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DEMAND-PULL AND TECHNOLOGICAL INVENTION: SCHMOOKLER REVISITED

F.M. Scherer

Abstract

This paper replicates the pioneering cross-sectional analyses of Jacob Schmookler for a comprehensive set of finely subdivided manufacturing industries. Invention patents originating from oofh-c0chcorporations were classified by specific industries of use. The correlations between using industry investment and the number of linked capital goods inventions, although not as high as those obtained by Schmookler for a small subset of industries, were nevertheless substantial. The link between demand-pull and the flow of capital goods inventions was at least as strong for inventions sold across industry lines as for those that represented internal processes to their originators. For industrial materials, the relationship between demand-pull (measured by using industry purchases or palui a b l

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Revised Version

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During the 1950s and 1960s, quantitative research on the economics of invention was spurred by awareness that technical change was a primary source of the rapid economic growth achieved by industrialized nations. A leader in this effort was Jacob Schmookler, whose analysis of patent statistics [2] [4] provided the first demonstration that inventive activity is responsive to the pull of demand. The motivation now is different but no less compelling: a decade of retarded productivity growth makes it imperative to understand the forces governing the rate of technical advance. This paper retests Schmookler's demand-pull hypothesis with a new and more comprehensive data set.

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[7] Professor of economics, Northwestern University. This research was supported under National Science Foundation grant PRA-7826526. The author is indebted to Mary Gianos, Chun Yue Lai, Brett Spencer, Pin Tai, and William Cork for classifying the patents analyzed here; to Mr. Lai for computer programming; and to Edward Klotz, David Walker, Marilyn Wagner, and Catherine Conrad for research assistance.

Use is made here of aggregated data collected under the Federal Trade Commission's Line of Business program. A determination has been made that the results do not disclose individual company data. The conclusions drawn are the author'sF d

I. The Schmookler Hypotheses

Schmookler's main contention, contrary to the prevailing emphasis on changes in scientific and technological kno, Although there were other (i.e., time series) tests supporting his simpler demand-pull hypotheses, the main confirmation of Schmookler's theory of the relative roles of demand-pull and technological opportunity came from analyses of patenting for various industry cross-sections. His prime focus was on capital goods inventions, measured by the number of U.S. patents linked by Patent Office sub-class codes to particular industrial end uses. The more investment there was in a using industry, Schmookler claimed, the more patented capital goods inventions directed toward that industry's needs one should observe. The source of those inventions could be the using industry, other industries that specialize in supplying capital goods, or independent (i.e., non-corporate) inventors.

Schmookl

II. The New Data

As part of a broader effort

their inventions. Roughly 7.4 percent of the sample inventions had consumer goods uses only, and another 34 percent had uses too broad to associate with any identifiable subset of using

and ours, needless to say, are subject to possible errors counted fully for each industry to which a prospective use was traced.[6]

Following Schmookler, the preferred measure of demand-pull for capital goods inventions is new capital investment in using industries. Data constraints required that the analysis be limited to manufacturing industries of use only, for which consistent Census statistics are available. Schmookler found that the strongest correlations emerged when patent applications were lagged two years after the year of investment [4, p. 147]. Since it took 19 months on average for a patent application to mature into an issued patent during the mid-1970s,[7] this implies a maximum effect on our patents, whose midpoint issuance date was October 1976, from 1973 capital investment. Investment data for 1972 through 1974 were therefore collected.

Equation			Independent		

class sample chosen by Schmookler,[10] or structural changes over the quarter century separating our samples. Given the broad coverage of our sample, it seems unlikely that the differences can be ascribed solely to origin industry sampling ratio errors. Fourth, logarithmic regressions 1.2, 1.5, and 1.6 reveal that the linear demand-pull relationships observed by Schmookler do not hold up for our sample. Rather, with elasticities in the range of 0.44 to 0.69, appreciable diminishing marginal returns appear to prevail.

To replicate Schmookler's test of the relative roles of demand-pull and technological opportunity, the 1974 sales of sample companies, broken down by individual lines of business, were aggregated to an almost identical industry code structure and level as that assumed in Table 1, and those aggregated origin industry sales s_{74i} were taken as the right-hand side variable in regressions explaining patents P_i classified and aggregated to *industries of origin*. The matching between patents, firms, and industries in this instance is nearly exact, stemming from a link effort exploiting extraordinarily rich data.[11] Owing to the precision of the link, one might expect less "noise" to infiltrate the relationship between origin industry sales and

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[10]That Schmookler's results are not invariant across samples is shown by the considerable increases in r^2 and logarithmic regression coefficient values as his sample was changed somewhat between his 1963 article with Griliches [2] and his 1966 book [4, p. 145]. The principal changes entailed eliminating the shoemaking industry, with high patenting but poorly measured investment, and adding railroads (which in most years had the highest investment and patenting of sampled industries).

[11]see [8].

patents than the relationship between diversely inflated using industry patents and demand-pull indices. R^2 values should be correspondingly higher, all else equal.

