NBER WORKING PAPER SERIES

LONG RUN TRENDS IN PATENTING

John J. Beggs

Working Paper No. 952

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

August 1982

This paper was presented at the Conference on R&D, Patents and Productivity, Lenox, Massachusetts, October 2-4, 1981. The research reported here is part of the NBER's research program in Productivity. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

NBER Working Paper #952
August 1982

LONG RUN TRENDS IN PATENTING

ABSTRACT

This paper examines the patenting in the U.S. from its origins in 1790 up to 1980. The prime intent was to identify relationships between patenting and the rate of industrial development, and to further look for any regular cyclical patterns in the time series of patents themselves.

To this end, detailed records were gathered on annual patenting, along with key descriptive data on industry structure for a sample of twenty industries for the period 1850 through 1940. In general the correlations between changes in the rate of patenting and changes in industry characteristics are small. A tentative conclusion is that the rate of change in patenting may move inversely with the rate of change in value added. This leads the author to speculate on a "defensive R&D hypothesis" which may reflect strongly the choice of sample industries. The industries in the study were in existence in 1850 and managed to ward off challenges from other new industries so as to still be in existence in 1940. At each new challenge from a new product or a foreign competitor these industries have attempted to protect their existing capital stock by upgrading the production process and final product. While these changes do not normally represent major technological advances they are of a "tinkering" variety which are likely to produce large numbers of patents.

A spectral analysis of the 190 year time series of patents issued suggests that the rate of change of this variable might be characterized as a moving average process with lags at five and eight years. An interpretation of this result is offered, along with caution against over interpretation.

Professor John Beggs (203) 423-4098
Department of Economics/Cowles Foundation
2125 Yale Station
Yale University
New Haven, CT 06520

LONG RUN TRENDS IN PATENTING

INTRODUCTION

By the beginning of the 19th century three of the important countries of the world 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 rights to their respective writings and discoveries" (Art. 1, Sec. 8(8)). Thefirst patent law was so passed in 1790. These laws were motivated by 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 which 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, there is much compounding of effects which 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 creating pre-conditions for break-throughs in other not obviously related fields. Industry structure and patenting may be linked in ways which depend on more than the underlying rate of technological advance in an industry. Firms may create patent portfolios as a direct instrument of competition, for example, by "fencing-in" technologies in a way which makes new entry into an industry more difficult.

Patents are one of the few immediately applicable statistical indicators of technological change. As an itemized list of per period inventions, there is a desirable amount of objectivity in the statistical series. The economic worth of individual patents varies greatly, and the intepretation of this 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 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 the type of inventive activity is more or is less susceptible to patenting.

This paper proceeds first to examine, at the industry level, the relationships between the rate of patenting and certain aggregate indicators of industry performance. Section 2 discusses the data set which has been prepared to investigate the question. Section 3 outlines certain hypotheses about the correlations between rate of patenting and industry performance variables, and then goes on to report statistical findings. Section 4 considers the dynamics of aggregate patenting and the role of inventions as preconditions to further inventions.

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 10 years from 1850 to 1940. The Census of Manufactures was taken separately in 1902, 1914, 1921, 1923, 1925, 1927, 1931, 1933, 1935, 1937, 1947, 1954, 1958, 1963, 1967, 1972, and 1977. In all years in which the Census of Manufactures was taken concurrently with the Census of the United States, the data on manufactures was 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 is generally comparable, but there were two changes in the Census of Manufactures which could not be back-dated. The Census of Manufactures data for number of wage-earners includes salaried employees in and before the year 1879 and does not include them after that date. Therefore, the data on number of wage-earners and average wage includes salaried employees and their salaries in 1879 and all previous years. The data for 1947 and all years thereafter uses the classification "production workers" in place of "wage-earners." This does not create a large ambiguity in the data, since the two classifications are very similar. Both classifications exclude salaried officers, non-working foremen, and clerical personnel. The 1947 Census of Manufactures states that the two classifications are "closely comparable." Capital data was included in the Censusof Manufactures from 1850 until 1919. Data pertaining to capital was not collected from 1919 until1933 when expenditure on plant and equipment was taken.

In some cases, there have been small changes in industry definitions 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 would be used.

