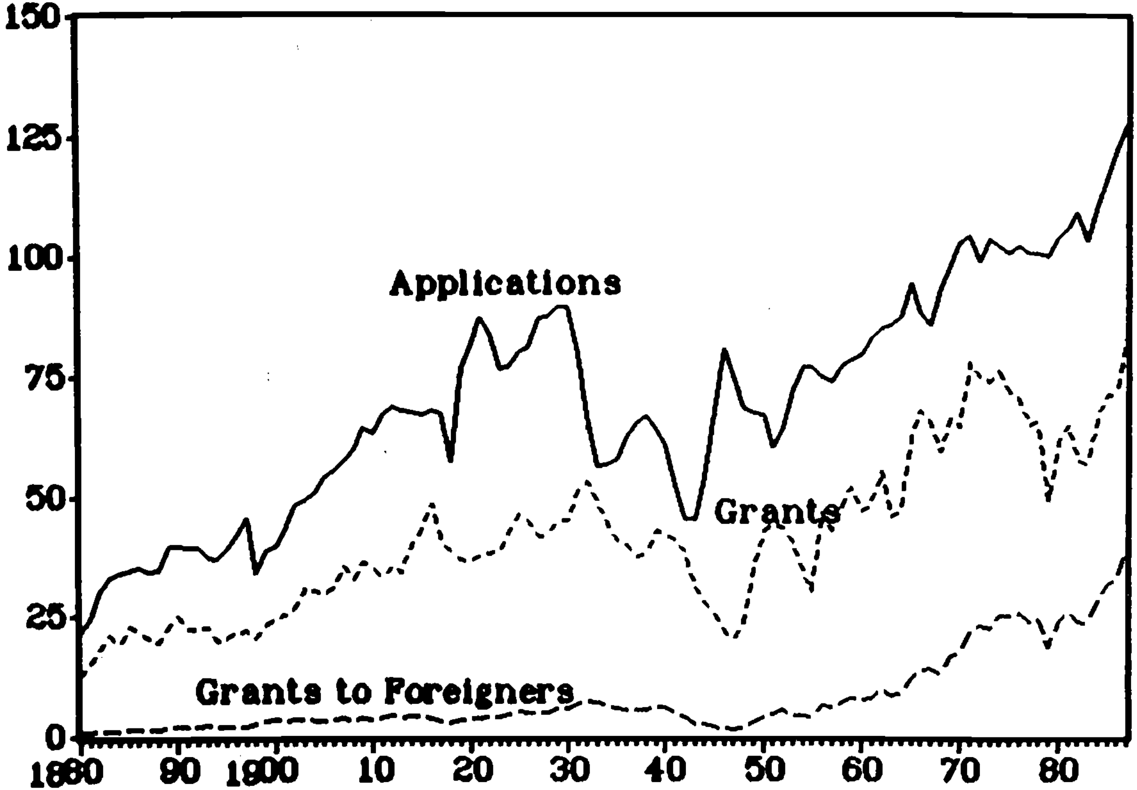
Table 5 (continued)

Sources:

R&D Data: National Science Foundation, National Patterns of Science and Technology Resources, 1986 (NSF 86-309) and Science and Engineering Indicators, 1987.

