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7 Long-Run Trends in Patenting

John J. Beggs

7.1 Introduction

By the beginning of the nineteenth century, three countries had firmly established patent systems. In the United States the Constitution gave Congress the power: "To promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries" (Art. 1, Sec. 8[8]). The first patent law was passed in 1790. These laws were motivated by a concern for the justice of protecting intellectual property rights and by economic concerns, such as the need to guarantee sufficient protection from competition to allow profitable development of inventions and the need to encourage the disclosure of new ideas that could form the building blocks for future advances.

This relationship between technological change and industrial development is at the core of the economists' interest in the patent system. However, much compounding of effects makes the statistical analysis of this relationship a difficult one. Essential dynamics are present in the creative process. Single inventions suggest the follow-up direction for future research as well as create preconditions for breakthroughs in other, not obviously related, fields. Industry structure and patenting may be linked in ways that depend on more than the underlying rate of

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The author has benefited from discussions with Derek de Solla Price and Gregory Dow. The author is continuing research with Gregory Dow on the issues raised in section 7.5 of this paper. Thanks are due to Dana Allen, Gary Pissano, John Berlyn, and Peter Fleisher, who sacrificed a summer of their youth to prepare the data that form the basis of this paper. Financial assistance from NSF grant PRA-8019779 is gratefully acknowledged.

technological advance in an industry. For example, firms may create patent portfolios as a direct instrument of competition by "fencing in" technologies, making new entry into their industries more difficult.

Patents are one of the few immediately applicable statistical indicators of technological change. As an itemized list of per period inventions, this statistical series contains a desirable amount of objectivity. The economic worth of individual patents varies greatly, and the interpretation of these data relies on "large-number-type" properties to help ensure that the average worth of a large number of patents is a meaningful quantity. More troublesome are the biases introduced both by changes in the laws and regulations governing patentability of inventions and by the possibility that the economy and particular industries may move through phases where a type of inventive activity is either more or less susceptible to patenting.

This paper first examines, at the industry level, the relationships between the rate of patenting and certain aggregate indicators of industry performance. Section 7.2 discusses the data set that has been prepared to investigate the question. Section 7.3 outlines certain hypotheses about the correlations between rate of patenting and industry performance variables, and section 7.4 reports statistical findings. Section 7.5 considers the dynamics of aggregate patenting and the role of inventions as preconditions for further inventions.

7.2 Data

The source of industry data for this study was the United States Census of Manufactures. The Census of Manufactures was taken as part of the Census of the United States every ten years from 1850 to 1940. The Census of Manufactures was taken separately in 1902, 1914, 1921, 1923, 1925, 1927, 1931, 1935, 1937, 1947, 1954, 1958, 1963, 1967, 1972, and 1977. In all the years when the Census of Manufactures was taken concurrently with the Census of the United States, the data on manufactures were from the year before the official Census year. The data collected included number of establishments, number of workers, average wage, capital expenditures, value added, and value of product.

The data collected from all years are generally comparable, but two changes in the Census of Manufactures could not be backdated. The Census of Manufactures data for number of wage earners include salaried employees in and before 1879 but do not include them after that date. Therefore, the data on number of wage earners and average wage include salaried employees and their salaries in 1879 and all previous years. The data for 1947 and all years thereafter use the classification "production workers" in place of "wage earners." This does not create a large ambiguity in the data, since the two classifications are similar. Both classifications exclude salaried officers, nonworking foremen, and clerical personnel. The 1947 Census of Manufactures states that the two classifications are "closely comparable." Capital data were included in the Census of Manufactures from 1850 until 1919. Data pertaining to capital were not collected after 1919 until 1933 when expenditures on plant and equipment were included.

Some small changes in industry definitions have occurred throughout the period. This generally occurred when a broadly defined industry was split into its component parts by the Census during the later years of this study. Since the earlier years often gave no breakdown of industries, the earlier definition has been used.

Data have been collected from a sample of twenty industries (listed in appendix A). The criteria for including particular industries were primarily associated with the complexity of their technologies. The industries included are chiefly those having more elementary technologies and those for which it is possible to identify the relevant patent statistics. It is important to recognize, for the purposes of later discussion, that the patents classified as belonging to a particular industry represent only a small part of the complex of technologies that must come together before a new industry can progress. For example, a patent for a new design of a sewing machine would appear in our statistics. The whole series of developments in metal alloys and machine tooling, which permitted this new sewing machine patent, would not appear in the data. As the economy has moved into the new electrical, electronics, and chemical technologies, these interdependencies have grown ever more interwoven and more difficult to unravel. For this reason, the data collecting exercise has focused primarily on "old" industries and, for the most part, on the period from 1850 through 1939.

