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Changing Production of Metalworking Machinery, 1860–1920

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Because of insufficient data, neither McDougall nor I could stick by our original resolve to treat the growth in output of nonelectrical machinery in general. But we need not apologize for restricting our investigations to the category of metalworking machinery, or, to use McDougall's somewhat more common and less inclusive term, machine tools.¹ Except for a few expensive toys of do-it-yourself addicts, metalworking machinery is a pure capital good, sold always in the producer-goods market, and the fluctuations in sales (output) of these products are a marvel to behold. It is common knowledge that the first industrial revolution, to say nothing of the second, would have been impossible without metalworking machinery.

Because of their obvious importance, machine tools have long since attracted historians, who have done yeoman service in tracing their evolution.² A marvelously inventive group of innovators started devising

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¹ As we proceed, the reason for making the inconsiderable distinction between metalworking machines and machine tools will become apparent. At the moment it is enough to observe that machine tools are usually defined as power-driven machines that *cut* metal, excluding the shaping or forming machines that press, forge, hammer, etc. Metalworking machinery includes both types. (See Duncan McDougall's paper which follows.)

² This literature is voluminous. At one time or another every economic historian has dipped into Joseph Wickham Roe, *English and American Tool Builders* (New Haven, 1916). For excellent historical summaries containing substantial bibliographical notation, see Bertold Buxbaum, "Der amerikanische Werkzeugmaschinen und Werkzeugbau im 18. und 19. Jahrhundert," *Beiträge zur Geschichte der Technik und Industrie*, Vol. X, 1920, pp. 121–154, and W. Paul Strassmann, *Risk and Technological Innovation*, Ithaca, 1959, pp. 116–157. Detailed studies of the development of the several types of machine tools are to be found in Robert S. Woodbury's little books, all published by the Technology Press at Massachusetts Institute of Technology. See, for example, his *History of the Gear Cutting Machine*, 1958; *History of the Grinding Machine*, 1959; *History of the Milling Machine*, 1960.

metal-cutting and metal-shaping machines before anyone had invented a generic term for them. Roe remarks that they were a well-established class of machines by 1830, but the earliest allusion that I have found to tools that are at the same time machines appears in a report of a select committee of the British House of Commons in 1841.³ The first U.S. Census designation of machine tools is found in the Eighth Census (1860) as "machinists' tools." The Ninth Census actually counted the output of two kinds of machine tools but did not refer to the category as a total. The Tenth Census (1880) contained an elegantly descriptive article on "machine tools" and their uses but included no quantitative information about them.⁴ Not until the Twelfth Census (1900) did "machine tools" receive the careful attention of enumerators, though "metalworking machinery" appeared as a category in export-import figures as early as 1898.

Another reason why it is so hard to obtain data on the machine tool industry is that, more than most, it was a "peel-off" industry. Beginning in the latter half of the eighteenth century, manufacturers of products requiring machine tools often had no realistic alternative to making their own. Even after English and American firms began to emerge as specialists in machine tool manufacture, thus dispensing the largesse of Marshallian external economies to their customer firms, many businesses continued to make metalworking machines for their own use. In the late nineteenth century many a Cincinnati firm requiring a lathe or a planer would order the tool from a reputable manufacturer and, needing others, would proceed to make copies. Even with the best definitions and the most conscientious census-taking techniques, this kind of production would surely have gone uncounted.

Whatever the difficulties of estimation, the problem of calculating output and price changes over a meaningful span of years remains. When the data are so much better at the end of the series than they are at the

³ *First Report from Select Committee Appointed to Inquire into the Operation of the Existing Laws Affecting the Exportation of Machinery; with the Minutes of Evidence and Appendix*, ordered by the House of Commons, to be printed April 1, 1841, p. 96.

Question 1314: "Much ignorance appears to prevail as to the nature and extent of this department of industry; can you give the Committee some outline of the extent of the manufacture of tools, in what degree they are now used in machine-making, and what are the descriptions of tools ranging under this general name?"

Witness W. Jenkinson: "What used to be called tools were simple instruments, as I should call them, such as hammers and chissels [sic] and files; but those now called tools are in fact machines, and very important machines; they are not only important but they are now made at very great cost, from £100 up to £2,000 each. . . ."

⁴ See *Tenth Census of the United States, 1880*, F. R. Hutton, "Report on Machine Tools and Woodworking Machinery," Vol. 22, pp. 5-294.

beginning, it seems best to start at the end and work backward. We first take a look at the output of metalworking machinery from 1900 to 1920 before examining the evidence for the two decades 1880–1900.