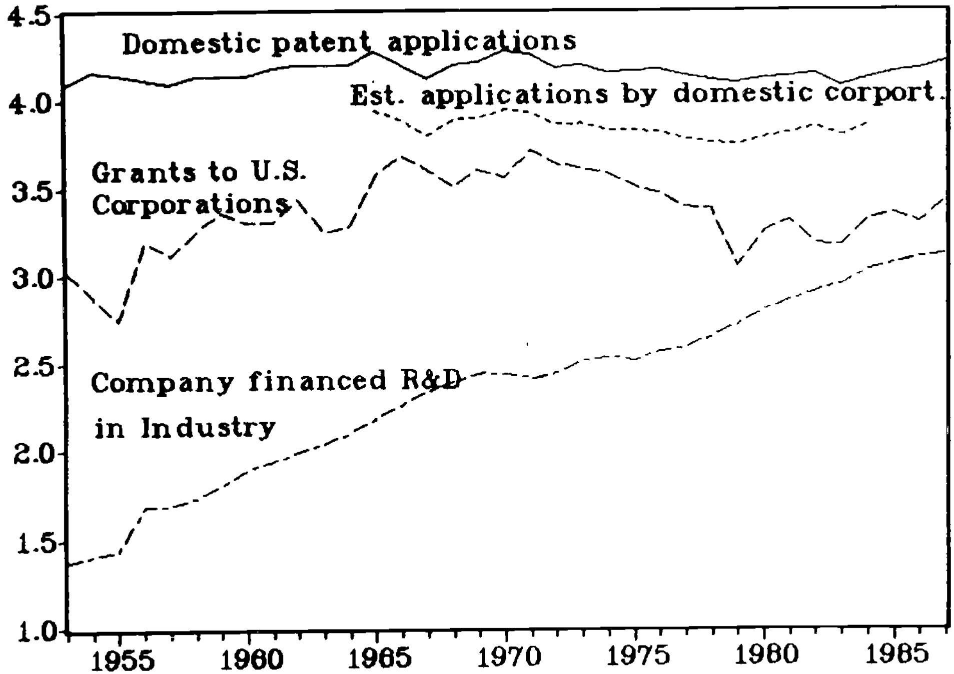
GNP and related data: Before 1929, from U.S. Department of Commerce, Long Term Economic Growth, 1860-1965, October 1966. 1927-87, from Survey of Current Business, September 1987, pp. 56-63 and the 1989 Economic Report of the President.

Figure 1: U.S. Patent Applications and Grants, 1880–1987, in Thousands.




Sources: U.S. Patent Office. See Notes to Table 2.

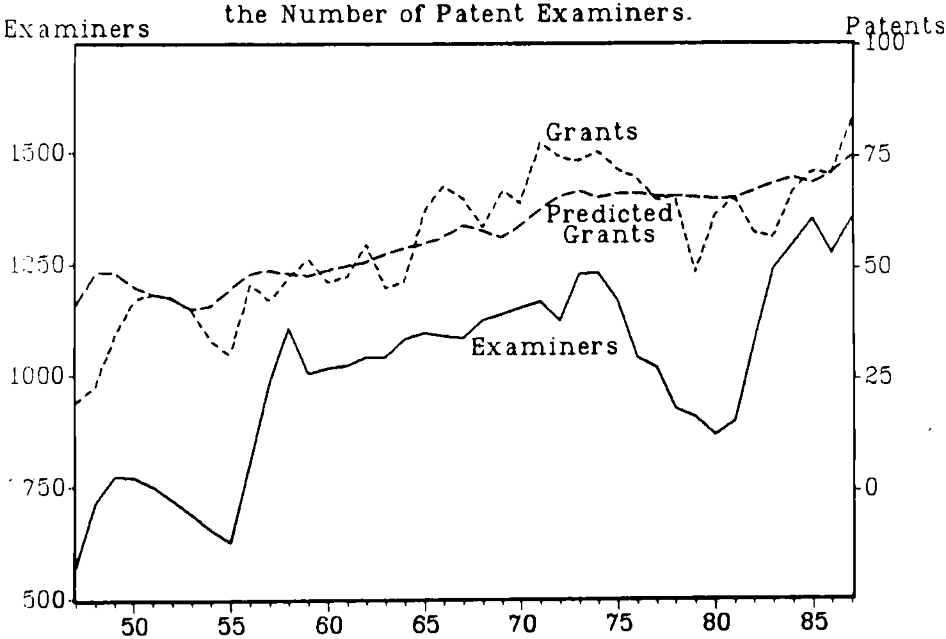
Figure 2: U.S. Domestic Patents and R&D, 1953–87, log scale.




**Est. applications— Corporate grants by date applied inflated by 1/.65, the average application success rate.**

Sources: U.S. Patent Office and NSF. See notes to Tables 2, 4 and 5 for details.

