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The Democratization of Invention During Early Industrialization: Evidence from the United States, 1790–1846

KENNETH L. SOKOLOFF AND B. ZORINA KHAN

The skills and knowledge necessary for patentable invention during early American industrialization were widely dispersed among the general population. This endowment permitted a rather elastic supply of patentable ideas over the relevant range as the expansion of markets induced more individuals to invent and innovate. Although a broadening of the ranks of patentees was primarily responsible for the initial acceleration of patenting, the importance of patentees with greater long-term investments in inventive activity increased during later stages of development.

Exogenous advances in knowledge, and in its diffusion, have long figured prominently in discussions of the acceleration of invention during early industrialization. Some scholars believe that at least in the American and British cases, fundamental breakthroughs in technology yielded a profusion of secondary applications.[1] They hold that these major improvements in the stock of knowledge available to "would-be" inventors, or a shifting outward of the supply curve, were the primary source of the increase in invention. Others, however, emphasize how an unparalleled expansion of markets helped frame new problems for people with ordinary skills and knowledge to resolve, and induced growing numbers of them to invest more in inventive activity.[2]

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[1] For example, see Joel Mokyr, *The Lever of Riches: Technological Creativity and Economic Growth* (Oxford, 1990).

[2] Historians of American technology generally emphasize that much of the population was very familiar with the basic technology of the period. See David Hounshell, *From the American System to Mass Production, 1800–1932* (Baltimore, 1984). For studies of the rise in patenting, see Kenneth L. Sokoloff, "Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790–1846," this JOURNAL, 48 (Dec. 1988), pp. 813–50; H. I. Dutton, *The Patent System and Inventive Activity During the Industrial Revolution, 1750–1852* (Manchester, 1984); Christine MacLeod, *Inventing the Industrial Revolution: The English Patent System, 1660–1800* (Cambridge,

Research on the role of advances in knowledge in stimulating the early rise of inventive activity has been hampered by the difficulty of distinguishing empirically between the different kinds of knowledge at issue. We try to overcome this obstacle here by using information about American patentees, including their occupation, degree of specialization in invention, and long-term commitment to patenting, to draw inferences about the knowledge they had and about other individual attributes relevant to their inventive activity. The analysis of how the characteristics of patentees varied over time and place yields much insight into their participation in invention. Particular attention is devoted to the prevalence of technical skills or knowledge which, like specific human capital, were largely restricted to members of particular occupations or industries, costly to obtain, and scarce among the general population.

We argue that the growth in patenting during the beginning of American industrialization was marked by a disproportionate increase in invention by ordinary citizens operating with relatively common skills and knowledge rather than by an elite with rare technical expertise or extensive financial resources. It was only at a later stage of development that individuals and firms with substantial investments in technical knowledge and long-term inventive activity came to receive a dominant share of patents. This interpretation is based on findings of: (1) shifts in the distributions of patentees from merchants/professionals to artisans/tradesmen and from urban to rural residents; (2) a rising share of patents to patentees with few patents over their career; (3) low specialization among patentees, with no trend over the period; and (4) a pattern of individuals with few career patents and low specialization being disproportionately represented among patentees in transitional counties which had only recently experienced substantial increase in per capita patents. These results are consistent with the hypothesis that both the state of technology and widespread familiarity with its basic elements permitted a range of relatively elastic supply of invention, through the broader participation in inventive activity induced by the early expansion of markets.

A random sample of U.S. patent records from 1790 to 1846 is the chief source of data, although additional information on many of the patentees has been added to the original data set.[3] Among the new variables are the number of career patents, compiled from a complete listing of patents through 1846, and a measure of the degree to which each

1988); and Richard J. Sullivan, "England's 'Age of Invention': The Acceleration of Patents and Patentable Invention During the Industrial Revolution," *Explorations in Economic History*, 24 (Oct. 1989), pp. 424–52.

[3] For discussions of the data set, and of the patent system during the period, see Sokoloff, "Inventive Activity."

patentee was specialized in any of five sectoral classifications. We also use a special sample of so-called "great inventors." Our key assumption is that careful analysis of patent counts can provide a valuable indicator of inventive activity over the period under study. Many scholars have found patent data useful for this and related purposes.[4]

Patent counts are not without limitations however. At least three deficiencies are relevant to the analysis presented here. First, patents do not include the many inventions for which patents are either difficult to enforce or not obtainable. Since patents are easier to enforce when they pertain to a physical product or capital equipment, they overrepresent such inventions. For this reason the use of patents may exaggerate the relative significance of inventors with large investments in skills or other capital which helped in the development of inventions (invention-generating capital).[5] Second, institutional and cultural factors can alter the proportion of inventions which are ultimately patented. Finally, patents do not contain direct information on the value of the underlying ideas, and thus patent counts provide a less reliable indicator of the value of inventions being introduced than would a series weighted by value (either ex ante or ex post). These issues are serious, but we have tried to maintain a sensitivity to them throughout our analysis. Objections to our inferences should be examined in context.

