

# Prologue to a Study of Patent and Other Factors in the Machine Tool Industry\*

MURRAY BROWN and NATHAN ROSENBERG, Research Associates

## S U M M A R Y

THIS PAPER PROVIDES SOME OF THE BACKGROUND material compiled for a questionnaire study of the role of patents and other factors in the development and the innovation process of the machine tool industry. The machine tool industry occupies a crucial position in modern industrial economies because of its relation to capital formation. It plays a strategic role in the twin processes of economic growth and fluctuations. Although the basic patents in the machine tool industry have long since expired, patents on control and transmission elements and other components of the machines are nevertheless important.

---

### *Purpose of Study*

OUR STUDY IS INTENDED TO THROW some light on the role of patents and other factors in the internal and external motivations for change in the technology of the machine tool industry. Clearly, these two kinds of motivation are conceptually and empirically separable. Does the patent system affect one more than the other? And, what is the influence of firm size, competitive conditions, nature of product, and export markets? These questions are starting points for our study, the main results of which will be derived from a survey of firms in the machine tool industry (and certain related industries). The survey will seek information from responding firms as to the role of patents and other factors in the development and the innovation process of the machine tool industry. In this paper, we present some of the information gathered from secondary sources, in preparation for the questionnaire phase of the project. The questionnaire will attempt to ascertain the role of owned and licensed patents in the origin, development, and current operation of the responding firms.

### *Patents in the Machine Tool Industry*

There are virtually no published materials which examine the role of the patent

---

\* This paper was prepared by Dr. Murray Brown and Dr. Nathan Rosenberg, Assistant Professors of Economics at the Wharton School of Finance and Commerce, University of Pennsylvania. This is an interim report of one of several studies conducted as part of *Project 3a*, Role of Patents in the Creation and Growth of Small Industrial Units, under the general direction of Dr. Irving H. Siegel, Principal Consultant.

system in the machine tool industry, although this role has clearly been a significant one. All the basic machine tools had been developed by the turn of the present century, but the industry has continued to experience significant change in the past 60 years. Innovations have made it possible to cut metals with increasing speeds, closer tolerances, and greater automaticity. The introduction of metals of greater durability, culminating in the general utilization of tungsten-carbide cutting tools, brought with it the redesign of machine tools for sturdier construction and operation at higher feeds and speeds. More recently, strides have been taken toward automatic control of operation sequences and the incorporation of electronic control systems. Another important trend is the increasing integration of formerly discrete machining operations.

In essence, there are only six basic machine-tool processes: grinding, planing, drilling, milling, turning, and metal forming. The origin of some of these goes back to antiquity; for example, the potter's wheel is the ultimate source of the lathe. The invention of the screw-cutting lathe was delayed until 1800; John Wilkinson had already invented in 1775 the machine that made it possible to bore cylinders for the steam engine, which in turn helped to increase the efficiency of metal-cutting tools. By 1875 the planer, the milling machine, and the drill press had been invented. These dates make it clear that the basic patents on the major types of machines have long expired.

It has been suggested in interviews and correspondence that patents today apply mostly to machine tool components, such as tool holding devices or hydraulic and electrical circuits, and that none of these patents is basic enough to constitute a significant monopoly. This view is confirmed to some extent by an authority on the industry, W. H. Brown, who comments that the great majority of patents protect only the control and transmission elements of the machines. Accordingly, machine tool designers appear to have been free to devise other methods of performing the same operation.<sup>1</sup> Some patents nevertheless have been of "major importance"—e.g., the Gleason Gear Works patent for bevel gear machinery and the Cincinnati Milling Company's patent for the centerless grinder.<sup>2</sup> The first contributed to the eminence of Gleason as a manufacturer of bevel gear machinery in the U. S., and the second patent did the same for Cincinnati Milling in the grinding product class until it expired in 1938.

The distribution of patents between large and small firms in the machine tool industry is a significant statistic. Quantitative data on patents frequently tell us little, since so many ancillary processes are patentable, but they do illuminate certain aspects of the innovation process. It seems plausible to relate the number of patents held by a firm to its size, its research expenditures, its growth, etc., and for this purpose the distribution of patents is invaluable. As a first step toward constructing such a distribution, we offer Table I, which shows selected firms having over 75 patents in the industry.

---

<sup>1</sup> Brown, "Innovation in the Machine Tool Industry," unpublished Ph.D. thesis, Yale University, 1952, p. 96.