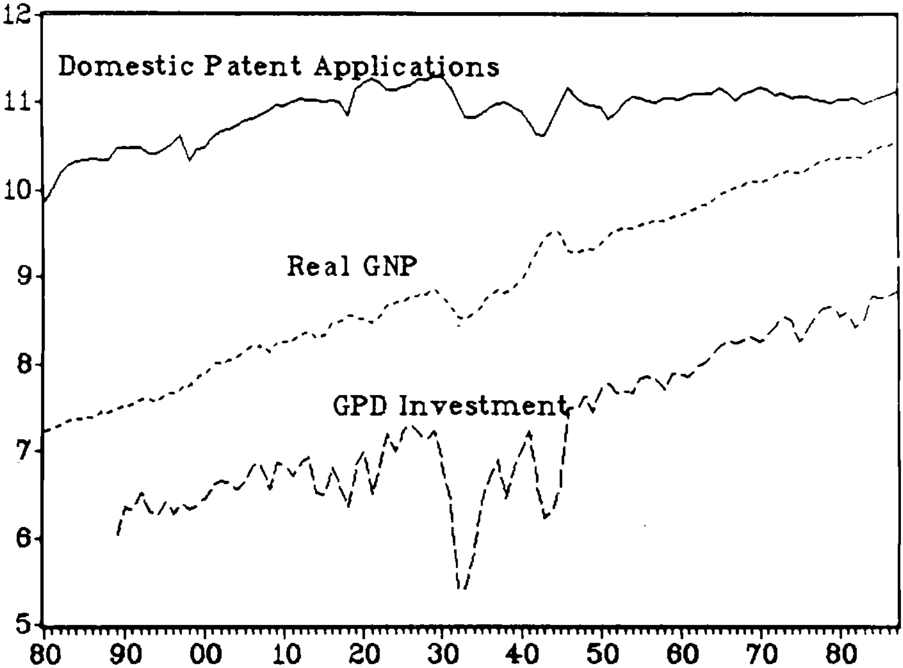
Figure 3: Actual versus Predicted Patent Grants and the Number of Patent Examiners.




**Predicted grants, based on a "fixed" Patent Office policy=** $.65(.1\ APPL_{-1}+.61\ APPL_{-2}+.25\ APPL_{-3}+.04\ APPL_{-4})$

Source: U.S. Patent Office. See notes to Table 2 for detail.

Figure 4: Patent Applications by U.S. Residents and Real GNP and Investment, 1880–1987. Log Scale.




**Domestic applications extrapolated back, before 1940, by the number of total applications.**

Source: U.S. Patent Office and U.S. Department of Commerce. See notes to Tables 2 and 5.

Figure 5a: U.S. Patents by Date Applied, Selected Electronics Firms, 1968–84.