I

A salient feature of the growth of patenting in early industrial America is that it was far from continuous. As is clear from Figure 1, patenting was cyclical, with virtually all of the increase between 1790 and 1846 realized during two concentrated intervals.[6] These periods of rapid growth were not stimulated by specific breakthroughs in technology. Instead, they seem related to macroeconomic events which promoted the expansion of markets. The first upswing in patenting began slowly during the prosperous 1790s, but accelerated during the years in which

[4] For a review of the economics literature using patent data, see Ariel Pakes and Margaret Simpson, "Patent Renewal Data," *Brookings Papers on Economic Activity: Microeconomics* (1989), pp. 331–401.

[5] Invention-generating capital encompasses any human and physical capital which raises productivity in inventive activity. Such capital can be either sector-specific or general in its effects. Individuals with large investments in such capital will presumably tend to focus on ideas which involve capital equipment—both because they may have a comparative advantage in such inventions and because private returns to such inventions are easier to appropriate. For an interesting treatment of the bias under patent systems toward inventions involving large-scale or capital equipment, see Stephen A. Marglin, "What Do Bosses Do?: The Origins and Functions of Hierarchy in Capitalist Production," *Review of Radical Political Economics*, 6 (Summer 1974), pp. 60–112. For estimates of manufacturing investment in capital equipment, see Kenneth L. Sokoloff, "Investment in Fixed and Working Capital During Early Industrialization: Evidence from U.S. Manufacturing Firms," this JOURNAL, 44 (June 1984), pp. 545–56.

[6] Jacob Schmookler, among others, noted the pro-cyclicality of patenting in *Invention and Economic Growth* (Cambridge, MA, 1966).

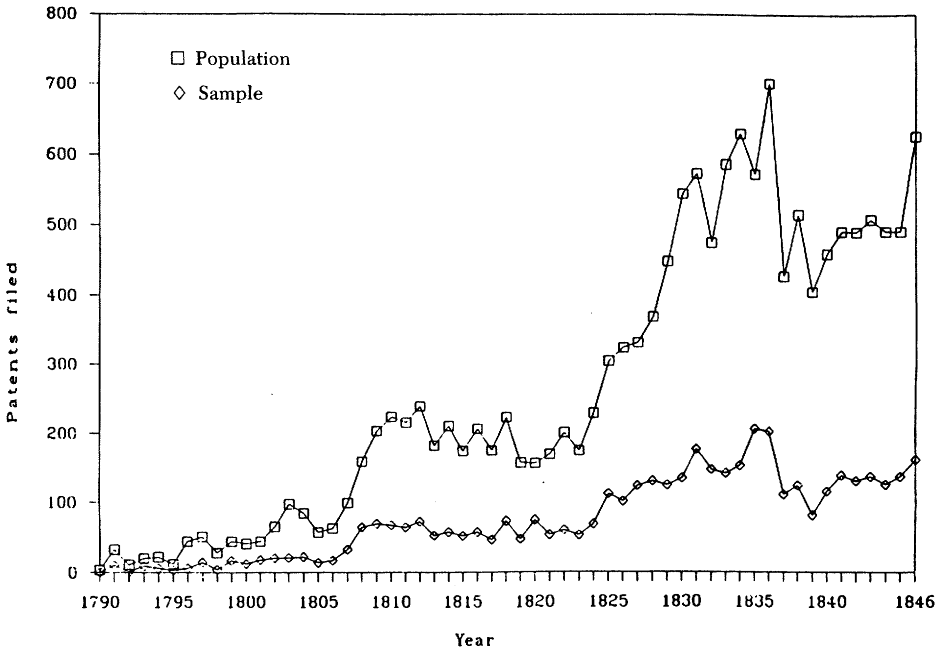

FIGURE 1

ANNUAL TOTALS OF PATENTS IN THE POPULATION AND THE SAMPLE, 1790–1846

British interference with shipping lanes and a series of non-importation acts, such as the Embargo of 1807, curtailed the supply of foreign manufactures. This interval of sustained increase in patenting was brought to an end by the War of 1812 and the long contraction which followed. The advent of the second span of rapid growth in patenting coincided with the economic recovery of the early 1820s. As the upturn in the economy continued, patenting increased steadily until a change in the patent system in July 1836 introduced more stringent requirements. The number of awards fell immediately, and then stabilized at this lower level for nearly eight years. It seems likely that the contraction, which began with the Panic of 1837 and persisted through the early 1840s, also played some role in accounting for this second spell of stagnation in patenting.