Data has been collected for a sample of twenty industries which are listed in Appendix I. The criteria for including particular industries were primarily associated with the complexity of the technology. The industries were chiefly those having more elementary technologies and industries for which it would be 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 which 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 focused primarily on "old" industries and for the most part on the period 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 II. Patents were identified with industries by making use of an exhaustive alphabetical index of patents published by the

Patent Office. This procedure is not entirely clean because no published (or apparently unpublished) record exists of how patents were indexed. Discussions with retired patent examiners seems to indicate that patents were indexed according to industry of predominant impact, be that either the industry of origin of the patent or the industry of use. Unfortunately, there is no entirely untainted way to handle this question. Appendix II gives, for comparative purposes, a brief summary of the Schmookler procedures. Schmookler's data does not match as well as the new data set with data collected by the Census of Manufactures.

3(a). SOME HYPOTHESES

In his classic work "Invention and EconomicGrowth," Schmookler asked the question "are inventions mainly inowledge-induced or demand-induced?" The up-side 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 the 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. It would seem that the wage bill would fall relative to value added in times of high investment and rise relative to value added in times of low investment levels.

The surrogate suffers from the deficiency that it includes 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 (3b).

There is also the possibility of a "down-side" effect of demand induced invention.[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 should then be an increased and more intensive search for better productionprocesses 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 due to some economy wide decline in output would be met in a different fashion to a decline 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 below where the results are discussed.

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, it seems that inventions such as power tools substantially reduced the skill levels required by the woodcraft artisan, and presumably lowered 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 associated with changes in the technical skill requirements of workforce. 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, there is the possibility that labor will be able to negotiate some share of the new surplus above that this it might have earned in competitive labor markets.

3(b). EMPIRICAL EVIDENCE

The data brought to bear on the above questions are discussed in Section 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:

$$X^1_{it} = \log \left[\frac{\text{Patents}_{it}}{\text{Patent}_t} \middle/ \frac{\text{Patents}_{t-1}}{\text{Patents}_{it-1}} \right]$$

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

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

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

A subscript (i, t) indicates an observation for the i^{th} industry in period t . Patents_t is a variable for all patents issued in the U. S. 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 difficiulty 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 on the process side), or could be compared to industries facing similar amounts of foreign competition or located in similar geographic regions. The development of such performance 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, it must be supposed that there is a considerable amount of measurement error in the data.

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

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 3a, the wage bill as a percentage of value added will be taken as an inverse surrogate for the rate of investment. Schmookler (1966, pp. 151-162) 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 equation (3) indicate

TABLE 1

Single Variable Regressions
Patenting and Industry Characteristics

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

Degrees of freedom = 362

Note that intercept terms are insignificant. This is to be 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 towards zero.

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 a new capital equipment. While this result is in good congruence with Schmookler's earlier mentioned work, the theory has been put to a far more rigorour 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, there remains the possibility that the causal direction is the reverse of that discussed above. It is again useful to reflecton 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] The point to be made is that such patents are only a very 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. It can be argued that these small inventions are less likely to explain movements in industry investment.

Of considerable interest are the results in equation (1). Here 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 apparent difference in the results is because the equations are testing for different effects. Schmookler's[3] (1966; pp. 160, 161) results 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. As well, 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 rather 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 up on the 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 into 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 of a 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, but it would seem that, to the extent that the fortunes of firms in an industry are tied to one another, those pressures will, in general, be greater when an industry is faring less well relative to other industries.[4]

4. INVENTIONS AND FURTHER INVENTIONS

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

It seems the history of patenting has indeed been a complicated one, and process of sorting out persistence effects, from changing underlying trends is not easily accomplished. The longest published series of patent statistics for the U. S. 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 envoke types of de-trending procedures. This is always, at best, a hazardous undertaking

(Nelson, Kang, 1981), and almost all procedures attempted for these particluar 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 de-trending, that this result cannot be taken seriously without much further investigation.

One de-trending 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 de-trending 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 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 de-trending has been considered at greater depth, it will be necessary to reconcile any differences in the time series behavior of the patents "issued" series and the patents "applications" series. The patents "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 complied 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. The questions do not arise immediately here since it appears that statistically meaningful results are only to be found in the 190 period patents "issued" series.