The simple regression of patents on origin industry sales (in millions of dollars) was as follows:[12]

$$(1) \quad P_i = 40.2 + \underset{(.0015)}{0.0135} \; S_{74i}; \quad r^2 = .243, \; N = 241,$$

with the regression coefficient's standard error given in parentheses. When logarithms are taken (requiring the omission of 17 industries originating no patents), the regression is:

$$(2) \quad \log P_i = -1.45 + \underset{(.083)}{0.904} \log S_{74i}; \quad r^2 = .351, \; N = 223.$$

In both instances, the r^2 are somewhat to substantially higher than those for the industrial materials use regressions. In untransformed regression (1), r^2 is less than half its capital goods industry-of-use counterpart, but in logarithmic regression (2), it is nearly as high as, and insignificantly different from, the value in equation 1.2. Here, in contrast to the Table 1 regressions, taking logarithms suppresses the noise associated with a few very large but low-patenting industries (notably, automobile assembly). The support for Schmookler is again equivocal. The flow of appropriately matched inventions appears to be

abservations

[12]when the same regression is run with observations weighted by the reciprocal of the industry coverage ratios, making the weights

more closely correlated with using industry demand (measured by investment or materials purchases) than with originating industries' sales only for capital goods inventions, and then only for one regression specification, and not for the logarithmic form emphasized in Schmookler's 1966 work.

The capital goods inventions analyzed in Table 1 consist of two rather different subsets: inventions that were internal processes to their originators, and those that were products to the originators but processes to their users. It would not be unreasonable to suppose that demand-pull influences are transmitted differently between these two cases, e.g., intra-firm markets (for process inventions) might work more efficiently than inter-industry markets. To explore this possibility, the invention sample was bifurcated into internal process inventions PCi_j (where using industry j = origin industry i) and externally sold products PCE_j (where jri).

An insight provided by this procedure merits a brief digression. Both our data and National Science Foundation surveys reveal that 96 to 98 percent of all industrial inventive activity and corresponding patenting occur in the manufacturing sector. The bifurcation disclosed that manufacturers are their own most active suppliers of specialized capital goods inventions. Fully 75 percent of the 7,935 (inflated) capital goods patents with specific manufacturing industries of use were internal processes. Of 214 manufacturing industries with non-zero capital goods invention use, 78 percent drew a larger fraction of inventions from inside than outside. However, the companies in our

by 0.107 to 0.651. No similar increase occurred for logarithmic analogue equation 1.10, apparently because the logarithmic regressions were better able to accommodate the nonlinearities associated with these outliers,[14] and perhaps also because there were other industries which, although much smaller, deviated proportionately from all-sample patterns at least as much as autos and steel. When capital goods inventions were broken down into internal and external processes, deletion of the three industries led to 0.07 and 0.08 increases in r^2 relative to full-sample untransformed regressions 1.7 and 1.8. It would appear that both external and internal demand-pull transmission mechanisms were unexpectedly weak. One cannot help wondering whether this failure to elicit process inventions might be related to the auto and steel industries' well-known import competition problems.[15]

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[14]Note the increase in the logarithmic regression coefficient toward unity when the three outliers were deleted.

[15]compare Abernathy [1], who argues that the auto industry has been deficient in product but not in process innovation. For autos, at least two extenuating explanations might exist. First, the technology of auto production may be such that productivity is most readily enhanced by general-purpose machine tools, computers, and the like, whose uses are less apt to be associated with specific industries and which therefore would not be included in our subsample. Second, although the number of capital goods inventions with specific auto industry uses is small, the average 1974 research and development outlay leading to an auto industry patent, $3.55 million, was much higher than the average of $588,000 for all sample companies. But this low "propensity to patent" is almost surely the result of an R&D orientation that stresses styling amd model testing rather than the creation of new mechanical features. It is noteworthy that the auto parts industry, with equally low patent pull relative to investment, spent only $230,000 on R&D per patent received. For steel, the dearth of process inventions probably reflects a lack of imaginative internal research and development plus the

IV. Further Analysis

We depart now from the direct Schmookler tradition to explore several further hypotheses. It is conceivable that demand-pull influences manifest themselves in ways other than, or in addition to, the level of using industry investment, purchases, or value added. One plausible hypothesis is that profit possibilities are signalled in part by <u>changes</u> in using industry output. Also, labor-saving capital goods invention may be stimulated by unusually rapid increases in using industry wages. To test the first hypothesis, a variable $6Q_j$ measuring percentage changes in real using industry output between the Census years 1967 and 1972 was computed.[16] To test the second, the percentage change AW_j in using industry production worker wage payments per manhour between 1968 and 1973 was estimated from Census data. The multiple regression incorporating these two variables along with 1974 investment to explain using industry capital goods inventions was as follows:

s s

$$(3)\quad PC_{1.j} = 22.9 \;!7\; \underset{(.014)}{0.229}\, r_{74j} \;!7\; \underset{(.090)}{0.271}\, AQ_j - \underset{(.468)}{0.828}\, IJW_j; \quad R^2 = .567,$$

$$N = 245.$$

Relative to otherwise comparable

increase in R^2 is 0.023, which is statistically significant in an incremental F-ratio test, with F = 6.26. The output change variable is positive as predicted and statistically significant. The wage change variable has a paradoxical negative sign and a t-ratio of 1.77, i.e., not quite significant. Similar results emerged when logarithms were taken of all but the output change variable (which had some negative values ahand when the automobile, auto parts, and steel industry observations were deleted. For industrial material inventions, the most closely corresponding regression is:

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differences in opportunity play a large and easily systematized role. Not surprisingly, the slope dummy coefficients for organic

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V. Conclusion

The analysis here