"Schemes of Practical Utility": Entrepreneurship and Innovation Among "Great Inventors" in the United States, 1790–1865

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The growth in inventive activity during early American industrialization is explored by examining the careers of 160 inventors credited with important technological discoveries. Analysis of biographical information and complete patent histories through 1865 indicates that these "great inventors" were entrepreneurial and responded systematically to market demand. Their inventions were procyclical and originated disproportionately from localities linked with extensive markets. Although unexceptional in terms of schooling or technical skills, they vigorously pursued the returns to their inventions, redirected their inventive activity to meet emerging needs, and were distinguished by high geographical mobility toward districts conducive to invention and its commercialization.

A central and long-standing question about the process of economic growth is the extent to which technical change responds to market forces or is otherwise endogenously determined. Some scholars believe that the timing of important inventions is typically due to chance or to the logical evolution of technical knowledge, and depict the individuals responsible as geniuses or eccentrics inspired by motives other than material gain. Even when conceding that incremental improvements, or "microinventions," might be induced by material incentives, they continue to hold that important discoveries, or "macroinventions," are largely exogenous with respect to market demand.[1] An alternative perspective regards all inventions as probabilistic outcomes of investments in inventive activity that are influenced, like any other investment, by an assessment of the potential financial returns. In this view, circumstances that enhance the expected net return to inventive activity, such as the characteristic expansion of markets during the initial

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[1] Joel Mokyr, *Lever of Riches*.

stages of industrialization, tend to stimulate higher rates of inventio and technical change.[2]

To better evaluate the sources of important technological advance this article examines a set of detailed information about the lives an careers of "great inventors" active in early industrial America. Instea of establishing that technologically significant discoveries were independent of demand conditions, the evidence indicates that they were lik ordinary patents in being procyclical and in originating disproportionately from geographic areas linked to extensive markets. Moreover, th "great inventors" were not exceptionally well endowed in terms o formal education or technical skills. Rather, they were distinguished b entrepreneurial abilities, for they were responsive to perceived deman and economic incentives, systematically invested in inventive activit rather than engaging in noneconomically oriented tinkering, and actively pursued the returns to their discoveries. Overall, their experienc lends strong support to the view that the expansion of markets durin early American industrialization induced a broad segment of the population increasingly to commit resources to inventive activity, which i turn raised the rate of technical change.

THE CHARACTERISTICS OF "GREAT INVENTORS" AND THEIR PATENTING

Our sample of "great inventors" consists of 160 individuals credite with at least one important invention between 1790 and 1846 b biographical dictionaries and histories of technology.[3] The data se includes complete patent histories through 1865 as well as informatio on place and date of birth, schooling, occupation before and after majo inventions, efforts to extract income from their discoveries, and othe variables. The 150 inventors who were also patentees received 1,17 patents, or somewhat less than 2 percent of the total awarded over th period.

One of the salient features of the great inventors is how similar thei patterns of patenting were to those of ordinary patentees. Most significant, perhaps, is the finding that important inventions resemble patents in being strongly and positively associated with the extent o markets. Like patentees in general, the great inventors were disproportionately concentrated in the Northeast, and especially in Souther New England and New York, where low-cost transportation network had facilitated a rapid expansion of commerce early in the antebellu period. This geographic distribution was characteristic of where the

[2] Schmookler, "Economic Sources" and *Invention and Growth*; also see Sokoloff, "Inventiv Activity" and "Invention, Innovation, and Manufacturing Productivity."

[3] The sample is drawn from Malone, *Dictionary of American Biography*; also refer to ou Appendix.

TABLE 1
REGIONAL SHARES OF PATENTS, GREAT INVENTOR PATENTS, AND POPULATION, 1790–1865

Region	1790–1825	1826–1845	1846–1865
Northern New England			
Patents	6.0	8.4	4.1
Great inventor patents	11.4	6.0	2.7
Population	9.2	6.7	4.5
Southern New England			
Patents	24.4	19.4	20.1
Great inventor patents	43.4	30.9	27.0
Population	11.8	7.2	6.1
New York			
Patents	30.3	32.5	28.8
Great inventor patents	15.4	37.3	35.2
Population	12.9	14.5	12.7
Pennsylvania			
Patents	14.9	13.1	11.7
Great inventor patents	10.9	6.7	5.1
Population	11.2	10.2	9.5
Southern Middle Atlantic			
Patents	12.6	7.0	6.6
Great inventor patents	10.3	8.7	15.2
Population	10.3	6.0	5.0
Other United States			
Patents	11.9	18.3	26.5
Great inventor patents	8.6	9.0	14.5
Population	44.7	55.4	62.2
Foreign			
Patents	0.1	1.5	2.2
Great inventor patents	0.0	1.5	0.3
Population	—	—	—

Notes and Sources: All figures represent percentages of the totals. The population figures were interpolated for the midpoints of the respective time periods. See the Appendix for sources.

filed their patents (see Table 1) as well as where they were born. The correspondence holds not only at the state level but also at the county level, where great inventors were even more concentrated than the ordinary patentees in counties with high rates of general patenting.