Patent data were collected annually for each industry from published reports of the U.S. Patent Office. The data collecting procedure is described in some detail in appendix B. Patents were identified with industries by using an exhaustive alphabetical index of patents published by the Patent Office. This procedure is not entirely clean because no published (nor, apparently, unpublished) record exists of how patents were indexed. Discussions with retired patent examiners indicate that patents were indexed according to industry of predominant impact, be that either the industry of origin or the industry of use. Unfortunately, there is no entirely untained way to handle this question. Appendix B gives, for comparative purposes, a brief summary of the Schmookler procedures. Schmookler's data do not match the data collected by the Census of Manufactures as well as the new data set does.

7.3 Some Hypotheses

In his classic work *Invention and Economic Growth*, Schmookler asked the question, "Are inventions mainly knowledge-induced or demand-induced?" The up-side effect of demand-induced invention is possibly the easiest and best understood of all the mechanisms for stimulating invention. Here an expansion of the market creates the opportunity for new products, for new investment, and for the replacement of old processes by new. Schmookler (1966) demonstrated the close links at the industry level between investment in plant and equipment and successful patent applications, perhaps nowhere more so than in the well-known example of the railroad industry. An investment series for our sample of industries could not be constructed from the available data. In its place a surrogate was considered, namely wage expenditures as a percentage of value added. The wage bill would seem to fall relative to value added in times of high investment and to rise relative to value added in times of low investment levels. The surrogate suffers from the deficiency of including the effect of changes in the wage rate and changes in the price of final output, but, in the absence of an alternative, it provides a crude indicator of changes in investment. The use of this surrogate is discussed further in section 7.4.

A "down-side" effect of demand-induced invention is also possible.[1] In the event that an existing industry is challenged by the emergence of a new industry, it will likely experience a slump in sales. In the absence of any competitive response, the industry will surely be driven out of existence. The natural reaction to competition should then be an increased and more intensive search for better production processes and better products for the industry. In the time period of our study, industries such as ice making; cotton manufacturers; wool textiles; flax, hemp, and jute; turpentine and rosin; clay products; and the confectionary industry have had to face such challenges. A fall in output caused by some economy-wide decline in output would be met in a different fashion than a fall in output resulting from the encroachment of other industries. For this reason, the relevant measure of changes in output is the change in output relative to the change in, say, gross national product. Such a variable is defined in section 7.4.

The nature of the technological change in an industry will determine how wages move relative to the national average. Labor mobility and the institutional response of organizations, such as trade unions, enter into the adjustment mechanism. Proceeding by example, inventions such as power tools seem to have substantially reduced the skill levels required by the woodcraft artisan, presumably lowering the marginal product of labor and, hence, the real wage in this industry. One can think of converse examples where the initial skill levels were quite low and the introduction of inventions required higher levels of skills, such as the ability to read and write. The phenomena discussed thus far are associ-

1. The term "Indian Summer" is also sometimes used to describe this phenomenon.

ated with changes in the technical skill requirements of the work force. Technological change may also be associated with rapid expansion of the market and increased demand for certain types of skilled labor or for labor in certain geographic localities. In the event of reasonable labor mobility, these fluctuations above or below prevailing average wage levels should soon disappear. In the event of significant productivity gains in strongly unionized industries, labor will possibly be able to negotiate some share of the new surplus above what it might have earned in competitive labor markets.

7.4 Empirical Evidence

The data brought to bear on the above questions are discussed in section 7.2. The variables cover twenty industries and, after expressing the variables in rates of change, there are 363 observations. Where relevant, the variables measure rates of change relative to the national aggregate. This has the effect of purging the data of movements in the macroeconomic aggregates associated with the trade cycle. Variables are expressed in logarithms to give the coefficients an elasticity-type interpretation. The variables are then:

(1) $$X^1_{it} = \log\left[\frac{\text{Patents}_{it}}{\text{Patent}_t} \cdot \frac{\text{Patents}_{t-1}}{\text{Patents}_{it-1}}\right].$$

(2) $$X^2_{it} = \log\left[\frac{\text{Value Added}_{it}}{\text{GNP}_t} \bigg/ \frac{\text{Value Added}_{it-1}}{\text{GNP}_{t-1}}\right].$$

(3) $$X^3_{it} = \log\left[\frac{\text{\# Wage Earners}_{it}\text{*Av. Wage}_{it}}{\text{Value Added}_{it}} \bigg/ \frac{\text{\# Wage Earners}_{it-1}\text{*Av. Wage}_{it-1}}{\text{Value Added}_{it-1}}\right].$$

(4) $$X^4_{it} = \log\left[\frac{\text{Av. Wage}_{it}}{\text{Av. Wage}_t} \bigg/ \frac{\text{Av. Wage}_{it-1}}{\text{Av. Wage}_t}\right].$$

A subscript (i, t) indicates an observation for the ith industry in period t. Patents$_t$ is a variable for all patents issued in the United States for period t. Av. Wage$_t$ is the average wage for production workers in manufacturing and was taken from the individual Census of Manufactures. The number of patents issued in any industry in a given year has a high variance. To help eliminate chance or measurement error influences, the variable Patent $_{it}$ is the average number of patents per year in periods t, $(t-1)$, and $(t-2)$.