The smoothed periodogram for the series of rates of change of patents issued is shown in Figure 1. The shape of the periodogram is suggestive of a process with a five period lag 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.

$$(5) \qquad y_t = \varepsilon_t + \underset{(0.030)}{0.264}\, \varepsilon_{t-5} + \underset{(0.011)}{0.071}\, \varepsilon_{t-8}$$

Asymptotic estimates of the standard errors are shown in parentheses. The theoretical spectrum for the estimated moving average process is shown in Figure 2. Visual inspection indicates that there is good conformity between the periodogram and the estimated spectrum. There are two-and-one-half waves in both (due to fifth order lag term), and the peaks and troughs are the correct relative magnitude (occasioned by the eighth order lage 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 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 semi-conductor invention may be associated with a rapid follow-up patent in semi-conductors, but the follow-up patent in, say, automated tool cutting will occur much later. Also, since the data covers the period from 1790 much of the sample is from an era when information transmission mechanisms were much less sophisticated than today, so that 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 indicates a reduction in the lag from five to three years. The magnitude of the coefficient on the second round should have magnitude of 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 of the order $(0.264)^3$ 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 one percent increase in patents in period t leads to subsequent 0.33 percent of patents over the next eight years (this is a rough calculation because of the non-linearity introduced by the compounding rates of growth),