Output in Current Dollars and Real Output, 1900–20

For the period 1900–20 there are Census figures of metalworking machinery output for four years—1900, 1905, 1914, and 1919. We also have estimates of the National Machine Tool Builders' Association for the years 1901–20.⁵ The estimates of the trade association are for metal-cutting tools as a component of the larger category of metalworking machinery.

Getting the Census definitions straight is a job in itself. The Census of 1900 gives the total value of all products manufactured by firms making metalworking machinery as \$44.385 million. From this figure has been subtracted the value of products not considered metalworking machinery, \$16.376 million, plus the amount received for custom work and repairs, \$3.271 million, the result being \$24.738 million. According to an explicit statement of the Office of the Census, the 1905 figure, \$32.409 million, is comparable to the 1900 figure. The 1914 Census figure for machine tool output is \$31.447 million, and for metalworking machinery other than machine tools \$17.420 million, which comes to a total of \$48.867 million. The 1919 machine tool figure was \$212.400 million and the figure for metalworking machinery other than machine tools \$57.541 million. Subtracting from this sum the value of all other products, \$32.653 million, yields an output of metalworking machinery for 1919 of \$237.200 million.⁶

The problem then becomes one of interpolation of time series.⁷ The approach taken is the common-sense one of relating the benchmark figures for metalworking machinery to the National Machine Tool Builders' Association estimates of the output of metal-cutting tools. The

⁵ This series has been continued to the present. See Release F-A40a, dated February 21, 1962, of the National Machine Tool Builders' Association. This is the same series cited by McDougall.

⁶ The foregoing data are taken from the following sources: *Twelfth Census of the United States, 1900*, Vol. X, Manufactures, Part IV, Selected Industries, p. 381; *Special Reports of the Census Office, 1905*, Manufactures, Part IV, Selected Industries, p. 227; *Census of Manufactures, 1914*, Vol. II, p. 272; *Fourteenth Census of the United States, 1920*, Vol. X, Manufactures, 1919, pp. 373 and 385; *Biennial Census of Manufactures, 1921*, p. 419.

⁷ At this point we embark on a venture beset by obvious pitfalls. For the kind of problems involved, see Milton Friedman, *The Interpolation of Time Series by Related Series*, NBER Technical Paper 16, New York, 1962.

relevant data are set forth in Table 1. It was assumed that the ratios of output of metalworking machinery to output of metal-cutting machine tools changed gradually between benchmark years. The ratios of the Census figures to the NMTBA figures were computed for 1905, 1914, and 1919, along with the ratio of the 1900 Census figure to an extrapolated NMTBA figure for 1900. On the assumption of linearity of change between benchmark years, expansion ratios were then computed for intervening years. Multiplying the dollar value of output in the NMTBA series by the computed ratios, we obtained the estimates of total output of metalworking machinery in current dollars, as shown in column 4 of Table 1.

It was felt that this series for 1900–20 was reliable enough to permit the computation of an index of real output of metalworking machinery. Since no index of prices of metalworking machinery was available for the entire period, a deflator was constructed by splicing the American Appraisal Company's index of machine tool prices for the period 1914–20 to the wholesale price index of the Bureau of Labor Statistics for the period 1900–13. (For alternative procedures, see Table A-2.) The resulting index of real output (1914 = 100) is shown in column 7 of Table 1.

Comparisons of output of metalworking machinery by regions are not altogether satisfactory because of odd and unexplained gaps in the data, especially for the Census of 1919. It is not far off, however, to assign the output for the year 1900 approximately as follows: 30 per cent to the New England states, 26 per cent to the Middle Atlantic states, and 34 per cent to the Midwestern states, with Ohio alone accounting for 29 per cent. The remaining 10 per cent was scattered among all other producing states, including Vermont, Michigan, and Wisconsin, for which data were not available in the 1900 Census. Over the ensuing two decades there was an appreciable shift in the relative importance of the Middle Atlantic and Midwestern states. In 1919, New England states (including Vermont) accounted for 35 per cent of machine tool output, the Middle Atlantic states for 14 per cent, and the Midwestern states of Ohio, Illinois, Michigan, and Wisconsin for 47 per cent.⁸ In 1919, metalworking machinery other than machine tools was produced for the most part in six states, Connecticut accounting for 12.2 per cent of this category of output, New Jersey for 5.1 per cent, New York for 18.7 per cent, Pennsylvania for 16.4 per cent, Ohio for 17.7 per cent, and Illinois for 16.4 per cent. On the whole, the Midwestern states of Ohio and Illinois were dominant in the total production of metalworking machinery, but the New England

⁸ Unfortunately, these data include the category "all other products" in addition to machine tools.