Examining movements in an industry series relative to movements in the national aggregate of the series is a particularly tough test of the theory. One difficulty is that the national aggregate may not be the most meaningful yardstick against which to measure performance. An industry's performance could be compared to industries of like technical characteristics (either on the product or the process side) or to industries facing similar amounts of foreign competition or located in similar geographic regions. The development of such peformance criteria is not an easy task either conceptually or as a matter of data preparation. Taken in conjunction with the difficulties in defining industry boundaries, a considerable amount of measurement error must be supposed in the data.

Interpreting the direction of causation among the above variables is difficult. The data are not particularly rich in time series, having on average only thirteen observations per industry. Furthermore, the time series data do not correspond to equally spaced time intervals. The period of time between Census of Manufactures varies from two years to ten years, and the data for each industry do not correspond to the same period of time. Some series commence earlier than others and some end earlier.

A series of two variable regressions were run and the results are reported in table 7.1. Statistical linkages appear to exist between the rate of patenting and the rate of growth of value added, and between the rate of patenting and the rate of change in the wage bill expressed as a proportion of value added. In both cases the coefficients on the regressions are negative. The wage rate variable does not appear to be correlated with the rate of change of invention in this data set. As was discussed in section 7.3, the wage bill as a percentage of value added will be taken as an inverse surrrogate for the rate of investment. Schmookler (1966, pp. 151–62) used a cruder surrogate for investment, namely, value added itself. Though our variable x^3 is far from a perfect surrogate for investment, it should represent an improvement over Schmookler's use of simple value added in that it corrects for the cost of labor. The results in

Table 7.1 Single Variable Regressions: Patenting and Industry Characteristics

(1) $X^1_{it} = -\ 0.113\ X^2_{it}$ (.031)	$R^2 = 0.035$
(2) $X^1_{it} = -\ 0.121\ X^3_{it}$ (0.041)	$R^2 = 0.042$
(3) $X^1_{it} = -\ 0.165\ X^4_{it}$ (0.192)	$R^2 = 0.015$
Degrees of freedom = 362	

Note: Intercept terms are insignficant as expected from the definition of the variables which effectively centers the regression around the origin. Measurement error will bias both the coefficients and the R^2 statistic toward zero.

equation (3) indicate that there is not an apparent link between wages and invention, giving us more confidence that movement in the variable x^3 is being driven more by investment than changes in the cost of labor. Since x^3 is an inverse surrogate for investment, equation (2) has the correct sign and supports the investment-demand-induced explanation of patenting, namely, that many new inventions are embodied in new capital equipment. While this result is in good congruence with Schmookler (1966), the theory has been put to a far more rigorous test. By defining variables in terms of rates of change *relative* to the national aggregates, one avoids the possibility of spurious relationships which might emerge as all the indicator series move together up and down the trade cycle. Since those regressions are "with-in" regressions, the relatively low value of the R^2 statistic is to be expected. Before leaving this equation, the possibility remains that the causal direction is the reverse of that discussed above. It is again useful to reflect on the nature of the patent "statistic." Patents do not measure technological change, though they are a manifestation that some change is taking place. Patents which represent *major* technological breakthroughs may well lead to growth in industrial investment.[2] But such patents are only a small percentage of total patents issued in an industry in a given year. The great bulk of patents are for inventions which represent incrementally small advances in knowledge. Such patents are for minor modifications, often of such devices as locks, switches, hinges, metal cutting devices, tools, etc. Arguably, these small inventions are less likely to explain movements in industry investment.