<sup>2</sup> Brown, *ibid.*, p. 97.

TABLE I  
 NUMBER OF PATENTS ISSUED TO SELECTED FIRMS IN THE  
 MACHINE TOOL INDUSTRY  
 1939-55

Norton Co.....	515
Cincinnati Milling Machine Co.....	274
Niles-Bement-Pond Co.....	215
Ex-Cell-O Corp.....	189
LeBlond Machine Tool Co.....	175
Warner & Swasey Co.....	123
Kearney & Trecker Co.....	107
Landis Tool Co.....	105
New Britain Machine Co.....	105
Fellows Gear Shaper Co.....	92
Bryant Chucking Grinder Co.....	91
Brown & Sharpe.....	75

Source: *Distribution of Patents Issued to Corporations (1939-55)*. Study of the Subcommittee on Patents, Trademarks, and Copyrights of the Committee on the Judiciary, United States, Senate 84th Congress, 2d Session, Pursuant to S. Res. 167, Study No. 3, Washington, 1957.

### *Characteristics of the Machine Tool Industry*

The machine tool industry is unique from the viewpoint of technology. It produces machine tools which it uses for the production of other machine tools—i.e., the industry reproduces itself. It produces machine tools for use by other industries in turning out consumer and investment goods. Everything fabricated of metal is, by ancestry, either a first or second generation offspring of the machine tool industry.

Although the production of machine tools for use in other industries is more important quantitatively, the reproduction function of the industry is especially significant for economic growth.<sup>3</sup> This reproduction characteristic motivates the machine tool industry to improve technology for producing its own tools, i.e., it has an internal motivation for technological change. Also, there are external technical specifications imposed upon the industry by its customers which encourage technological change. Since all industrial establishments engaged in the production of machinery and consumer durable goods use machine tools, these externally imposed changes permeate the entire structure of the modern economy.

Examples of technological changes in machine tools associated with the external developments are (1) the demand for guns even prior to the Civil War, (2) the demand for bicycles in the 1890's which stimulated production of handscrew and other machines, (3) the rise of the automobile industry, and (4) the rise of the aircraft industry. Examples of technological changes in machine tools arising within the industry itself will be noted in the section on history.

Recently, another aspect of machine tool technology has received attention in the press.<sup>4</sup> It has been argued that the industry has been delinquent in adapting mass production techniques for machine tools, in contrast with practice in the Soviet Union. Consequently, the U.S.S.R. apparently can supply tools to under-indus-

<sup>3</sup> See A. Lowe, "Structural Analysis of Real Capital Formation," in *Capital Formation and Economic Growth* (National Bureau of Economic Research, 1956).

<sup>4</sup> *New York Times*, November 26, 1959.

trialized areas at advantageous prices and thus expand its political influence. Furthermore, it is argued that the mass production of industrial equipment at low prices may allow the more rapid replacement of older machine tools and thereby increase efficiency. It is the latter aspect of the argument that is interesting for the present study, for it points up the role of technological change in the machine tool industry in terms of an objective economic phenomenon: the replacement of machine tools. Although the press did not mention the following point, it too is relevant to this argument: Competition in the machine tool-using industries may tend to limit the mass production of standardized machine tools,<sup>5</sup> for competition often forces firms into making frequent design changes, which in turn require specialized tools.

There is considerable doubt, however, as to the validity of the above argument. It is not clear that the criterion for the replacement of machine tools should only be technological change, as suggested above. At least as relevant is the economics of replacement: Does the reduction in costs attributable to the new machine compensate for the replacement of a tool which is still physically productive? Another pertinent question is whether mass produced or standardized machine tools provide the technology that is optimal for economic growth. Could the customized machine tools produced in the U.S. perhaps satisfy this need better? We shall consider such problems in the second phase of the study.

Perhaps the most important underlying characteristics of the machine tool industry which is pertinent to the study of the factors influencing the origin, growth, and innovational processes of the industry is the structure of its demand—the distribution of its total sales among other industries.