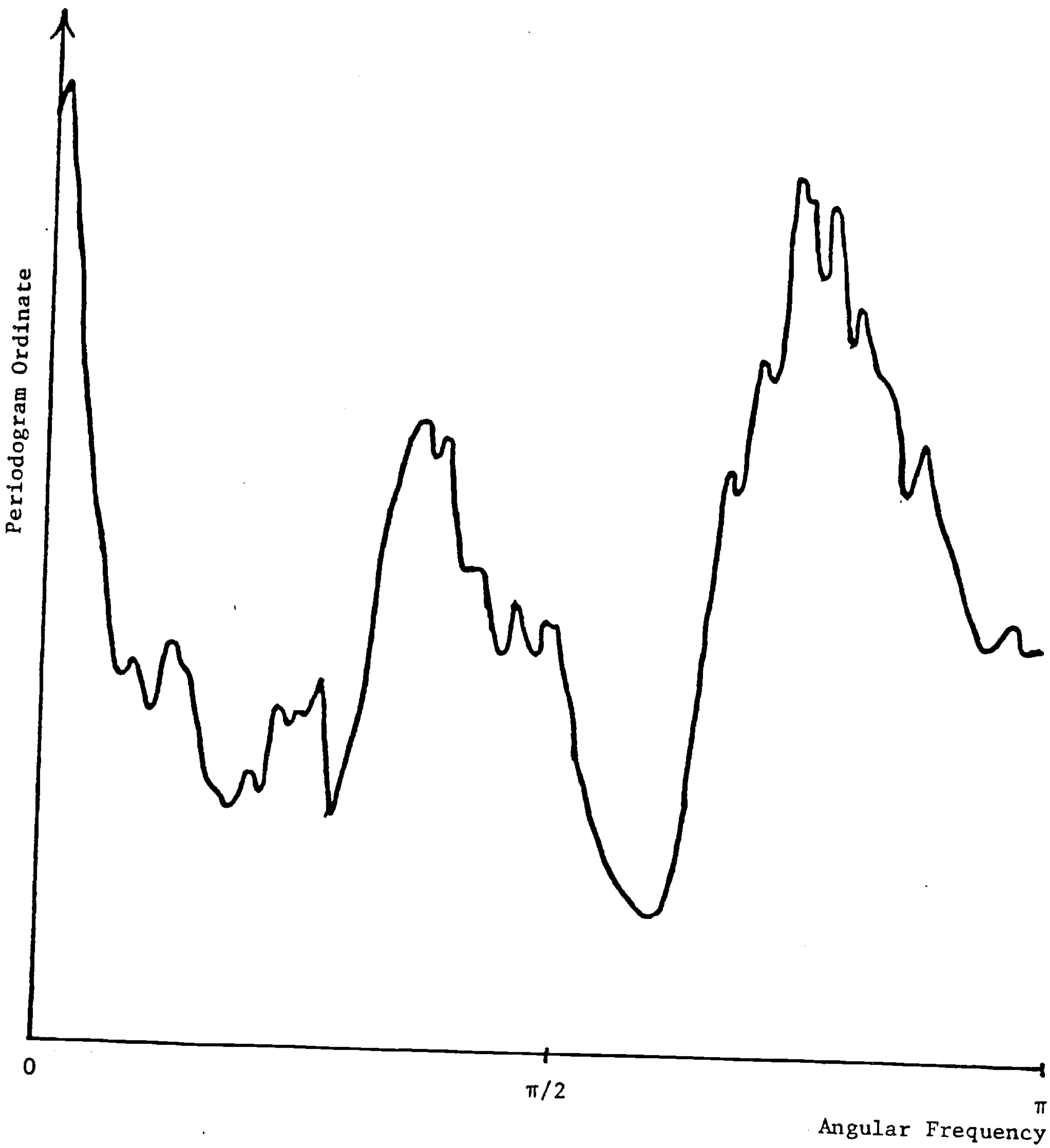

Figure 1: Smoothed Periodogram: Annual Rate of Change of Aggregate U. S. Patents Issued, 1790-1-80.