The procyclicality of both great inventor patents and overall patents during the antebellum period provides further support for the thesis that inventive activity responded to market conditions.[4] As Figure 1 shows, the two annual series track each other closely, with rapid growth during the years of interruptions in foreign trade prior to the War of 1812, as well as during the economic expansions from the early 1820s to the mid-1830s and in the 1850s. Moreover, they both exhibit periods of stagnation or slight decline during the protracted economic downturns

[4] An extended treatment appears in Sokoloff, "Inventive Activity," and Sokoloff and Khan, "Democratization." The number of great inventor patents shown in Figure 1 declines after 1846 relative to all patents because of the bias introduced by including only inventors whose first invention had occurred by that year.

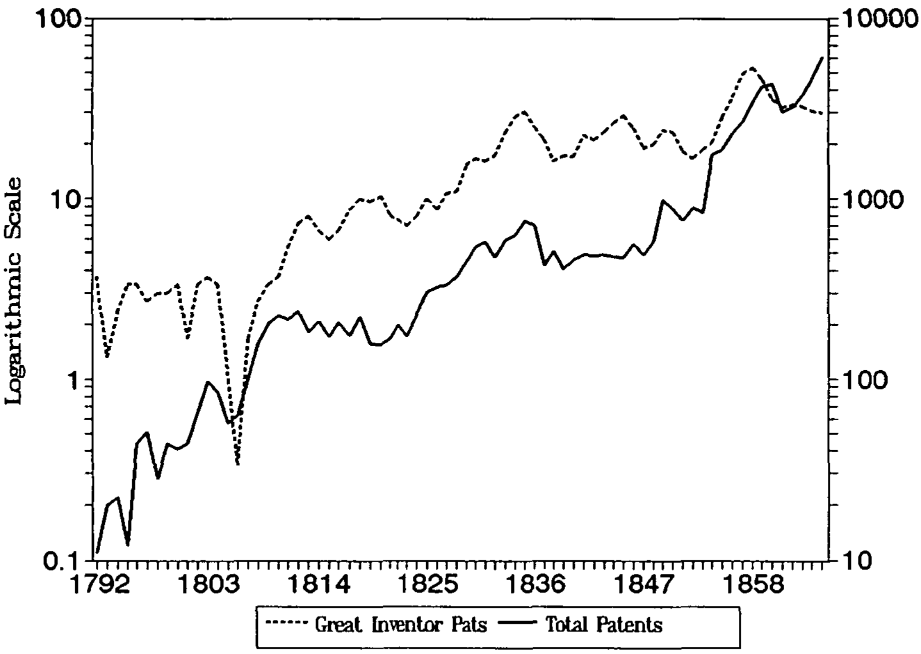

FIGURE 1

ANNUAL TOTALS OF ALL PATENTS AND OF GREAT INVENTOR PATENTS, 1792–1865

Notes and Sources: Annual totals are three-year moving averages. See the Appendix for sources.

following the War of 1812 and the panic of 1837. This evidence suggests that, far from being exogenous, inventive activity by great inventors was influenced by much the same market-related forces as invention by ordinary patentees.

In previous work we have argued that both the procyclicality and the geographic clustering of patenting in areas with low-cost access to major economic centers were consistent with the responsiveness of inventive activity to market conditions during early industrialization.[5] It is of course possible that the clustering was partially due to geographic variation in population characteristics related to inventive potential, such as the level of education or the distribution of technical skills. Judging from the experience of the great inventors, however, such supply-side variables do not offer much explanatory power. As Table 2 makes clear, higher education was hardly a prerequisite for producing important inventions. Nearly half of the sample had little or no formal schooling, and less than a quarter attended college.[6] The latter were certainly overrepresented relative to the general population, but they tended to be merchants or professionals with credentials in law or the

[5] Sokoloff, "Inventive Activity."

[6] Inventors whose extent of schooling is unknown seem likely to have had low levels of education.