This pattern affects technological cross-fertilization. Even the competition among firms in the industries comprising the markets for machine tools may influence innovation in the tool industry. Furthermore, if the structure of demand is changing with respect to secular and cyclical changes in business activity, opportunities may be provided for systematic innovation in the machine tool industry. Another pertinent fact is that machine tools are vital for producing armaments. The government is, in fact, an owner of machine tools on a massive scale.<sup>6</sup>

To delimit our study area, we shall focus on the Standard Industrial Classification number 3541, which is defined as:

Establishments primarily engaged in manufacturing power driven machine tools that shape metal by grinding or progressively cutting away chips. Important products of this industry include forging, broaching, drilling, gear cutting and finishing, grinding, milling and planing machines; lathes, shapers, and slotters; honing and lapping, polishing and buffing, sawing and cutting off; contour-sawing and filing, tapping, threading and rifling machines, and replacement and repair parts for machine tools. The rebuilding of machine tools is included in this industry.

---

<sup>5</sup>The small size of the capital coefficient in machine tools bears out the contention that machine tools are not mass-produced. For 1939 the capital coefficient was .501. W. Leontief, *et al*, *Studies in the Structure of the American Economy* (Oxford, 1952), p. 220.

<sup>6</sup>In 1955 the U. S. Government owned about 400,000 machine tools which were conservatively valued at \$2,000,000,000. It is not without interest that one of the key proposals in the post World War II plans for the "demilitarization" of Germany was the imposition of severe restrictions upon her output of machine tools.

#### 44 Patent, Trademark, Copyright Journal of Research, Education

The machine tool industry, so defined, is heavily concentrated in the East North Central section of the U. S. In 1954, 24% of the employment in the industry was in Ohio and 54% in the states of Ohio, Indiana, Illinois, Michigan, and Wisconsin. Approximately 33% of the industry's employment was in the New England states, and over 9% in the Middle Atlantic states of New York, New Jersey, and Pennsylvania. Table II presents a detailed distribution of the establishments and employees in the machine tool industry by location for 1954.

TABLE II  
NUMBER OF ESTABLISHMENTS AND EMPLOYEES IN MACHINE TOOL INDUSTRY BY REGIONS  
1954

LOCATION	ESTABLISHMENTS*	EMPLOYEES
INDUSTRY TOTAL.....	639	80,959
East North Central.....	326	43,736
West North Central.....	27	1,197
New England.....	105	27,099
Middle Atlantic.....	109	7,656
West.....	62	764
South.....	10	505

Source: Bureau of Census, U. S. Department of Commerce.

\* Definition of "Establishments" includes individually located plants of each company.

Although there are many different machine tools performing numerous functions, the structure of a machine tool has certain fixed characteristics. There is the feed mechanism which provides the tool with a flow of materials; there are controls which guide the input during the cutting; and there are the cutting elements. This invariant structure may be one of the essential reasons for the type of innovation that has occurred in machine tools.

The extreme durability of the industry's chief products is related to many special problems such as the high degree of cyclical instability that are characteristic of the industry. The useful working life of a machine tool (especially the more general-purpose types) may be 20 or 30 years, but changes in final products and productivity-increasing innovations typically induce replacement at far shorter time intervals. Nevertheless, in a recent year it was estimated that more than one-half of the machine tools in use in the U.S. were more than 10 years old, and one-fifth of all machine tools were at least 20 years old.

According to the Bureau of the Census, the machine tool industry in 1954 consisted of 627 companies which operated 639 plants. The value of shipments by the industry in that year exceeded \$1.1 billion and the number of employees was 80,959. As may be seen from a distribution of these workers according to the size of establishment, the industry consists of a large number of very small firms.

Entry into the industry is relatively easy, at least as far as financial requirements are concerned. This is reflected in the growth in the number of machine tool firms to accommodate the rapid expansion in machine tool demand after the Korean outbreak in 1950. Between 1947 and 1954 the number of machine tool companies doubled, rising from 312 companies in 1947 to 627 in 1954.

TABLE III

ESTABLISHMENTS IN MACHINE TOOL INDUSTRY LISTED BY EMPLOYMENT SIZE, 1954

*(Value figure in thousands of dollars)*

Number Employees, Establishments, and Value Added by Manufacture	Total, All Establishments	Establishments with average of				
		1-9 Employees	10-19 Employees	20-49 Employees	50-99 Employees	
Number of Establishments . . . . .	639	296	77	89	54	
Number of Employees . . . . .	80,959	1,082	1,110	3,005	3,726	
Value Added by Manufacture . . . . .	788,219	8,847	8,007	23,300	32,486	
		100-249 Employees	250-499 Employees	500-999 Employees	1,000-2,400 Employees	2,500 and over Employees
Number Establishments . . . . .	57	34	11	17	4	
Number Employees . . . . .	10,001	12,438	7,932	26,147	15,515	
Value Added by Manufacture . . . . .	98,980	126,471	86,858	262,886	140,381	

Source: Bureau of Census, U. S. Department of Commerce.