Of considerable interest are the results in equation (1) where there is a negative relationship between the *relative rate of patenting* and the *relative rate of growth of value added*. This result is different from the Schmookler results, which used level of value added as a surrogate for investment and found a positive relationship between the level variables of value added and patenting. The reason for the apparent differences in the results is that the equations are testing for *different effects*. Schmook-

2. Often these breakthroughs came very early in the sample period for the industries being studied. For example, Goodyear purchased the patent for sulphur vulcanization of rubber in 1839; most of the ideas and patents on synthetic rubber were available by 1910 (by 1939 synthetics were still less than 2 percent of the market); the ammonia absorption system for icemaking and refrigeration was patented in 1862; plate glass was first manufactured in 1852; the electric typewriter was patented by Edison in 1872; Singer patented a sewing machine in 1851 with a straight needle, stationary hanging arm, fed by roughened wheel, material held in place by presser foot beside the needle (in subsequent years, there have been as many as three hundred patents per year on sewing machines, each a small variation on an established idea); Ivory soap, special characteristics being that it was white and would float, was manufactured in 1879; first friction match was patented in 1827, and the safety match was patented in 1855; the first battery clock was patented in 1840, the self-winding watch in 1924, and the Quartz crystal clock in 1927; chocolate was invented in Switzerland in 1872, and the first packaging for national distribution of a confectionary was in 1872, when Mr. Cracker Jack (real name) launched his famous popcorn product; other technologies, such as iron, steel, and sugar refining, were well established by the 1880s.

ler's (1966, pp. 160–61) results[3] are across industry regressions with a trend variable included. Industries with large value added have larger numbers of patents per year, so there is considerable regression on the scale of the industry. Also there is possible synchronous behavior of the series through the trade cycle. The proposition being tested in equation (1) is somewhat more subtle. The question is how an industry behaves as it goes faster or slower *relative* to the other industries about it. The evidence in equation (1) is that when industries do well relative to other industries about them, they slacken their rate of patenting relative to all other industries. This would be consistent with the Kamien and Schwartz (1978) argument that, in the absence of a financial constraint, individual firms experiencing high profits will be less likely to innovate, since such innovation serves to cannibalize existing profitable market positions. Conversely, if an industry goes more slowly relative to its neighbors, it responds by quickening the rate of invention. In periods of severe competitive pressure, brought on by the encroachment of other industries onto its turf, firms may respond by quickening the tempo of their inventive efforts. Under such circumstances, there may be an undue increase in the "number" of patents if the patents are the type which attempt to modify and upgrade an existing capital stock or an existing product. Such patents will be small, low-value patents but could, given the nature of the activity, be very numerous. Inventions are made by firms and by individuals rather than by an "industry," and the extent of competitive pressures will surely change from industry to industry. However, to the extent that the fortunes of firms in an industry are tied to one another, it seems that those pressures will, in general, be greater when an industry is faring less well relative to other industries.[4]

7.5 Inventions and Further Inventions

Though invention is undoubtedly a response to market opportunities (and hence an economic phenomenon), the direction and pace of invention may well depend on previous inventions. Previous inventions may establish the necessary technological preconditions for the development of some new product or process as well as shape tastes and preferences for the developments which should follow.

The history of patenting seems to have been a complicated one, and the process of sorting out persistence effects from changing underlying trends is not easily accomplished. The longest published series of patent statis-

3. Similar results were found in the current data series; they are not reported here as they are almost an exact replication of Schmookler's findings.

4. Results similar to the above results are also reported in Beggs (1981) where the data are again industry level, but for the period 1953–78. In that paper, a short-run negative relationship is found between the growth rate of R & D expenditures and the growth rate of industry profits.

tics for the United States is for patents "issued," which runs continuously from 1790 to the present. A shorter published series is available on patent "applications," commencing some fifty years later. To study these series and their time series behavior, it is necessary to evoke types of detrending procedures. This is, at best, a hazardous undertaking (Nelson and Kang 1981), and almost all procedures attempted for these particular series result in a residual series exhibiting a long swing. While it remains possible that such long swings exist in the data, it is sufficiently easy to artificially create such cyclical behavior by incorrect detrending that this result cannot be taken seriously without much further investigation.

One detrending procedure which does not induce long swings in the data is a transformation to rate of change of patenting, that is, $(P_t - P_{t-1}/P_{t-1})$. Some interesting results are reported below when this detrending procedure is applied to patents "issued," a series of 190 observations. A word of warning at the outset, though: The results reported here are not robust to segmentation of the data set and do not apply to the shorter time series on patent "applications." It is certainly true that the signal-to-noise ratio in these series is very high and it appears that reductions in sample size are not well accommodated. More seriously, of course, one must recognize the possibility that the results reported are merely a sampling artifact of one particular sample series. In subsequent research, when the question of detrending has been considered in greater depth, it will be necessary to reconcile any differences in the time series behavior of the patents "issued" series and the patent "applications" series. The patent "applications" series contains noise and related effects associated with changes in the general desire to patent inventions (either for economic reasons or whimsical social reasons). The patents "issued" series is a more seriously compiled series in that each patent issued has passed some rigorous technical examination of its merit. On the debit side, however, various forms of bureaucratic inertia may induce artificial cycles in this series. These questions do not arise immediately here since statistically meaningful results appear to be found only in the 1790–1980 period patents-"issued" series.