In general the tendency for patenting to increase during business expansions or episodes like the Embargo, which raised the effective demand for domestic manufacturers and encouraged the extension of domestic markets, is consistent with an emphasis on demand-induced advances in inventive activity.[7] This does not imply, however, that

[7] For more discussion of the Embargo period and cyclicality, see Sokoloff, "Inventive Activity"; Robert C. Allen, "Collective Invention," *Journal of Economic Behavior and Organization*, 4 (Mar. 1983), pp. 1–24; and Andrei Shleifer, "Implementation Cycles," *Journal of Political Economy*, 96 (Dec. 1986), pp. 1163–90. For a related theoretical treatment of trade and invention,

TABLE 1
DISTRIBUTION OF PATENTS BY PATENTEE COMMITMENT TO PATENTING, 1790–1846

Period	Number of Career Patents by Patentee					
	1 Patent	2 Patents	3 Patents	4 to 5 Patents	6 to 9 Patents	More than 10 Patents
1790–1804	77	35	12	20	17	6
	46.1%	21.0%	7.2%	12.0%	10.2%	3.6%
1805–1811	186	63	50	19	19	12
	53.3%	18.1%	14.3%	5.4%	5.4%	3.4%
1812–1822	388	117	50	51	35	42
	56.8%	17.1%	7.3%	7.5%	5.1%	6.2%
1823–1829	435	132	52	58	43	28
	58.2%	17.7%	7.0%	7.8%	5.8%	3.7%
1830–1836	686	190	95	100	80	45
	57.4%	15.9%	7.9%	8.4%	6.7%	3.8%
1836–1842	416	127	61	53	28	40
	57.4%	17.5%	8.4%	7.3%	3.9%	5.5%
1843–1846	329	96	48	39	13	19
	60.5%	17.7%	8.8%	7.2%	2.4%	3.5%
All Years	2,517	760	368	340	235	192
	57.1%	17.2%	8.3%	7.7%	5.3%	4.4%

Notes and Sources: Career Patents consists of the total number of patents filed between 1790 through 1846. The figure was compiled for each patentee in the sample from Edmund Burke, *List of Patents For Inventions and Designs Issued By the United States From 1790 to 1847* (Washington, 1847). For a description of the sample, see Kenneth L. Sokoloff, "Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790–1846," this JOURNAL, 48 (Dec. 1988), pp. 813–50.

supply conditions were irrelevant. On the contrary, if the level of technical knowledge previously available had not been sufficient to yield new inventions worthy of being patented (with expected private returns exceeding the cost of securing a patent), growth in market demand alone could not have produced much change in the number of patents filed. Hence the pro-cyclicality of patenting suggests that at least a significant portion of invention involved the application of known principles and techniques or modest extensions of them. In conventional economic terms the supply of patentable ideas must have been somewhat elastic, at least in the short run.

Another perspective is provided by Table 1, which presents the distribution of patents over time by classes of patentees, the latter defined by using the total number of patents ever received as a measure of long-term commitment to patenting.[8] The most important finding here

see Paul M. Romer, "Endogenous Technological Change," unpublished working paper (Chicago, 1989).

[8] Patentees active at the beginning or end of the period might have patentable ideas unrecorded in our data and accordingly have their career patents (or would-be patents) undercounted. Although careful examination indicated that patentees active after 1842 suffered from this problem

is the growing prominence of patentees with only one or two patents over their career. Whereas patentees with only one career patent took out 46.1 percent of those awarded between 1790 and 1804, their share rose to 53.3 percent during the Embargo years and remained in the high fifties and low sixties through the 1840s. This change implies that patentees with relatively small long-term investments in inventive activity responded most strongly to whatever conditions were responsible for the economy-wide increase in invention and innovation. Their sensitivity to economic conditions is shown by the contrast between the pro-cyclicality of their activity and the virtual absence of pro-cyclicality on the part of those with many awards as reflected here in the sharp rises in the share going to patentees with 10 or more patents during the two prolonged economic downturns (averaging 64 percent).

The increase in the proportion of patents granted to individuals with few career patents raises questions about how significant technical skills and knowledge were in accounting for the growth of inventive activity during the period. After all, if investment in such human capital helped generate patentable ideas (implying, on average, that patentees with more career patents had more of this human capital), and if this advantage became larger over time as technology advanced, then one would expect patentees with many career patents to have garnered an increasing share. Moreover, the same logic should apply to improvements in the diffusion of knowledge: if individuals with substantial investments in technical skills and knowledge were better equipped to understand and act on the significance of new information, then their share of patents should have risen with a geographically wider diffusion of information. Given that the proportion of patentees with multiple career patents actually declined, however, it would appear that the developments most central to the growth in patenting during the era were those which stimulated individuals with relatively modest amounts of such invention-generating capital.