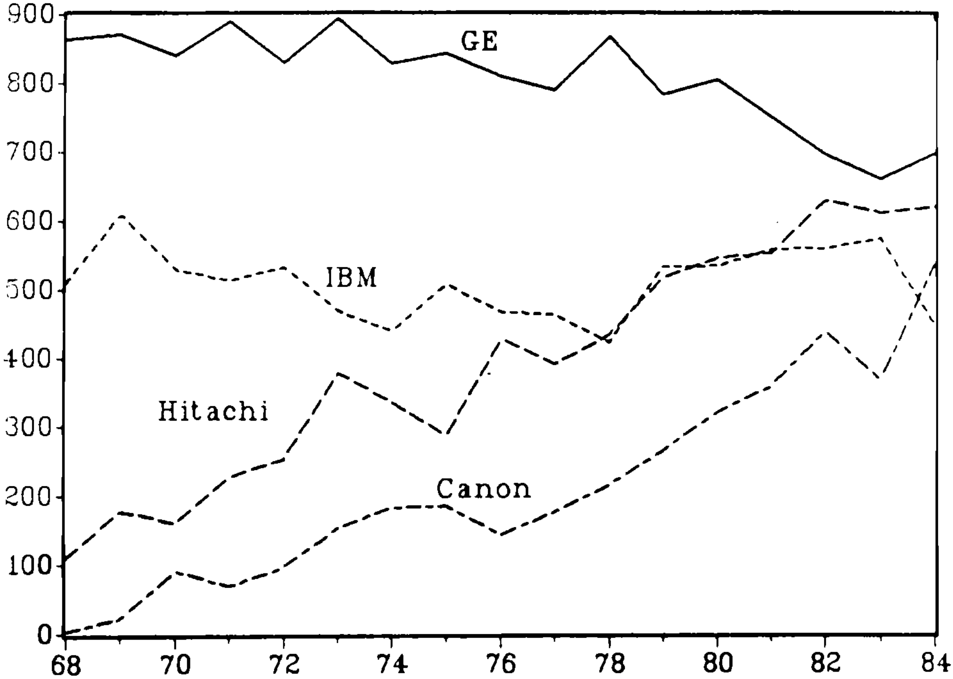


Figure 5b: Selected Chemicals Firms.