TABLE 1

PRODUCTION OF METALWORKING MACHINERY IN CURRENT AND IN CONSTANT DOLLARS, 1900-20
(million dollars)

Year	Shipments of Metalcutting Tools (current dollars) (1)	Output of Metalworking Machinery ^b (current dollars) (2)	Expansion Ratios (3)	Output of Metalworking Machinery (current dollars) (4)	Index of Metalworking Machinery Prices (1926=100) ^c (5)	Estimated Output of Metalworking Machinery (1926 dollars) (6)	Index of Real Output of Metalworking Machinery (1914=100) (7)
1900	(17.3)	24.7	142.8	24.7	41.4	59.7	55.7
1901	17.9		136.8	24.5	40.8	60.0	56.0
1902	22.8		130.8	29.8	42.9	69.5	64.8
1903	23.7		124.8	29.7	43.9	67.7	63.2
1904	18.3		118.8	21.7	44.0	49.3	46.0
1905	28.7	32.4	112.9	32.4	44.3	73.1	68.2
1906	36.4		115.7	42.1	45.6	92.3	86.1
1907	41.3		118.5	48.9	48.1	101.7	94.9
1908	16.8		121.3	20.4	46.4	45.3	42.3
1909	33.5		124.1	41.6	49.8	83.5	77.9
1910	44.3		126.9	56.2	51.9	108.3	101.0
1911	32.8		129.7	42.5	47.8	88.9	82.9
1912	44.4		132.5	58.8	50.9	115.5	107.7
1913	44.6		135.3	60.3	51.5	117.1	109.2
1914	35.3	48.9	138.4	48.9	45.6	107.2	100.0
1915	103.4		140.2	145.0	49.4	293.5	273.6
1916	141.4		142.0	198.2	62.0	319.6	298.0
1917	168.5		143.8	242.3	82.3	294.4	274.5
1918	220.6		145.6	321.2	101.2	317.4	295.9
1919	161.0	237.2	147.3	237.2	106.3	223.1	208.0
1920	151.5		149.1	225.9	116.5	193.9	180.7

^a Estimates of National Machine Tool Builders' Association.

^b Census figures include both cutting and forming tools.

^c For alternative computations of price indexes, see Table A-2.

states were still major producers of metal-cutting tools, and the Middle Atlantic states even surpassed Ohio and Illinois in the production of metalforming tools.

In general, attempts to estimate foreign trade in metalworking machinery for the entire period 1840–1920 met with frustration. One set of statistics emerged that ought to be included. These are the exports of metalworking machinery, with major countries of destination, for 1898–1920. A comparison of domestic output with exports for 1908 and 1914 suggests how important foreign sales were to the metalworking machinery industry during lean years at home (see Table A-1).

Evidence of the Level of Output, 1860–1900

A quantitative study of metalworking machinery output in this or any other country for the latter half of the nineteenth century faces formidable data problems. McDougall takes the view that it was not until the end of the period “that a distinct machine tool industry emerged in the sense of a group of firms whose principal product was machine tools.” I would place this emergence some twenty years earlier, or about 1880. If it is true that a church denomination has come of age when it creates a seminary, it is equally true that a group of firms begins to constitute an “industry” in some formal sense when a trade magazine is established to minister to it. *American Machinist* began publication in 1878 and in its issue of June 28, 1879, published a list of machine tool builders that constituted, in the editor’s words, a “distinct branch of industry.” Again in its issue of November 11, 1882, a list of machine tool builders, purporting to be exhaustive, is offered.⁹ One reason, then, for selecting 1880 as the earliest date for estimating a nineteenth century time series for metalworking machinery production is that by this time an industry had clearly formed. But a more compelling reason is that before 1880 it is possible to estimate output only for 1860 and 1870, and there is presently no really adequate basis for interpolating figures for the interim years in the two decades of 1860–80.

Standard sources for data before 1880 were combed with unusual care. In addition to such ordinarily productive periodicals as *Hunt’s Merchants’ Magazine*, *DeBow’s Review*, *Niles’ National Register*, and *Hazard’s United States Commercial and Statistical Register*, much of the nineteenth century literature on manufacturing and technological change was examined. Relevant public documents were combed, including some

⁹ For these lists, see *American Machinist*, June 28, 1879, pp. 8–9, and November 11, 1882, p. 7.

exciting material in the Pennsylvania State Library.¹⁰ British Parliamentary reports from 1830 on were examined, as were British Consular reports, largely in the hope of finding knowledgeable English estimates of the proportion of machine tool output accounted for by various major cities.¹¹ But except for a few gems to be noted later, these researches produced little of value, though several bits and pieces will ultimately be useful in reconstructing a production series for nonelectrical machinery as a whole.