It is true that patentable ideas vary enormously in both private and social returns and that the larger share of patents does not necessarily indicate an increase in the relative value of inventions contributed by "low-commitment" patentees. Indeed, some would assert that these patentees produced few important inventions and were responsible for low-value patents only. This possibility is difficult to evaluate with our current data, but indirect evidence bears against it. Since the 1836

(biasing estimates downward), no such effect was detected for those who filed before. Hence only the observations from 1843 on are suspect and deleted from the regressions below. Since any bias during the 1790s would work against us, no adjustments were made there. The 1836 change in the patent system could also explain some decline in the average number of career patents, but since most of the shift toward patentees with few patents was realized during the Embargo, it is unlikely that either this change or the cutoff at 1846 could provide an adequate explanation.

TABLE 2
DISTRIBUTION OF URBAN PATENTS BY PATENTEE OCCUPATION

	1790–1804	1805–1822	1823–1836	1836–1846
General Commerce and Professional	13	60	59	43
(merchants, doctors, gentlemen)	50.0%	38.7%	24.6%	18.6%
Artisans Working with Renewable	4	32	58	41
Materials (carpenters, shoemakers)	15.4%	20.7%	24.2%	17.8%
Precision Artisans (makers of	5	16	22	26
watches, jewelry, instruments)	19.2%	10.3%	9.2%	11.3%
Machinists/Toolmakers	1	17	34	40
	3.9%	11.0%	14.2%	17.3%
Other Producers/Dealers of Metal	2	17	40	49
Products (stove manufacturers, blacksmiths)	7.7%	11.0%	16.7%	21.2%
Other Occupations or None Listed	1	13	27	32
	3.9%	8.4%	11.3%	13.9%

Notes and Sources: Table 2 reports the number and share of patents filed by patentees of each occupational category during four subperiods. The occupations for 444 patentees were retrieved from various issues of city directories. Since the surviving directories are disproportionately from later years, it was easier to establish the occupation for patentees who were active later. Hence the increase in the number of patentees covered over time is not significant. Among the cities represented in this table are Albany, Buffalo, New York, Rochester, Troy, and Utica in New York; Newark in New Jersey; Bangor and Portland in Maine; Philadelphia and Pittsburgh in Pennsylvania; Baltimore in Maryland; Boston, Newburyport, and Salem in Massachusetts; Providence in Rhode Island; and Hartford and New Haven in Connecticut. The third subperiod runs through July 3, 1836, when the patent law was changed. Of the 1,057 patents in the sample awarded to residents of these cities over the entire period, occupations were retrieved for 458 (or 43.3 percent) of the respective patentees (with many patentees responsible for more than one patent). See the note to Table 1.

change in the patent law tightened requirements for an award, had individuals with few career patents filed patents of lower average quality, the new standards would have screened out a larger fraction of their applications. As their share did not decline, this rough test supports the inference about the increased role of inventions from those with few career patents.

Dividing patentees into occupational groups, as Table 2 does for an urban subset, reveals a major shift over time from a predominance of men of commerce to one of artisans and the like. Merchants and professionals were by far the most active up to the Embargo, with half of urban patents, but saw their proportion fall to less than one in five by the late 1830s and 1840s.[9] Since rural patentees, few of whom were merchants, also increased their share over time, the overall occupational shift was even stronger than these urban data alone indicate.

One interpretation of this change in the occupational composition is that it reflected an opening up of opportunities for deriving returns from

[9] The lack of information about the occupations of individuals who did not receive patents, as well as for most of the sample, raise questions about the interpretation of the regressions presented below.

invention. Prior to the Embargo, when domestic markets were less developed, the bulk of patenting was carried out by merchants and men of similar occupations, who were best placed to make commercial use of good ideas. Not only did they have the most direct access to wider markets, but they also were more likely to control financial resources to support inventive activity and innovation. Francis Lowell, founder of the Boston Manufacturing Company, epitomizes this class of merchant. Having decided to expand from a profitable base in foreign trade into textiles, he and a fellow merchant proceeded, without previous mechanical experience, to study the existing technology and construct their own power loom. For the most part enterprises such as Lowell's were inspired by superior business acumen, not advanced technical knowledge.

With the growth of domestic markets more and more individuals began to compete to satisfy extensive demand for their products, as well as to exploit expanded opportunities for extracting returns from invention. These developments should have boosted invention and patenting throughout the population, but such gains were likely proportionally higher for occupational groups other than commerce because they had less previous experience with the opportunities and pressures of large markets.[10] It is hardly surprising, therefore, that the major rise in patents per capita was accompanied by a shift in the occupational mix of patentees.