The smoothed periodogram for the rate of change of patents issued series is shown in figure 7.1. The shape of the periodogram suggests a process with a five-period lag and with a small coefficient (i.e., the periodogram is rounded rather than spiked). An autoregressive process with a five-period lag was fitted to the data and the residuals were examined. The periodogram of the residuals suggested an eight-period lag. The model finally fitted to the data was a moving average process, where y_t is the rate of growth of patents issued per year.

$$y_t = \epsilon_t + \underset{(0.030)}{0.264}\epsilon_{t-5} + \underset{(0.011)}{0.071}\epsilon_{t-8}. \quad (5)$$

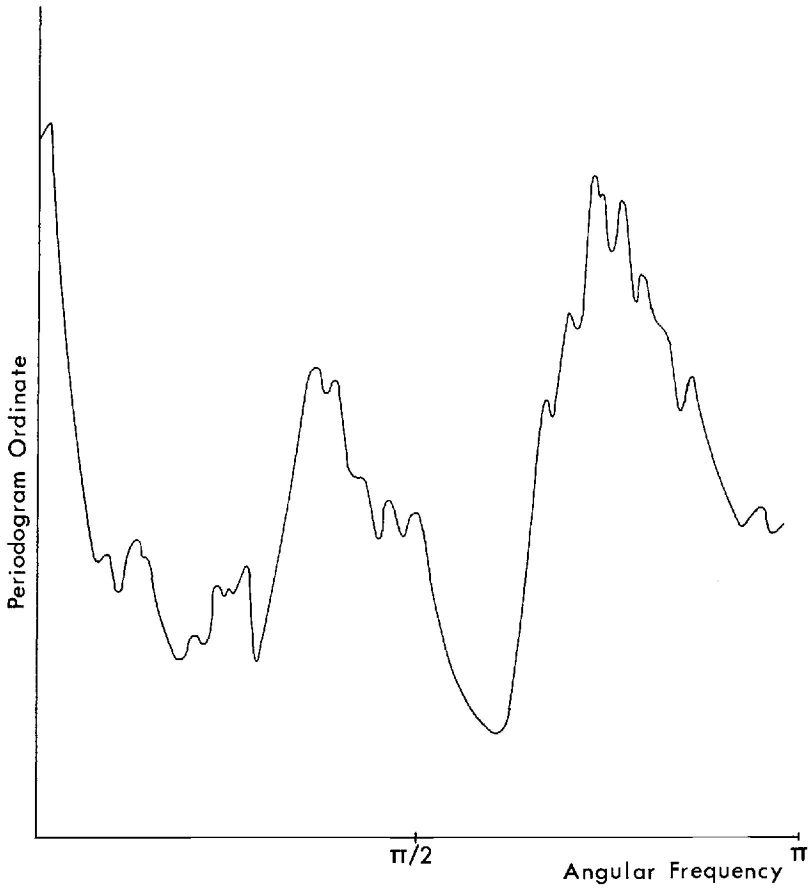

Fig. 7.1 Smoothed periodogram: annual rate of change of aggregate U.S. patents issued, 1790–1980.

Asymptotic estimates of the standard errors are shown in parentheses. The theoretical spectrum for the estimated moving average process is shown in figure 7.2. Visual inspection indicates good conformity between the periodogram and the estimated spectrum. There are two-and-one-half waves in both (caused by the fifth-order lag term), and the peaks and troughs are the correct relative magnitude (caused by the eighth-order lag term).

The initial five-year lag from patent invention to patent invention is the result of time taken to understand and develop the original patent and to then understand and produce the appropriate follow-up invention. Since these are national aggregate patents, one might expect longer lags than if one simply studied a patent series within a single industry. Inventions in