As nearly as I can determine, estimates of output of metalworking machinery in the nineteenth century must begin with the Eighth (1860) Census of the United States. Here for the first time there is specific reference in an official American document to machine tools. "Machinists' tools employed 17 manufactories, a capital of \$536,150, and 455 hands, and the value of the manufacture was \$540,292, of which \$205,000 was the product of one establishment in Philadelphia, having a capital of \$280,000 and employing 190 hands and turning out machinists' tools of acknowledged excellence. Nine establishments in Massachusetts reported a value of \$165,600 made, and two in New Haven, Connecticut, a product of \$71,600. Three in New York, made tools of the value of \$47,950; one in New Jersey, \$2,800; and one in Delaware, \$22,142."¹²

The separate amounts cited do not add up to the total Census figure, but there is another difficulty. From two other sources, one unofficial and the other official, there are estimates of the output of metalworking machinery in Philadelphia, both of them suggesting that the Census summary is in error. Edwin T. Freedley, a contemporary observer, estimated that for 1857 the two principal machine tool manufacturing

¹⁰ Among the U.S. documents, the biggest disappointment was the Special Census of Manufactures ordered by the House of Representatives in 1832. Had the census of the several states been properly taken, the data compilation would have been invaluable, but as far as I can tell only the Massachusetts enumerators did a creditable job. In other states data are sketchy and incomplete; not all firms were polled, and some that were refused to respond. See *Executive Documents*, 1st Sess., 22d Congress, Serial Numbers 222 and 223, *Documents Relating to the Manufactures in the United States*, collected and transmitted to the House of Representatives in compliance with a resolution of January 19, 1832, by the Secretary of the Treasury, 2 vols., 1833. The Pennsylvania documents referred to are *Census of the United States, Original Returns of the Assistant Marshals, Products of Industry*, housed in the Law Library, Pennsylvania State Library, Harrisburg, Pennsylvania.

¹¹ In the context of the present study, the most valuable information obtained from the British Parliamentary Papers was a list of prices of American machine tools and allied products quoted English buyers by Mr. Ames of Chicopee, Massachusetts, and Messrs. Robbins and Lawrence of Windsor, Vermont. See *Report of the Committee on the Machinery of the United States*, 1855, pp. 75-79.

¹² *Eighth Census of the United States, 1860*, Statistics of Manufactures, Vol. 3, p. clxxxviii.

firms of William Sellers & Co. and Bement & Dougherty turned out a product of \$350,000, employing together about 300 hands.¹³ More important, the original Census returns for Philadelphia for the years 1860 and 1870 give the following information:

William Sellers & Co., Inc.
1600 Hamilton Street
Philadelphia, Pa.
15th Ward, 43rd District

1860 Census:

Product:	Machinists & Foundry
Hands employed:	190
Value of product:	Machine Tools, \$80,000
	Total (all goods), \$205,000

1870 Census:

Hands employed:	423
Value of product:	Machine Tools, \$273,962
	Total (all products), \$707,542

Bement & Dougherty
15th Ward, 43rd District
Philadelphia, Pa.

1860 Census:

Product:	Machinery & Tools
Hands employed:	180
Value of product:	Machinery & Castings, \$198,000

1870 Census:

Hands employed:	375
Value of product:	Machine Tools, \$401,000
	Total (all products), \$511,918

Comparison of the original reports with the summary from the 1860 Census quoted above reveals the inaccuracies of the Census writer. He took the *total* output of Sellers for 1860 as the output of machinists' tools only, and he failed to include the machine tool output of Bement & Dougherty and other Philadelphia firms. If Bement & Dougherty devoted 80 per cent of its production to machine tools in 1860, as it did in 1870, then the two firms, Sellers and Bement & Dougherty, produced \$240,000 worth of machine tools rather than the \$205,000 assigned to Philadelphia

¹³ Edwin T. Freedley, *Philadelphia and Its Manufactures*, Philadelphia, 1858, pp. 314-316. This same figure was picked up by *Hunt's Merchants' Magazine* and quoted in the issue of July-December, 1958, p. 629.

by the 1860 Census. The adjusted figures fall considerably short of the Freedley estimate for 1857, the discrepancy doubtless being the result of the ambiguity of the term "machine tools." At least three other Philadelphia firms were then in business, but original Census returns could not be found for them. They were certainly much smaller than the two major firms, for neither Freedley nor Buxbaum mention them by name; together they require an increase in the adjusted Census total of at least 10 per cent to give an estimate for Philadelphia production in 1860 of \$264,000. The actual value of output probably lay between this figure and the Freedley estimate, and I have taken a Philadelphia production figure of \$300,000 as plausible for 1860.

For 1870 the Census figure of machine tool output of the two reporting firms totaled \$675,000. We have no information on their share of Philadelphia production, but Buxbaum indicates no reason for thinking that their share changed during the Civil War decade. At their estimated 1860 shares, a production for Philadelphia of approximately \$750,000 is implied for 1870.