Prior to the Embargo the more technical groups, such as machinists and metalworkers, whose skills and knowledge were scarce and costly to acquire, received only 3.9 and 7.7 percent respectively of patents.[11] Their relative significance among urban patentees did increase substantially over time, perhaps signaling an enhanced importance of a technical background for effective invention, but even by the 1840s, when mechanization was spreading quickly, their shares had risen to only 17.3 and 21.2 percent. The totals are large, but their impact is diminished somewhat when one remembers that machinists and metalworkers/dealers were certainly overrepresented among urban patentees as compared to the general population of patentees and that the share of patents going to urban centers had declined.[12] Given these caveats, and the relatively few patents awarded to these trades before the 1830s, it is doubtful whether breakthroughs in machine and metalworking technology alone could go far in explaining the rise in patenting during the early

[10] Part of the trend in the occupational distribution may be due to the development of markets which eased capital requirements. See Dirk J. Struik, *Yankee Science in the Making* (Boston, 1948). Also see MacLeod, *Inventing the Industrial Revolution*, chap. 7, for evidence of a similar trend in England.

[11] Commercial patentees may have patented ideas conceived by others.

[12] Metropolitan patentees received 31.3 percent of all patents during 1805–1811, but only 22.1 and 28.0 percent in 1830–1836 and 1836–1842.

nineteenth century. Rather, this progress depended more on the problem-solving abilities of a kind pervasive among artisans of the era. As George Gibb suggested, "varied and dextrous mechanical abilities were all but universal . . . the Industrial Revolution in its infancy produced surprisingly few basic technical skills not already familiar to American mechanics."[13] Indeed, the major inventions of the age, such as Whitney's cotton gin or Blanchard's lathe, were typically based on commonly available information applied to a specific problem.

Another way to explore the significance of technical skills and knowledge is to examine the extent of specialization by patentees. One would expect most technical knowledge at the frontier to be sector-specific or limited in direct applicability to inventions in the same sector.[14] Hence, if such human capital did raise the productivity of inventive activity in a particular sector, and was costly to acquire, a patentee who had invested in it would tend to concentrate his efforts, as well as his patents, in that sector. For example, individuals who had acquired an expertise in power looms or sewing machines would tend to file manufacturing patents, as opposed to ones in agriculture, construction, transportation, or miscellaneous (the other four sectors in our classification). In short, the more important these sector-specific skills and knowledge, the more specialized by sector the patents of inventors were likely to be.

In Table 3 we present estimates of the proportions of patentees who were specialized—with over 75 percent of their patents in any one of the five sectors—for both the general sample and the sample of "great inventors." Opinions may vary when there is no clear standard for comparison, but the percentages seem rather low, especially during the early years when barely over half of the patentees with two patents were specialized. Even the "great inventors," who might be expected to possess highly specialized knowledge, were only slightly more specialized than the average.[15] Overall, the modest proportions of specialized patentees imply that much of the human capital tapped by inventors could be applied to problems in a wide variety of economic activities.

[13] George S. Gibb, *The Saco-Lowell Shops* (Cambridge, MA, 1950), p. 10.

[14] Although some patentable inventions could be used in more than one sector, our sectoral classification mitigates the potential mismeasurement of specialization. We were consistent about classifying closely related inventions in the same sector. Hence even though a patentee might have registered several patents for steam engines to be used in different sectors, all of his patents would be in the same category, and he would be considered specialized. Inclusion of dummy variables for sectors in the specialization regressions below did not alter the qualitative results.

[15] Dutton argued that patentees during early British industrialization were not very specialized. Although his estimates of the degree of specialization are not directly comparable, American patentees seem to have been less specialized. His data also imply that British patents were more concentrated among patentees with many career patents than U.S. patents were. Many factors may contribute to these differences, including the much higher cost of securing a patent in Britain. See Dutton, *The Patent System*, chap. 6.

TABLE 3
SPECIALIZATION OF PATENTEES IN THE SAMPLE AND AMONG GREAT INVENTORS

Patentees with		1790–1822 Sample	1790–1822 Great Inventors	1823–1846 Sample	1823–1846 Great Inventors
Two Patents	%	52.2%	62.5%	57.7%	66.7%
	N	113	8	248	21
Three Patents	%	25.6%	70.0%	43.1%	58.8%
	N	39	10	65	17
Four or More Patents	%	32.3%	30.8%	46.5%	50.0%
	N	31	26	43	44

Notes and Sources: The figures report, for the general sample and for a special group of "great inventors" responsible for especially notable patents, the number of patentees in each cell, and the proportion with over 75 percent of their patents in one of five sectors: agriculture, construction, manufacturing, transportation, and other. The number of patents refers to the total appearing in the sample. Hence the numbers of patentees with three patents refer to those individuals who had three patents appearing in the sample. The analogous percentages for all patentees with two or more patents in the sample are 40.0 percent during 1790–1822 and 52.1 percent during 1823–1846. For information on the general sample, see the note to Table 1. The list of 129 "great inventors" was drawn from inventors appearing in the *Dictionary of American Biography* (New York, 1937); and *Who Was Who in America: Historical Volume, 1607–1896* (Chicago, 1963).