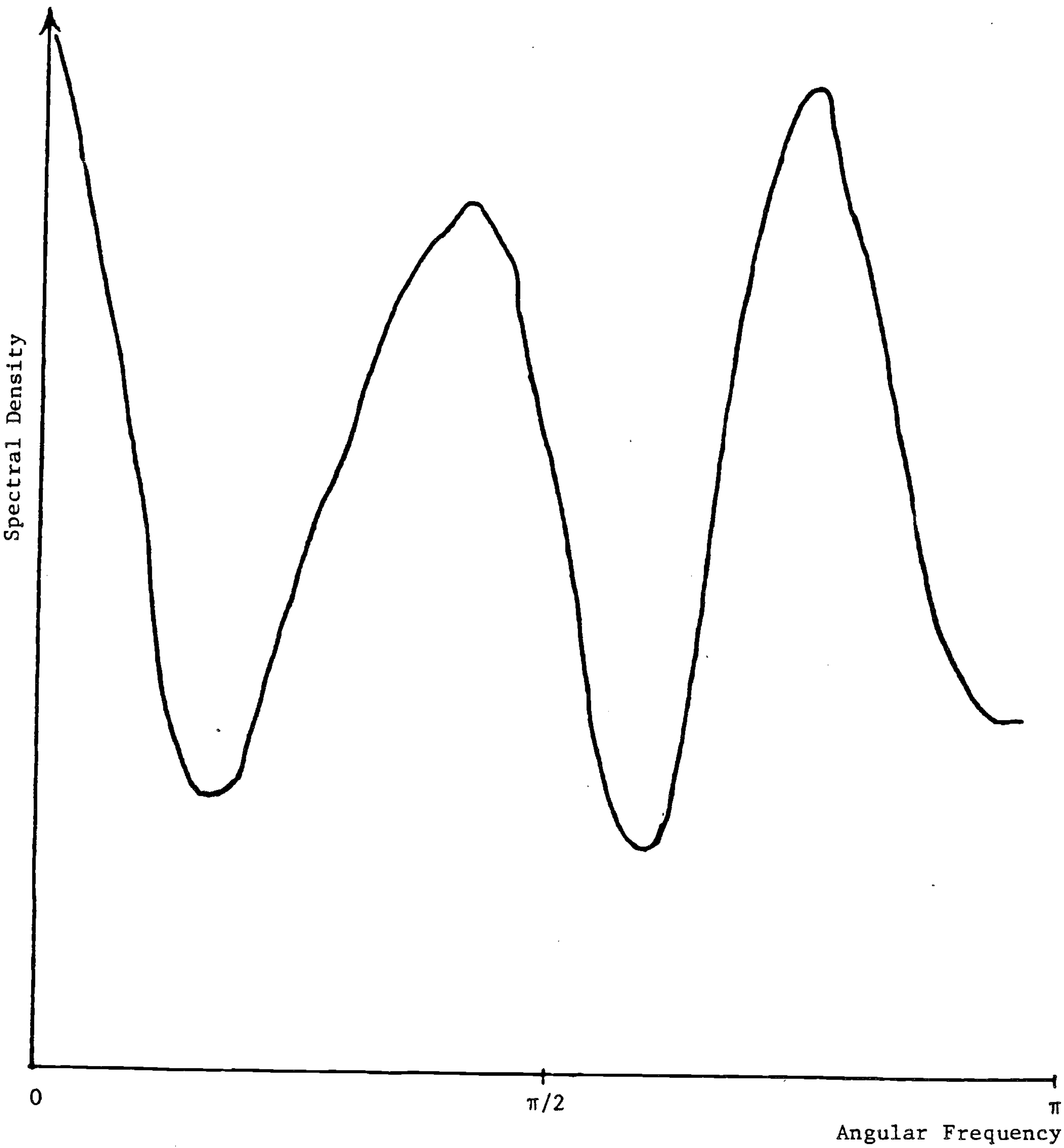

Figure 2: Theoretical Spectral Density Function for Moving Average Process given in Equation (5)

which is on average four 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 five percent. We conclude that though the model in (5) is not statistically robust, it is particularly rich in interpretation, and hence of interest in guiding future research on this topic.[5]

CONCLUSIONS

The history of the links between technological change and economic progress can yield a deeper understanding of 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 times in institutional structure. The results are, however, amenable to interesting interpretation and do point the direction for future research, both in the collection of better data and in the formulation of more exacting tests of our models.

APPENDIX I

INDUSTRIES INCLUDED IN STUDY

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. Chicolate and Candy
17. Sugar
18. Matches
19. Watches
20. Typewriters

APPENDIX II

PROCEDURES FOR COLLECTING PATENT DATA

I. 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 16 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 patent: (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 subheading system was adopted. The procedure for linking patents to industries would then be 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 gr-ups 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.

II. Collecting the Patent Data

The same procedure was used to obatin a patent series for each of the 20 industries. The only variation in the reports is the number of years covered. The series begins for each industry ten years before the Census of Manufacturers 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 the industry and under related headings were counted. Each patent title was examined to determine whether it had a meaningful bearing upon the industry under consideration.

III. 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 is given on a "when-issued" basis for the years 1837-1876 and 1947-1957. Schmookler's study covers "capital goods inventions classified according to the industry expected to use them." Schmookler assigned Patent Office subclasses to SIC industries. The Patent Office classification system is based on technological-functional not industrial principals, 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 2/3 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 inter-industry features of many inventions was 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 railroads 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 <u>or</u> 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, and it is from these that the time series of data is constructed.

FOOTNOTES

1. The term "Indian Summer" is also sometimes used to describe this phenomenon.
2. Often these breakthroughs came very early in the sample period for the industries being studied here. 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 amonia absorption system for ice-making 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 confectionery was in 1872 when Mr. Cracker Jack (real name) launched his famous popcorn product; other technologies such as iron and steel and sugar refining were well established by the 1880's.

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 is again industry level, but for the period 1953 to 1978. In that paper, a short-run negative relationship is found between the rate of growth of R&D expenditures and the rate of growth of industry profits.

5. My interpretation of these results has benefited from discussions with Derak de Sola Price.

REFERENCES

Beggs, J. J. (1981), "The Dynamic Interaction Between Industry Level Profits and Research and Development," *Cowles Foundation Discussion Paper No. 588*.

Kamien, M. I. and N. L. Schwartz (1978), "Self-Financing of an R&D Project," *American Economic Review*, Vol. 68, No. 3, pp. 252-261.

Nelson, C. Ri, and H. Kang (1981), "Spurious Periodicity in Inappropriately Detrended Time Series," *Econometrica*, Vol. 48, No. 3.

Penrose, E. T. (1951), *The Economics of the International Patent System*, Greenwood Press, Connecticut.

Schmookler, J. (1966), *Invention and Economic Growth*, Harvard University Press, Cambridge, Mass.

__________ (1972), *Patents, Inventions and Economic Change and Selected Essays*, edited by Z. Griliches and L. Hurwicz, Harvard University Press, Cambridge, Mass.