Because the Censuses of 1860 and 1870 are not reliable as a guide to estimation of production by geographical regions, these estimates must be inferred from three major sources that span the decades of the 1860's and 1870's.¹⁴ A count of the known firms in the industry as of 1860,

¹⁴ The count of firms in the several regions is based on companies mentioned in the works by Roe and Buxbaum (especially pp. 132-140) mentioned in footnote 2, with some adjustment in the light of firms contained in lists of the *American Machinist* for 1879 and 1882 (see *American Machinist*, June 28, 1879, pp. 8-9, and November 11, 1882, p. 7).

In 1879 the *American Machinist* listed nine tool-producing firms in the Midwestern group of a total of seventy-three that had been in the business within the past ten years; but only forty-six of this group were manufacturing tools at the time of the count, of which six were in the western group. The 1882 list contained 132 firms, twenty-one of them in the Midwest. Many of the firms in the later list were new and still small, and at this date the western tool builders could not have accounted for more than 10 or 12 per cent of the country's production of metalworking machinery.

As nearly as I can determine, Philadelphia in 1882 still held its dominant position as a producer of large tools, although the city's proportion of total output may have begun to fall. In his report on the industries and products of the Consular District of Philadelphia for 1883 and a part of 1884, British Consul Clipperton made the following comment:

"Lovin Blodget, Esq., the eminent statistician, has for many months been engaged, assisted by the mayor and the entire police force of the city, in collecting industrial returns for 1882 and 1883, a brief summary of which is herein given by permission."

The Blodget estimates for the city of Philadelphia in 1882 report a category of "iron working machine tools." Ten firms, employing 1289 hands, turned out a value of product of \$2,255,750 (see *Accounts and Papers, Commercial Reports*, Vol. LXXXI, pp. 1933-1938). This figure is close to 30 per cent of my estimated 1880 output of metalworking machinery for the country.

TABLE 2
ESTIMATE OF CINCINNATI MACHINE TOOL OUTPUT, 1880-1900

Year	Number of Firms Established in Year Cited (1)	Total Number of Cincinnati Firms (2)	G.A. Gray Co. Actual Output (dollars) (3)	Estimate of Cincinnati Machine Tool Output (dollars) (4)
1880	2	6	--	250,000
1881	2	8	--	360,000
1882	0	8	--	410,000
1883	0	8	--	510,000
1884	2	10	--	600,000
1885	0	10	--	650,000
1886	2	12	--	870,000
1887	4	16	80,500	1,270,000
1888	1	17	91,800	1,330,000
1889	2	19	113,100	1,600,000
1890	0	19	176,700	1,830,000
1891	0	19	169,600	1,790,000
1892	2	21	161,400	1,770,000
1893	1	22	86,300	1,300,000
1894	0	22	58,600	820,000
1895	0	22	123,400	1,380,000
1896	1	23	111,300	1,340,000
1897	2	25	137,200	1,800,000
1898	3	28	185,900	2,100,000 ^a
1899	1	29	288,600	3,340,000 ^a
1900	0	29	362,500	3,375,000 ^b

^aObtained from "Leading Industries of Cincinnati," published by the *Cincinnati Enquirer*, 1900, p. 26.

^b*Twelfth Census of the United States, 1900.*

adjusted for type of output,¹⁵ indicates that New England tool builders were turning out at least 40 per cent of total output of metalworking machinery, and I estimate a figure of 25 per cent for the Middle Atlantic states, including Pennsylvania outside Philadelphia, Delaware, and Maryland. Not more than 5 per cent of total output was accounted for by tool builders west of Pennsylvania.¹⁶ Thus, 30 per cent of output is attributable to the part of the industry located in Philadelphia, and there

¹⁵ There seems little question that by 1860 Philadelphia firms were specializing in heavier, higher-priced machines, most of them in the metal-forming category. New England manufacturers, on the other hand, were doubtless making a much smaller proportion of metalworking machines and were even then specializing in the light production machine tools that McDougall believes were not quantitatively important in the period of rapid American industrialization.

¹⁶ As early as 1860, Cincinnati machinery manufacturing firms were beginning the production of commonly used tools, such as lathes, but output was almost negligible (see Fredrick V. Geier, *The Tool Builders of Cincinnati*, New York, 1949). In 1868 the Niles Tool Company, then of Cincinnati, was specializing in the production of machine tools, and the Cincinnati firm of John Steptoe was certainly building a few tools by 1870.

is no evidence to indicate much change in these geographical ratios for 1870. Assuming that Philadelphia output was 30 per cent of the total in both 1860 and 1870, we may take U.S. totals of approximately \$1 million and \$2.5 million as plausible for these two dates.