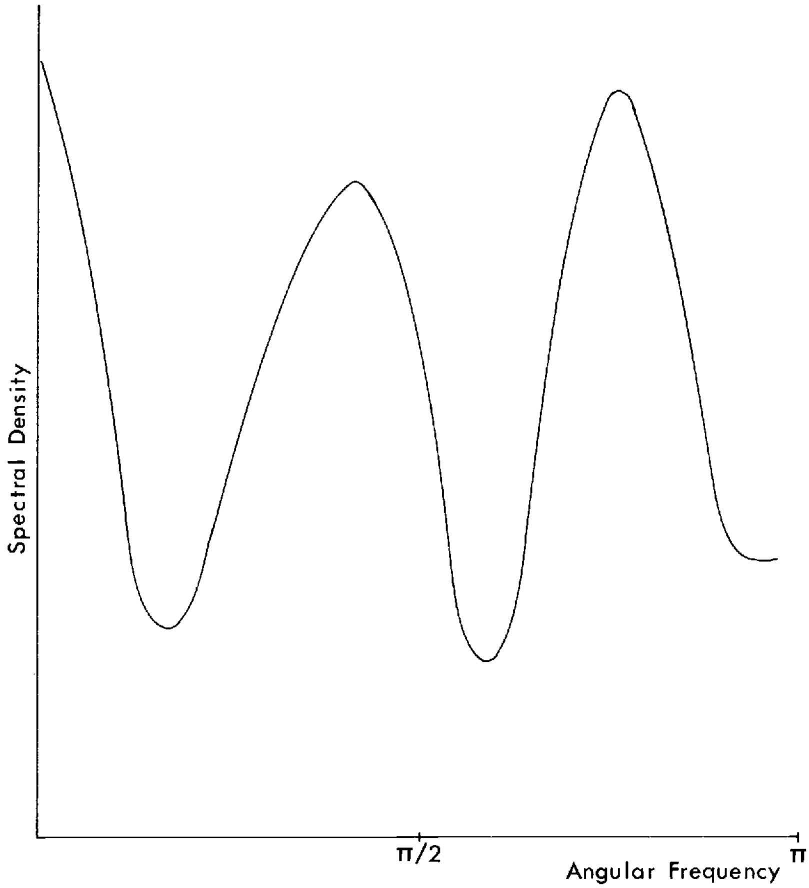

Fig. 7.2 Theoretical spectral density function for moving average process given in equation (5).

one industry may lead to follow-up inventions in other industries, but the transmission process will be slower. For example, a patent issued for a semiconductor invention may be associated with a rapid follow-up patent in semiconductors, but the follow-up patent in, say, automated tool cutting will occur much later. Also, since the data cover the period from 1790, much of the sample is from an era when information transmission mechanisms were much less sophisticated than today, so the intuition of everyday experience in 1981 may not be particularly relevant to most of the sample.

A burst of patents in period t leads to follow-up patents in period $(t + 5)$, hence it is reasonable to expect further follow-up patents some period later. The lags associated with this second round of follow-up patents are likely to be shorter than the first round because there has been a period of growing awareness and experience of the new technology. The data indicate a reduction in the lag from five to three years. The magnitude of the coefficient on the second round should have a magnitude on the order of the first coefficient squared, $(0.264)^2$. This gives a value of 0.0696, which is remarkably close to the estimated coefficient of (0.071). The magnitude of third round follow-ups will likely be on the order of $(0.264)^3$ and, hence, too small to be estimated from the available data set. The actual magnitudes of the coefficients seem to fall within a reasonable range. A 1 percent increase in patents in period t leads to a subsequent 0.33 percent increase in patents over the next eight years (this is a rough calculation because of the nonlinearity introduced by the compounding rates of growth), which is on average 4 percent of a patent per year. This is quite close to the average rate of growth of patents issued per year over the entire sample period, which is about 5 percent. We conclude that though the model in equation (5) is not statistically robust, it is particularly rich in interpretation and, hence, of interest in guiding future research on this topic.[5]

7.6 Conclusions

The history of the links between technological change and economic progress can yield a deeper understanding of the mechanism driving our modern economy. The results reported here are conditional on the nature of the sample data employed and are very much affected by measurement errors and changes through time in institutional structures. The results are, however, amenable to interesting interpretations, and do indicate the direction for future research, both in the collection of better data and in the formulation of more exacting tests of our models.

5. I have benefited from discussions with Derek de Solla Price about the interpretation of these results.

Appendix A

Industries Included in Data

1. Pulp and paper
2. Rubber tires
3. Ice making
4. Iron and steel
5. Glass
6. Salt
7. Meat packing
8. Cotton manufacture
9. Wool
10. Flax, hemp, and jute
11. Sewing machines
12. Tobacco
13. Turpentine and rosin
14. Soap
15. Clay (including bricks)
16. Chocolate candy
17. Sugar
18. Matches
19. Watches
20. Typewriters

Appendix B
Procedures for Collecting Patent Data

Published Patent Statistics

With its founding in 1830, the U.S. Patent Office began publishing an "Annual Report of the Commissioner of Patents." This volume listed the patents issued each year under one of sixteen headings. Also included was a detailed description of each invention. By 1871 there were 145 such subheadings. In 1871 the "Official Gazette of the Patent Office" and an accompanying index replaced the annual report. The descriptions of inventions were published in a monthly magazine and the alphabetical index directed the reader to the relevant monthly volume. In 1898 the Patent Office modified the method of classification to distinguish three categories of patents: (i) method or process, (ii) function, and (iii) structure. In 1954 the Patent Office ceased publishing the alphabetical index to inventions. At this time a strictly numerical classification system was adopted. The procedure for linking patents to industries was as follows:

(a) Find desired industry in the "Index of Classification."