The smallness of the typical machine tool firm is closely connected with another very important feature of the industry. This is the highly specialized nature of the bulk of its final products. The output of the industry consists of a very wide assortment of tools, many of which are individually designed and custom-built to specifications established by the final user, or, alternatively, on a small job-lot basis. Not only are there well over 400 distinct types of machine tools, but each is in turn available in a variety of different sizes and with a wide array of special attachments and accessories. Individual machine tool plants typically produce a single or, at most, a few, types for the highly specialized uses of their industrial customers. Thus, the machine tool industry is composed of a large number of firms whose final products, metal-cutting instruments, possess a certain technical common denominator but may otherwise bear little economic resemblance to each other. In a recent year only three companies manufactured turret lathes with a bar capacity of  $3\frac{1}{2}$  inches or larger; only four companies produced vertical boring mills with tables of at least 60 inches in diameter; and only five made large horizontal boring machines.

Table IV shows the growth of the machine tool industry over two decades, 1937-57. From the low starting point (a depression year) shipments more than doubled during this period. The peak years occurred earlier, however, in 1952-53, during the Korean conflict. The industry is well known for the variability of its output according to general business conditions and defense requirements.

In the postwar period, between 20 to 30% of the tool output has been exported. The principal importing countries have been the United Kingdom, Canada, France, Argentina, Brazil, and Mexico. Our own imports are small, amounting to approximately 1% of domestic production.

TABLE IV  
VALUE OF SHIPMENTS BY MACHINE TOOL INDUSTRY

YEAR	VALUE OF SHIPMENTS (\$1,000)	PER CENT OF 1947
1957.....	\$1,209,071	245
1956.....	1,270,470	257
1955.....	1,007,752	204
1954.....	1,146,932	232
1953.....	1,541,374	312
1952.....	1,566,024	317
1951.....	953,124	193
1950.....	486,662	99
1949.....	395,035	80
1947.....	493,853	100
1939.....	221,267	45
1937.....	202,739	41

Source: Bureau of Census, U. S. Department of Commerce.

Lathes and grinding machines constitute the largest component of machine tool exports. These product classes are among those for which the "concentration ratios" published by the Senate Committee on the Judiciary are the lowest. (See Table V). Apparently, the more "competitive" sector of the industry is also the sector most strongly oriented toward foreign trade.

TABLE V  
CONCENTRATION RATIOS IN THE MACHINE TOOL INDUSTRY

SIC CODE	PRODUCT CLASS AND PRODUCT CLASS-GROUP	VALUE OF SHIPMENTS (\$000's)	CONCENTRATION RATIO: % OF VALUE OF SHIPMENTS ACCOUNTED FOR BY:		
			4 LARGEST COS.	8 LARGEST COS.	20 LARGEST COS.
3541	Machine tools.....	1,000,152	18	27	49
35411	Boring machines.....	114,443	51	73	92
35412	Drilling machines.....	86,066	36	56	87
35413	Gear cutting and finishing machines.....	48,111	69	90	99
35414	Grinding and polishing machines.....	154,396	43	59	79
35415	Lathes, except woodworking.....	206,886	38	63	89
35416	Milling machines.....	121,494	65	77	92
35417	Other machine tools, except home workshop.....	239,011	21	34	53
35418	Machine tools, primarily for home workshop.....	9,283	40	59	85
35419	Rebuilt machine tools.....	15,012	32	49	75
35410	Machine tools not specified by kind..	5,450	—	—	—

Source: *Concentration in American Industry*, Report of the Subcommittee on Antitrust and Monopoly to the Committee on the Judiciary. U. S. Senate U.S.G.P.O., Washington, 1957, p. 57.

### *History of Industry*

The emergence of a recognizable machine tool industry in our country was historically coincident with the growth of mass production methods of industrial manufacturing. Indeed, its very development helped encourage adoption of such methods.

Its earliest growth was intimately connected with the advance of metallurgy and the utilization of steam as a general source of industrial motive power.