For the period 1880-1900, it is possible to add to the Brown and Sharpe series given by McDougall a series for Cincinnati production. Estimates of production of metalworking machinery in Cincinnati before 1880 would have dubious validity, for up to that date the producing firms, with the possible exception of the H. Bickford Company, also manufactured a variety of other machinery that could not be classed as metalworking. But on the basis of the known output of the largest Cincinnati firm existing in 1880—Lodge, Barker & Company—Cincinnati production for 1880 was reckoned at \$250,000 for the six firms then in existence. George Wing, Xavier University, Cincinnati, has made year-by-year estimates of output up to 1898 (see Table 2); local Census information is available

TABLE 3

ESTIMATED PRODUCTION OF METALWORKING MACHINERY IN CINCINNATI, 1880-1900

Year	Cincinnati Metalworking Machinery Output Trend (dollars) (1)	Number of Machine Tool Shipments ^a (2)	Number of Machine Tool Shipments Trend (3)	Shipments Divided by Trend (4)	Adjusted Cincinnati Output ^b (5)
1880	250,000	264	264	100.0	250,000
1881	353,333	319	270	118.1	417,286
1882	456,666	303	277	109.4	499,593
1883	560,000	302	285	106.0	593,600
1884	663,333	241	293	82.3	545,923
1885	766,666	197	302	65.2	479,166
1886	870,000	508	510	99.6	866,520
1887	967,500	587	567	103.5	1,001,363
1888	1,070,000	702	625	112.3	1,201,610
1889	1,172,500	868	683	127.1	1,490,248
1890	1,275,000	1,011	760	133.0	1,695,750
1891	1,377,500	905	832	108.8	1,498,720
1892	1,480,000	955	925	103.2	1,527,360
1893	1,582,500	795	1,030	77.2	1,221,690
1894	1,685,000	523	1,140	45.9	773,415
1895	1,787,500	1,081	1,250	86.5	1,546,188
1896	1,890,000	1,345	1,380	97.5	1,842,750
1897	1,992,500	1,571	1,520	103.4	2,060,205
1898	2,100,000	1,963	--	--	2,100,000
1899	3,340,000	2,591	--	--	3,340,000
1900	3,375,000	2,295	--	--	3,375,000

^aNumber of machines shipped by Brown and Sharpe and Bullard, 1880-85, and by Brown and Sharpe, Bullard, and Gray, 1886-1900 (1886 estimated for Gray).

^bColumn 1 times column 4 for 1880-97. Amounts for 1898 and 1899 are from a Cincinnati census, and the 1900 figure is from the U.S. Census for that year. The values in this column reflect cyclical variations.

for 1898 and 1899, and the U.S. Census count serves for 1900. The annual estimates are shown in Table 2.¹⁷ Because Wing made no allowance for cyclical variation in 1880–86 and because it seemed best to add more firms before computing irregular and cyclical variation from 1887 to 1898, a linear trend of Cincinnati output was computed (column 1 of Table 3). The Cincinnati time series was then constructed by adjusting the trend values of output between the benchmark years of 1880 and 1898 for irregular and cyclical disturbances. To compute the index of irregular and cyclical variation, exponential trend lines were fitted to the time series of shipments of machine tools by (1) Brown and Sharpe and (2) Bullard for 1880–85, and by (1) Brown and Sharpe, (2) Bullard, and (3) Gray for 1886–1900.¹⁸ The indexes of irregular and cyclical variation were derived by computing the ratios of actual shipments to shipment trend values. An 1886 shipment value for Gray was estimated in order to obtain a better fit.

Reflections on the Foregoing Estimates

Except for inconsequential details, the Cincinnati data are consistent with McDougall's findings. Output of this essential category of capital goods was extremely volatile over the period 1880–1920, as indeed it has been since 1920.¹⁹ The rate of increase of output was likewise remarkable, in current dollars approximately doubling in the 1860's, trebling in the 1870's, and probably quadrupling in the 1880's.²⁰ Although this study did not develop a measure of pre-1900 price changes of metalworking machinery, large gains in real output, especially during the 1870's and 1880's, may be inferred from the current dollar figures. During the nineteenth century, manufacturers of metal-cutting and metal-forming tools set carefully reckoned prices on their wares and were not inclined to change them over a long period of years. Prices of machine tools in Cincinnati, for example, did not rise more than 10 or 15 per cent during the 1880's and were very

¹⁷ Details of this process of estimation may be obtained from Wing's Ph.D. dissertation at Indiana University.

¹⁸ The data for Brown and Sharpe and Bullard were obtained from McDougall's paper. McDougall has pointed out that Brown and Sharpe specialized in lighter machines and Bullard in heavier. Gray's output was similar to that of Brown and Sharpe. The year-to-year movements in shipments of the three companies showed remarkable similarity in amplitude and direction.