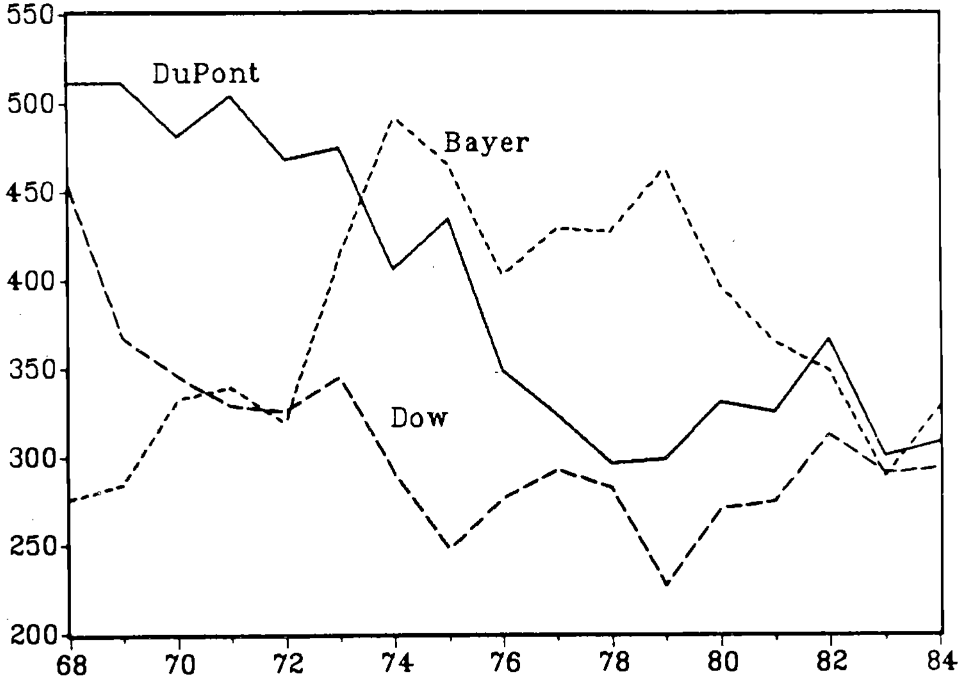
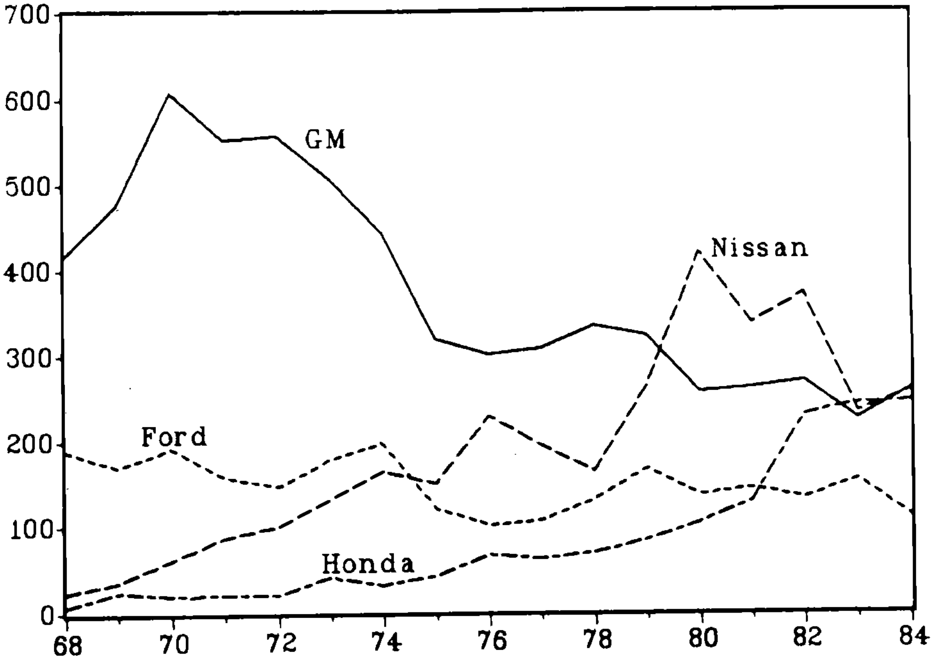
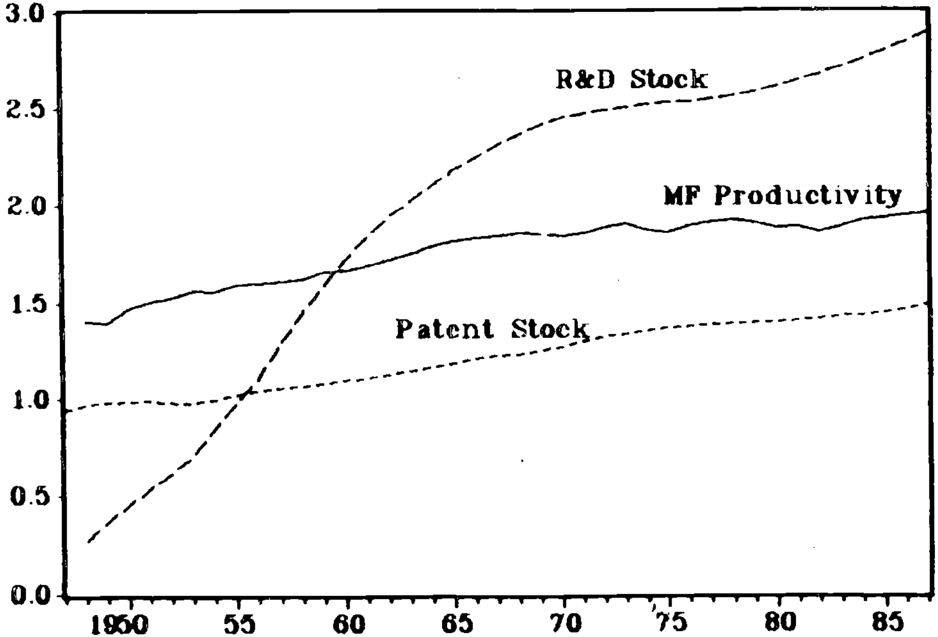


Figure 5c: Selected Automobile Firms.




Source (for 5a, b, and c): Office of Documentation Information, U.S. Patent and Trademark Office, "Patenting by Organizations," March 1988 and earlier releases.

**Figure 6. Multifactor Productivity in the Private Business Economy and Patent and R&D Capital "Stocks". Log Scale.**




R&D and Patent Stocks computed from aggregate data (see Tables 2,4, and 5 for detail) using a 15 percent declining balance depreciation formula and estimated initial conditions. Multifactor Productivity estimates in the Private Business Sector from BLS Multifactor Productivity Measures, 1987, Washington, September 20, 1988.