(b) Record headings and subheadings and obtain one-line description of headings.
(c) Check the current "Classification Bulletins" to insure that pertinent patent groups had not been reclassified during the year.
(d) Examine the technical "Definitions of the Subclasses" (a volume several thousand pages long) to determine whether subheadings are pertinent to industry.
(e) Use the "Index to the Gazette" and find patent numbers issued that year in the appropriate subheading.
(f) Finally turn to the "Official Gazette" and monthly "Volumes of Patents" to find descriptive information on the invention.

Collecting the Patent Data

The same procedure was used to obtain a patent series for each of the twenty industries. The only variation in the reports is the number of years covered. The patent series begins for each industry ten years before the Census of Manufactures commenced publishing data for that industry. The patent series continues either until Census figures were no longer available or until 1953. After 1953 the Patent Office began using a classification system which makes obtaining an accurate count difficult.

For each year the patents listed in the index under the name of industry and under related headings were counted. Each patent title was examined to determine whether it had a meaningful bearing on the industry under consideration.

Notes on Schmookler Patent Data

The patents in Schmookler's (1972) study were counted according to the date of application between 1874 and 1950. Data are given on a "when issued" basis for the years 1837–76 and 1947–57. Schmookler's study covers "*capital goods inventions* classified according to the industry expected to use them." Schmookler assigned Patent Office subclasses to standard industrial class (SIC) industries. The Patent Office classification system is based on technological-functional not industrial principles, so Schmookler had to "convert from the Patent Office classification system to the industrial classification." If an entire subclass seemed to apply to an industry, he automatically included it. Otherwise, he took a sampling, and if two-thirds of the patents seemed to belong, he included the entire subclass. Once Schmookler determined the subclasses to be included, the Patent Office counted the number of patents granted per year in each class between 1836–1957.

The interindustry features of many inventions were also addressed in the data set. If Schmookler could not determine which industry to assign a patent to, or if an invention could be used in many industries, the patent was simply disregarded. Hence, he did not include steam engines with railroad data or tractors with farm data.

Along these lines, some uncertainty arises as to whether Schmookler grouped the patents according to industry of origin or industry of use. One quote indicates that "the inventions were to be assigned to the current main producing *or* using industry." However, it was also stressed that patents be assigned to "the industry expected to use them." In some cases, patents were included twice, once in the "using" industry and once in the "manufacturing" industry.

Schmookler breaks down broad industrial classifications, like "agriculture," into activity types, like "harvesting," and finally into commodity groups, like "plows." Patent Office subclasses are assigned to commodity groups from which the data time series is constructed.

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Comment Mark Schankerman

In his seminal work, Schmookler (1966) attempted to demonstrate the importance of demand as a determinant of inventive activity. The basic idea behind demand inducement is that the monetary returns to a given

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The author benefited from discussions with John Beggs on the contents and interpretation of his paper. The author retains responsibility for the views expressed here.

piece of produced knowledge vary directly with the number of output units which embody the new knowledge, or the expected size of the market. Given the cost of producing the new knowledge, it follows that the profit-maximizing level of inventive activity should vary directly with expected market size.[1] As one leading test of the hypothesis, Schmookler organized a time series of patents on capital goods inventions according to the industry in which the invention is primarily used[2] and performed log-linear regressions of patents against value added in the industry of use. As we all know, the empirical results indicated a rough proportionality between patents and value added and strongly supported the demand-inducement hypothesis.

As Schmookler emphasized, the appropriate scheme for assigning patents to industries depends on the purpose of the analysis. For example, if one were interested in relating patents as an indicator of inventive output to some measure of inventive input, such as R & D expenditures, patents should be assigned to the industry of origin where the R & D is spent to produce them. To study demand inducement, however, one should assign patents to the industry of use and then correlate them with the level of demand for the products which embody (or which are produced with the process which embodies) the patents. The proper measure of demand depends on the type of patents under study. For capital goods patents the level of investment in the industry of use is appropriate (Schmookler 1966, chaps. 6 and 7), whereas for materials-embodied patents the intermediate purchases by the industry of use is more suitable. For a mixed sample of patents, one can either employ an assignment of patents by industry of use and the level of output in the industry of use, or an assignment by industry of origin and the level of output in the industry of origin.[3]

With these principles in mind, we turn to Beggs's examination of the demand-inducement argument. He constructs patent statistics for the period 1850–1939 and assigns them to one of twenty industries according to the "industry of predominant impact, be that either the industry of origin or the industry of use." This criterion is somewhat ambiguous and may not be entirely suitable for a test of the demand-inducement hypothesis. Beggs indicates that these patent data correlate better than

1. For more detailed theoretical statements of demand inducement, see Nordhaus (1969) and Pakes and Schankerman (this volume, Chap. 9).