Most of the skills and knowledge needed for patentable invention appear to have been either of general applicability or easily acquired.

Although these figures hint at an increase in specialization over time, the multivariate regressions presented in Table 4 reveal no trend (judging from the insignificant time period dummies). The stationary pattern may seem surprising because it conflicts with the normal conceptions of what the advance of knowledge and the development of markets lead to, but it is robust to whatever other variables are controlled for. Skeptics may question whether our measure is actually picking up specialization, but confidence in the analysis is bolstered by the finding that the degree of specialization was greater among occupations associated with technical knowledge (such as machinists), among individuals with a high career commitment to patenting (beginning to rise with six patents), and for "great inventors." All conform well with our expectations about the relationship between investments in invention-generating capital and specialization.

As patenting increased over time, two streams of development might offset each other in the time trend. On the one hand the expansion of markets, which both enhanced the commercial value of inventions and enlarged the population who could benefit from patents, attracted new patentees whose long-term investments in invention-generating capital were relatively modest and whose efforts were accordingly not as specialized as those of their more committed peers. On the other, a growing competitive advantage to technical skills and knowledge may have served over time to promote greater investment in such sector-

TABLE 4

REGRESSIONS OF SPECIALIZATION IN PATENT SECTOR, 1790–1846

Dependent Variable: Percent Specialization of Patentee	(1)	(2)	(3)	(4)
Constant	106.864	79.829	79.056	81.615
	(16.53)	(9.66)	(9.09)	(9.83)
Proportion of Labor Force in Manufacturing	−1.134	−0.176	−0.140	−0.171
	(−1.61)	(−2.12)	(−1.69)	(−2.07)
Log (Annual Patents per Million in County)		7.828	7.729	7.839
		(5.15)	(5.16)	(5.16)
(Number of Patents Over Which Index Computed)^2	0.984	0.940	1.032	1.024
	(3.84)	(3.72)	(4.12)	(4.00)
Number of Patents Over Which Index Computed	−12.00	−11.869	−12.945	−12.774
	(−4.98)	(−4.97)	(−5.46)	(−5.26)
Time Dummies				
1790–1804	−2.143	4.819	5.048	4.326
	(−0.44)	(0.97)	(1.02)	(0.87)
1805–1822	−3.542	−3.487	−2.155	−3.337
	(−1.46)	(−1.45)	(−0.90)	(−1.40)
1823–1836	3.411	1.095	2.066	1.318
	(1.63)	(0.52)	(0.99)	(0.62)
Regional Dummies				
N. New England	1.433	−2.769	−1.761	−3.119
	(0.32)	(−0.61)	(−0.40)	(−0.69)
S. New England	−2.063	−8.002	−8.969	−9.112
	(−0.72)	(−2.61)	(−2.96)	(−2.93)
New York	1.492	−2.093	−2.333	−2.453
	(0.55)	(−0.75)	(−0.85)	(−0.88)
S. Middle Atlantic	4.401	4.145	5.162	3.485
	(1.31)	(1.25)	(1.56)	(1.05)
Urbanization Dummies				
Urban	5.366	4.687	3.636	4.035
	(2.59)	(2.29)	(1.79)	(1.95)
Metropolitan	1.389	−4.662	−7.531	−4.379
	(0.66)	(−1.94)	(−3.07)	(−1.82)
Transportation Dummies				
Located on Navigable River or Canal	−7.669	−8.284	−7.006	−8.447
	(−2.36)	(−2.57)	(−2.20)	(−2.63)
Located on Ocean	−14.531	−14.087	−13.418	−13.032
	(−3.40)	(−3.33)	(−3.21)	(−3.06)
Occupational Dummies				
Commerce/White Collar			2.475	
			(0.81)	
Traditional Artisan			7.901	
			(2.83)	
Machinist/Toolmaker			13.030	
			(3.63)	
Metalworker/Dealer			20.234	
			(4.64)	
Great Inventor Dummy				6.090
				(2.00)
R^2	0.093	0.114	0.144	0.117
N	1,016	1,016	1,016	1,016

Notes and Sources: The regressions were estimated over all of the individual patent records for patentees in northeastern states who had more than one patent appearing in the sample. The constant refers to a patent filed during 1836–1846 in a rural Pennsylvania county without access to a navigable waterway by an individual for whom either no occupation was retrieved or whose occupation was different from those represented by the occupational dummy variables. The traditional artisan category refers to artisans who worked with nonmetallic raw materials or did fine crafts such as jewelry or watchmaking. For a discussion of the sample, see Kenneth L. Sokoloff, "Inventive Activity in Early Industrial America: Evidence from the Patent Records, 1790–1846," this JOURNAL, 48 (Dec. 1988), pp. 813–50, and the notes to Tables 1 and 2. Regression coefficients are reported, with *t*-statistics in parentheses below.

specific human capital and greater specialization, particularly by patentees in districts with highly developed and competitive markets. As long as the former mechanism continued to operate with sufficient strength, it might on average net out the effect of the latter in the aggregate pattern.