Most of the basic machine tools were developed in the last quarter of the eighteenth and the first half of the nineteenth century. The start of the modern machine tool industry may be related to the development of the steam engine itself. James Watt's brilliant conception of the separate condenser long proved impractical because of his inability to secure for his engine a cylinder bored to a sufficient degree of accuracy. At one time he actually operated a cylinder containing an error of  $\frac{3}{8}$  inch in its diameter. The incredible improvisations, by modern standards, to which he resorted are indicated in the following quotation:

The close fitting of the piston in the cylinder, which did not so greatly matter in the Newcomen engine, was essential to the proper working of Watt's. For want of an accurate boring-machine, the cylinder of his first engine was made of tin and hammered to shape against a hard-wood block; the gaps between piston and cylinder were sealed as far as possible with felt, paper, oiled rags, and the like.<sup>7</sup>

The precision required by Watt was eventually achieved only with the assistance of John Wilkinson's boring machine which finally supplied cylinders of the required degree of accuracy and, in so doing, immediately rendered the steam engine a commercially practicable proposition. Wilkinson's boring machine may justly be regarded as the beginning of the modern machine tool industry.

The machine tool industry developed at an extraordinary speed in the first half of the nineteenth century. The pioneers in England, including such men as John Wilkinson, Joseph Bramah, Samuel Bentham, Henry Maudsley, James Nasmyth, and Joseph Whitworth, directed their energies primarily toward the production of the general purpose machine tools. They concentrated their efforts upon creating machinery to accommodate the growing demands of the steam engine, mining equipment, railroads, naval machinery and equipment, etc.

In America the machine tool industry achieved its first significant growth in the production of firearms, built with standardized and interchangeable parts by Eli Whitney, Simeon North, and later on, Samuel Colt.<sup>8</sup> So successful were these efforts that, by 1853, a British Royal Commission, which included Whitworth and Nasmyth, visited the U. S. to study the manufacture of small-arms. Almost immediately "The American System" (as manufacture with interchangeable parts was then called) was adopted in Britain, and American machinery was even being exported to England for use in British armories.

Although the earliest development of machine tools in the U. S. was centered upon the introduction of the principle of interchangeability in the production of firearms, its major achievements came in the extension and application of the interchangeable system to the production of other products which were themselves de-

---

<sup>7</sup> K. R. Gilbert, "Machine Tools," in *A History of Technology*, Charles Singer, et al (eds.), IV, 421.

<sup>8</sup> It is one of the minor ironies of history that Eli Whitney turned to the development of a system for the manufacture of firearms on an interchangeable basis because of his failure to derive a substantial income from his cotton gin, which failure was in turn due to the difficulties and frustrations which he encountered in attempting to enforce his patent rights! Joseph Wickham Roe, *English and American Tool Builders*, pp. 131-132.

veloped in the second half of the nineteenth century. The machine tool industry grew in importance with the attempt to achieve large quantity production of machines which were composed of separate metal components requiring accurate fitting, i.e., sewing machines, typewriters, bicycles, agricultural machinery, automobiles, and electrical equipment. In all these and many other cases, mass production and commercial success were dependent upon the introduction of an appropriate battery of machine tools which were geared to the specific needs of the new product.

Technological change in the machine tool industry continued at a very rapid rate between 1850 and 1900. In addition to the introduction of significant new devices such as the turret lathe, multiple-spindle drilling machines, automatic lathes, automatic gear cutters, grinding machines, and a vast proliferation of special purpose tools, the introduction of superior cutting tool materials such as mushet steel and high speed steel, and the electrification of machine tools, exerted a diffused effect in increasing productivity and flexibility throughout the entire industry.

The machine tool industry began to approximate its present form in the second half of the nineteenth century. Throughout this period an increasing amount of attention was devoted to the construction of special-purpose machine tools. Individual firms increasingly specialized in the production of one or, at best, a very limited family of tools. In spite of the increasing predominance of the corporate form of organization, the machine tool industry long remained a stronghold of the individual proprietorship and family-owned firm. Although financial requirements for the establishment of a machine tool firm remained small by comparison with the rest of industry and never constituted a serious obstacle to entry, business success in the production of machine tools was heavily dependent upon the possession of highly specialized skills and technical abilities, both on the managerial and labor force levels. New machine tool firms were frequently organized by young men after having served extensive apprenticeships and having acquired their familiarity with the exacting requirements and technology of the industry in well-established firms.<sup>9</sup>

---

<sup>9</sup> See the various "genealogies" of individual firms in Roe, *op. cit.*