2. As Beggs notes, this procedure was not always followed but it does seem to have been the guiding principle. See Schmookler (1972, p. 87–91).

3. Since Schmookler worked only with capital goods inventions, most of his empirical work is based on investment goods demand. To extend the time series coverage backward, he used value added as a proxy. He explored both an industry of use (chap. 7) and an industry of origin (chap. 8) criterion, but used the criterion both for the assignment of patents and the definition of value added.

Schmookler's industry of use patents with other data collected from the Census of Manufactures. It would be useful to know more about the relationship between the two data sets. With what Census data is the comparison made? Are the trends in patenting similar? How are they correlated with each other? With what are the differences correlated?

Because investment data are not available for the entire sample period, Beggs tests the demand-inducement hypothesis by regressing the rate of growth of patents against the labor share in value added as a proxy for investment, on the heuristic argument that this proxy should vary inversely with the level of investment. (Actually, the variables are defined relative to the corresponding aggregate variables, but this is immaterial for our discussion.) I do not see how such a result can be derived from any familiar model of investment, and I am therefore skeptical of this proxy. In any event, since Beggs's sample of patents is expressly not limited to capital goods inventions, it would seem more appropriate to measure demand by the level of output or value added in the industry of "predominant impact," which is available for the entire sample period.

Beggs does use value added data, but to test the different and interesting hypothesis that an industry's patenting activity depends directly on the degree of competitive encroachment by other industries. Beggs tests this hypothesis by regressing the relative rate of growth of patents assigned to an industry (relative to the growth of total patents) against the relative rate of growth in value added, on the argument that the correlation should be positive if the hypothesis is true. He obtains a positive correlation, but I do not find this evidence very convincing because I think that the assignment of patents by "predominant impact" is inadequate to test the hypothesis. The essence of the proposition is that an industry's patenting activity in particular markets is related to the competition it faces from other industries in those markets. The hypothesis says nothing (directly at least) about the total level of patenting for use in a given industry, which would seem to depend on the strength rather than just the existence of such an effect. I think that to test this hypothesis one needs a two-way classification scheme, by industry of use (or predominant impact) and by industry of origin. For example, one might test whether the number of patents produced by industry i for use in industry j is related to the number of patents produced by all other industries for use in industry j. I do not think that any one-way classification scheme for patents is adequate to test the competitive encroachment hypothesis as presently formulated.

While Beggs correctly emphasizes that this hypothesis is different from demand inducement, his empirical finding does appear to contradict Schmookler's results on demand inducement. Beggs's regression of the relative rate of growth of patents in an industry against the relative rate of growth in value added is essentially the same as adding time dummies to Schmookler's log-linear regression of patents against value added. Yet when Schmookler included a time trend in his regressions, the results remained essentially unchanged. Does the dramatic difference in findings simply reflect time effects which are so poorly approximated by a time trend? This apparent empirical contradiction is worth exploring.

Beggs also reports some interesting findings from a long time series of patents issued, extending from 1790–1980. His remarks on the nonrobustness of the results to data segmentation and to the use of patent applications instead of patents issued should be kept in mind, but I want to focus on the interpretation of his findings. Beggs finds that the rate of patenting is well approximated by a moving average scheme with fifth- and eighth-order lags, and he interprets the result as reflecting a first and second round of information transmission, according to which a burst of patents induces subsequent patenting once the technological information has a chance to diffuse. This idea has some kinship to the innovation business cycle theory advanced by Schumpeter a long time ago. The hypothesis is worth pursuing and may explain patterns of patenting for specific classes of patents, but I find it hard to believe that this can rationalize spikes in the spectrum of the rate of patenting in aggregate data. If there is any distribution across patents in the time it takes for their technological information to diffuse (and surely there is), I would expect the spectrum of the aggregate patent series to exhibit more smoothness. I would like to suggest an alternative (perhaps complementary) explanation. If demand inducement is what moves patenting activity, then the (detrended) aggregate time series of the rate of patenting should reflect cyclical movements in aggregate output (presumably with some lag).[4] Hence, I would like to see the cross spectrum between the rate of patenting and the rate of growth of aggregate output. Using this information, one could deduce the coefficients in the (possibly two-sided) lag distribution connecting patenting and output, and bivariate exogeneity tests on the two series could be conducted. Disentangling the effects of demand inducement from information diffusion remains an interesting and important research challenge.

References

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4. The underlying model I have in mind consists of a behavioral link between R & D activities and expected output, an expectational link between expected output and past output, and a production function relation between patents and past research activity. This would translate into a reduced form relation between patents and past output, and possibly between output and past patents.

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