¹⁹ For recent data in convenient form, see Milton H. Spencer, "Demand for Machine Tools," *California Management Review*, Vol. 5, No. 4, 1963, pp. 75–84.

²⁰ My estimates of national output for 1880 and 1890 are, respectively, \$7.5 and \$32 million, the estimates being based largely on changes in Cincinnati and New England production over these decades. With the depressed years of the 1890's, the industry fell on bad days, estimated output for 1894 dropping to a mere \$11 million for the nation.

nearly constant during the 1890's. The rapid growth of the industry after 1860 was probably halted by the onset of depression in the 1890's; the industry was struck a tremendous blow by the slump in general activity. The automobile industry doubtless accounted in large part for the doubling of real output of metalworking machinery between 1900 and 1913. Stimulated by war demand both overseas and at home, real output approximately trebled between 1914 and the years of peak output, 1916 and 1918.

The small magnitudes of the output figures, even in the World War I period of soaring production, furnish evidence to support the proposition with which Nathan Rosenberg introduces his discussion of technological change in the machine tool industry.²¹ Even when the industry was booming, annual production of metalworking machinery amounted to but a small fraction of 1 per cent of the country's annual product. Clearly the importance of metalworking machinery as a variable in U.S. industrialization was out of all proportion to the dollar value of production of this crucial form of capital. The foregoing data furnish a telling example of the way in which qualitative change in the stock of capital dwarfs quantitative change as an influence on economic growth.

The output figures finally derived may indeed be biased on the low side. Any process of counting is almost certain to miss some items, and this likelihood becomes greater the farther back we go in time. Moreover, as both McDougall and I have observed, metalworking tools were for a long time made on an *ad hoc* basis by clever craftsmen who needed them, and the most diligent census-taker would never have included this part of output in his totals.

Any substantial improvement in nineteenth century time series must come from detailed investigation of narrowly defined product categories. Future research will require better cooperation from the Bureau of the Census. Inquiries addressed to Census officers invariably receive a polite response, but, with the single exception noted above, I have yet to obtain historical information from official Census sources that is not already available in published form. Indeed, on at least three occasions I was informed that original nineteenth century Census returns relevant to this study had been destroyed, only to discover a batch of them, filed in an apparently routine way, in a state library.

But the last great untapped resource of the historian dealing in economic quantities lies in the files of business firms. The problems of developing a national estimate before 1900 would be substantially reduced by the

²¹ Nathan Rosenberg, "Technological Change in the Machine Tool Industry," *The Journal of Economic History*, December 1963, pp. 414-443.

papers of only two firms in Worcester and two in Philadelphia.²² Even such modest results as were achieved would have been impossible without access to business records. It is only from such sources that time series like the one presented in this paper can be extended and refined. To be really useful, the points should be quarterly instead of annual, and they should reach back to the 1850's. The tenuous basis of inferring national output, particularly from 1860 to 1880, should be strengthened. If, as Friedman has suggested, time series are highly manufactured products, there is no reason why more of them, including this one, should not be given a better finish.

²² After more than two years of correspondence a few papers have been discovered in the files of the Farrel Corporation, successor firm to William Sellers and Company, and the Sellers Family Association of Ardmore, Pennsylvania, may provide some help.

TABLE A-1

EXPORTS OF METALWORKING MACHINERY WITH MAJOR COUNTRIES
OF DESTINATION, 1898-1920
(thousand dollars)

Year Ending June 30		Exports	Total	Year Ending June 30		Exports	Total
1898	Germany	1,670		1910	Germany	1,805	
	U.K.	1,461			U.K.	1,363	
	France	577			France	691	
	Belgium	252	4,619		Canada	336	5,976
1899	Germany	2,638		1911	Germany	2,524	
	U.K.	1,681			U.K.	2,319	
	France	741			France	963	
	Belgium	338	6,492		Canada	766	9,627
1900	Germany	2,480		1912	Germany	2,953	
	U.K.	1,883			U.K.	2,687	
	France	1,090			Canada	1,362	
	Belgium	656	7,193		France	1,268	12,152
1901	U.K.	1,482		1913	U.K.	3,418	
	Germany	1,035			Germany	3,175	
	France	441			Canada	2,326	
	Belgium	246	4,054		France	1,937	16,097
1902	U.K.	1,706		1914	U.K.	3,179	
	France	307			Germany	2,167	
	Germany	259			France	1,771	
	Belgium	117	2,977		Russia	1,335	14,011
1903	U.K.	1,309		1915	U.K.	12,295	
	France	375			France	8,696	
	Germany	318			Russia	2,489	
	Belgium	185	2,826		Canada	1,813	28,163
1904	U.K.	1,122		1916	U.K.	20,438	
	Germany	887			France	13,317	
	France	369			Russia	12,333	
	Belgium	282	3,717		Canada	6,464	61,315
1905	U.K.	1,038		1917	France	29,254	
	Germany	913			U.K.	16,300	
	Belgium	592			Russia	15,329	
	France	392	4,333		Italy	8,771	84,935
1906	Germany	1,814		1918	France	20,271	
	U.K.	1,361			U.K.	18,396	
	Italy	737			Italy	5,077	
	France	654	6,446		Canada	3,751	58,408
1907	Germany	2,245		1918 ^a	U.K.	9,833	
	U.K.	1,937			France	6,331	
	France	1,304			Canada	3,072	
	Italy	1,146	9,369		Japan	2,254	25,183
1908	Germany	1,935		1918 ^b	U.K.	19,296	
	U.K.	1,642			France	15,351	
	France	1,063			Canada	4,814	
	Belgium	702	8,696		Japan	4,047	51,620
1909	U.K.	952		1919 ^b	France	15,785	
	Germany	943			U.K.	15,210	
	France	307			Japan	5,383	
	Austria- Hungary	255	3,640		Canada	4,035	58,508
			1920 ^b	U.K.	10,999		
				France	7,596		
				Canada	5,815		
				Japan	4,251	44,312	