The regression results are consistent with this perspective. They suggest that patentees from rural counties on navigable waterways were less specialized than their counterparts in counties without such low-cost transportation. This finding is of special interest because the transitional nature of these counties captures an important stage in the process by which levels of inventive activity rose during early industrialization. As documented in previous work, rural counties realized substantial and rapid increases in patents per capita as they gained access to waterways.[16] Moreover, cities invariably emerged in these counties along the water routes, boosting patenting rates further. Whereas inventive activity appears to have risen continually once the extension of the waterways opened up an area to wider markets, the pattern of coefficients in these regressions implies that the degree of specialization by patentees did not move solely in one direction. Indeed, because the coefficient on the waterway dummy is large and negative, and those on the urban and patents per capita variables positive, the evidence indicates that the average patentee became less specialized when water transportation first became available, but that this change was reversed over time as urbanization and further investment in inventive activity progressed. Although other explanations are possible, the above hypothesis seems straightforward. With the initial phase of the increase in patenting driven by an increase in the proportion of the population awarded patents, the influx of new inventors produced a temporary shift in the composition of patentees towards individuals who had no major investments in sector-specific capital and were accordingly less specialized. During the later phases, as local populations adjusted to the greater opportunity and competition of an urban and extensive market, residents made larger investments in invention-generating capital, and focused more on their particular niches.

In Table 5 we present regressions with the log of the number of patents ever received by the patentee as the dependent variable. They reinforce the univariate analysis in indicating that the early acceleration of inventive activity was associated with a disproportionate rise in patenting by individuals without much of a previous record in invention. Perhaps most telling is the robust finding that career patents per patentee peaked during 1790–1804. In all of the specifications estimated, the coefficient on the dummy for these years was positive and statistically significant, while those for later subperiods were close to zero and

[16] See the discussion in Sokoloff, "Inventive Activity," pp. 830–47.

TABLE 5
REGRESSIONS OF NUMBER OF LIFETIME PATENTS, 1790–1842

Dependent Variable: Log of Lifetime Patents to Patentee	(1)	(2)	(3)	(4)
Constant	0.275	−0.048	−0.023	−0.026
	(3.27)	(−0.41)	(−0.20)	(−0.24)
Proportion of Labor Force in	0.001	0.001	0.002	0.000
Manufacturing in County	(0.83)	(0.52)	(1.35)	(0.41)
Log (Annual Patents per		0.100	0.080	0.098
Million in County)		(3.98)	(3.25)	(4.20)
Time Dummies				
1790–1804	0.192	0.287	0.273	0.328
	(2.16)	(3.12)	(3.04)	(4.03)
1805–1822	0.030	0.028	0.039	0.049
	(0.66)	(0.61)	(0.88)	(1.15)
1823–1836	0.027	−0.011	0.025	0.002
	(0.65)	(−0.27)	(0.60)	(0.05)
Regional Dummies				
N. New England	0.074	0.042	0.059	0.075
	(1.08)	(0.61)	(0.89)	(1.20)
S. New England	0.213	0.138	0.119	0.072
	(4.31)	(2.62)	(2.31)	(1.47)
New York	0.139	0.095	0.102	0.067
	(3.03)	(2.02)	(2.21)	(1.57)
S. Middle Atlantic	0.107	0.111	0.158	0.166
	(1.71)	(1.77)	(2.58)	(2.79)
Urbanization Dummies				
Urban	0.186	0.185	0.142	0.142
	(5.32)	(5.31)	(4.13)	(4.34)
Metropolitan	0.116	0.025	−0.088	−0.055
	(2.85)	(0.54)	(−1.88)	(−1.28)
Transportation Dummies				
Located on Navigable	−0.001	−0.021	−0.026	−0.020
River or Canal	(−0.01)	(−0.41)	(−0.52)	(−0.44)
Located on Ocean	−0.010	−0.022	−0.052	−0.060
	(−0.13)	(−0.32)	(−0.78)	(−0.97)
Occupational Dummies				
Commerce/White Collar			0.605	0.492
			(8.60)	(7.37)
Traditional Artisan			0.259	0.224
			(4.23)	(3.83)
Machinist/Toolmaker			0.830	0.607
			(9.16)	(7.72)
Metalworker/Dealer			0.420	0.330
			(3.98)	(3.19)
Great Inventor Dummy				1.009
				(18.13)
R^2	0.035	0.040	0.090	0.211
N	2,957	2,957	2,957	3,140

Notes and Sources: The first three regressions were estimated over all of the patents in the general sample; the data for the fourth regression also included the additional observations from the "great inventors" sample. The constant refers to a patent filed during 1836–1842 in a rural Pennsylvania county without access to a navigable waterway by an individual for whom either no occupation is available or whose occupation is different from those represented by the occupational dummies. See the note to Table 4.

insignificant. Evidently the decrease in the number of career patents for the average patentee during the Embargo years, when there was the first major surge in patenting, was sustained afterwards.

Although the time trend shows a decline to a lower plateau, most of the other coefficients suggest that career patents increased with conditions normally associated with development. For example, career patents were higher in urban and metropolitan areas, in counties in which patents per capita were higher, and in Southern New England and New York—the most economically developed regions. A variety of explanations could be offered for the greater commitments to patenting in such districts, including differences in occupational composition or the responses of individuals to the greater opportunities derived from larger markets and richer supplies of capital and information. Whatever the particular source, however, the small coefficient on local patents per capita implies that most of the variation in patents per capita across place and time was due to differences in the proportion of the population who patented, not to differences in the number of patents per patentee.[17]

This aspect of the spread of high levels of inventive activity during early industrialization is reflected in the performance of the dummy variable for proximity to a navigable waterway. Although such access to transportation raised county-level patents per capita between 55 and 90 percent, the regression in column 1 indicates that it did not lead to any immediate increase in career patents per patentee. Again it appears that the growth of patenting in rural counties when they were first opened up to low-cost transportation was realized virtually exclusively through individuals with limited experience in patenting. These additional patentees were like their more isolated peers in terms of their long-term commitment to invention, but there were many more of them in proportional terms.[18] Notions that the early rise in inventive activity was confined to a technical elite who were best positioned to recognize and exploit new information do not, therefore, seem to capture what happened during the first stage of the transition in rural counties.

Although individuals with a small number of career patents accounted for most of the growth in patents per capita, the regressions demonstrate that individual investments in invention-generating capital, as proxied by occupation, did yield more patentable ideas. This is a crucial point, because the inferences drawn about long-term commitments to invention from information on career patents rest on an assumption that such returns were present. The evidence consists of the large positive

[17] Accounting decompositions of the differences between metropolitan, urban, and rural counties, or between regions, yield the same conclusion.

[18] Those on waterways were less specialized, however, perhaps because they changed their livelihoods after the opening to the wider market.

coefficients on the dummy variables for machinists, metalworkers/dealers, and "great inventors," classifications we associate with investments in technical or specialized knowledge. Moreover, the greater number of career patents among inventors in commerce and the professions may reflect other sorts of investment which encouraged the development and use of patentable ideas.

II

The beginning of rapid growth in inventive activity in the United States coincided with a substantial broadening of the segments of the population who participated in patenting. Indeed, nearly all of the rise in patenting per capita during the early nineteenth century was produced by the increased proportion of the population who patented, as awards became less concentrated among commercial/professional occupations, urban residents, and individuals with multiple career patents. This shift in the distribution of patentees was especially pronounced in transitional counties which had gained access to water transportation but lacked significant urban centers. At a later stage, activity may have shifted back toward patentees with more career patents, especially in the more developed areas, because the occupational composition of the population changed and returns to investment in invention-generating capital rose.

One of the implications of these results is that the skills and knowledge necessary for patentable invention at the beginning of industrialization were widely dispersed among the population. Although training in technical occupations did yield more patents for individuals, such backgrounds were not at all required. The state of technology combined with the endowment of the population evidently permitted a rather elastic supply of patentable ideas. These special circumstances undoubtedly made it easier for the economy to realize major and broadly based increases in invention and productivity growth, once conditions raised the private return to inventive activity and encouraged a reallocation of resources in that direction.[19]

All of this enhances our understanding of the record of inventive activity, but the fundamental issue still remains. What do these patterns indicate about the source of the sharp rise in patenting during the early nineteenth century? The answer will certainly not be as simple as the question, but it is clear that the explanation will have to focus on what pulled men with relatively common skills and knowledge into invention. For this reason, the new evidence makes it more difficult to maintain that exogenous advances in technical knowledge, or in its diffusion,

[19] See Kenneth L. Sokoloff, "Productivity Growth in Manufacturing During Early Industrialization: Evidence from the American Northeast, 1820–1860," in Stanley L. Engerman and Robert E. Gallman, eds., *Long-Term Factors in American Economic Growth* (Chicago, 1986).

drove the beginning of the process. Instead, we would highlight the disproportionate response of "low-commitment" individuals during the period overall, and particularly in transitional counties. The case is not yet closed, but the greater sensitivity of this key group of patentees to economic conditions provides further evidence that the expansion of markets was a powerful inducement to the increase of inventive activity during early American industrialization.