Source: *Commerce and Navigation of the United States.*

^a July 1 to Dec. 31.

^b Calendar year.

TABLE A-2

ALTERNATIVE COMPUTATIONS OF REAL OUTPUT OF METALWORKING MACHINERY, 1900-20

Year	Output of Metalworking Machinery in ^a Current Prices (mill. doll.) (1)	Cincinnati Price Index (Alternative ²) (1900=100) ^b (2)	Output of Metalworking Machinery in 1900 Prices (mill. doll.) (3)	Index of Real Output (Alternative 2) (1914=100) (4)	U.S. Price Index (Alternative 3) (1926=100) ^c (5)	Output of Metalworking Machinery in 1926 Prices (mill. doll.) (6)	Index of Real Output (Alternative 3) (1914=100) (7)
1900	24.7	100	24.7	66.8	37.6	65.7	61.2
1901	24.5	100	24.5	66.2	37.0	66.2	61.8
1902	29.8	100	29.8	80.5	39.0	76.4	71.3
1903	29.7	103	28.8	77.3	39.9	74.4	69.4
1904	21.7	103	21.1	57.0	40.0	54.3	50.7
1905	32.4	104	31.2	84.3	40.3	80.4	75.0
1906	42.1	118	35.7	96.5	41.4	101.7	94.9
1907	48.9	118	41.4	111.9	43.7	111.9	104.3
1908	20.4	122	16.7	41.5	42.1	48.5	45.2
1909	41.6	125	33.3	90.0	45.3	91.8	85.6
1910	56.2	125	45.0	121.6	47.2	119.1	111.1
1911	42.5	131	32.4	87.6	43.5	97.7	91.1
1912	58.8	131	45.0	121.6	46.3	127.0	118.5
1913	60.3	140	43.1	116.5	46.8	128.8	120.1
1914	48.9	132	37.0	100.0	45.6	107.2	100.0
1915	145.0	138	105.1	284.1	49.4	293.5	273.6
1916	198.2	186	106.6	288.1	62.0	319.6	298.0
1917	242.3	254	95.4	257.8	82.3	274.5	274.5
1918	321.2	311	103.3	279.2	101.2	317.4	295.9
1919	237.2	333	71.2	192.4	106.3	223.1	208.0
1920	225.9	380	59.4	160.5	116.5	193.9	180.7

NOTES TO TABLE A-2

^a Taken from Table 1.

^b Price index of metalworking machinery constructed from list prices of firms in the Cincinnati area. See George Wing's "History of the Cincinnati Machine-Tool Industry," unpublished Ph.D. dissertation, Indiana University. This method of computation was considered Alternative 2.

^c For 1900-13, the Bureau of Labor Statistics Wholesale Price Index--all commodities; for 1914-20, the American Appraisal Company's machine tool price index. The base year 1926 was used for both indexes. The BLS Wholesale Price Index was spliced to the American Appraisal Company's index by dividing each BLS index number from 1900 to 1913 by the ratio of the 1914 BLS price index number to the 1914 American Appraisal Company's index number, the ratio being 149.3 This method of computation was considered Alternative 3. However, the constant used for splicing was the average ratio of BLS to American Appraisal Company price indexes for 1915-20. These ratios ranged between 130 and 140, with a mean of 135.7. It was thought that the mean better represented the relationship between the two price indexes, and this second splicing alternative was used to adjust the BLS index numbers before computing the index of "real" output that was carried to Table 1.