TABLE 2
PERSONAL CHARACTERISTICS OF THE GREAT INVENTORS

Characteristics	Number	Percentage
Educational background		
None to several years of schooling	76	47.5
More than several years	22	13.8
Attended college	38	23.8
Unknown	24	15.0
Occupational class at first major invention		
Artisan	24	15.0
Farmer	8	5.0
Engineer/machinist/full-time inventor	53	33.1
Merchant/professional	36	22.5
Manufacturer	37	23.1
Other/missing	2	1.3
Age at first major invention		
<20	9	5.6
20–29	41	25.6
30–35	42	26.3
36–40	26	16.3
41–45	13	8.1
46–55	21	13.1
>55	8	5.0
Duration (in years) of career in patenting		
0–5	45	28.1
6–10	11	6.9
11–20	31	19.4
21–30	37	23.1
>30	36	22.5
Number of patents by place of birth of inventor and percentage by outmigrants		
Northern New England	92	87.0[a]
Southern New England	537	55.5
New York	213	34.7
Pennsylvania	45	64.4
Southern Middle Atlantic	118	91.5
South	48	64.4
Other United States	34	44.1
Foreign	91	100.0

[a] The percentages in this section are the fraction of patents filed by inventors born in each region who had filed in a state other than that of their birth.

Notes and Sources: Duration of career is the period between first and last patent. Inventors with careers briefer than 6 years filed 1.9 patents over their careers, on average. Those with careers of 6 to 10 years, 11 to 20 years, 21 to 30 years, and more than 30 years filed 3.2, 8.2, 8.8, and 13.1 patents, respectively, on average. Those who never filed a patent are included in the briefest category. See the text and Appendix for sources and further information on the construction of variables.

arts rather than in engineering or scientific fields. The shares of great inventor patents were even more heavily weighted toward those with limited schooling, because they produced larger numbers of patents on average than their more erudite peers. This qualitative pattern held over time through 1865, in all sectors and for virtually all subregions, patentees from the South and foreign countries being the only exceptions.[7] As such, it is highly unlikely that this factor could explain geographic differences in rates of invention.

Among ordinary patentees, machinists and engineers were overrepresented relative to the general population, but they were outnumbered by those from commercial, artisanal, professional, and other less technical occupations.[8] As is evident from Table 2, the occupational distribution for great inventors exhibits a similar pattern. Roughly one-third of our sample comprised machinists, engineers, and full-time inventors. The majority, however, were merchants, manufacturers, farmers, and others whose jobs did not require exceptional technical skills; artisans from traditional crafts accounted for the remainder. As became clear in our earlier study, an impressively broad spectrum of the population was participating in invention. Technical backgrounds and skills were clearly an advantage, especially in the transportation sector, but the nature of technology at the time was such that they were far from indispensable even for "great" inventions. Skepticism about the idea that such population characteristics account for regional patterns is reinforced by the observation that great inventors in Southern New England were markedly less well educated and less inclined toward technical occupations than their counterparts in areas with lower inventive activity, such as the Southern Middle Atlantic and the South. The evidence on great inventors conforms well with the view that high regional inventiveness was associated with a wider segment of the population directing its resources toward invention and innovation, in response to the opportunities presented by expanding markets.[9]

It is sometimes posited that successful invention is largely a matter of individual genius or fortune, which makes it unlikely that technological discoveries could be endogenous with respect to demand. The current sample enables us to systematically evaluate the empirical basis for that hypothesis. The first problem for this perspective comes from the clustering in patenting, as well as in the origins, of these inventors. If successful invention were driven by randomly distributed factors like genius or luck, one would not expect the manifest extent of geographic concentration. Greater doubt is fostered by an examination of the life cycles of the great inventors. Thomas Blanchard notwithstanding, less than a third of the sample came up with their first significant invention

[7] Little or no trend is apparent in the patent shares of those with formal schooling over the period. College-educated individuals were least important in manufacturing and agriculture but relatively more important in transportation. Although dominant in the South, they comprised a distinct minority in all other regions and were least evident among the inventors in Southern New England.

[8] Refer to Sokoloff and Khan, "Democratization," for details on occupational distributions and trends for urban patentees.

[9] Sokoloff and Khan, "Democratization," made the same argument for ordinary patentees. Our evidence indicated that high inventive activity was typically market induced and associated with a wider segment of the population committing resources to invention and innovation.

before the age of 30. The distribution of age at first patent indicates that middle-aged and older men were predominant in inventive activity (see Table 2). Great inventors were on average older than the general working population, and more than 25 percent were in their 40s or 50s. Because a dominant role for genius would presumably be reflected by an age distribution skewed toward youth, these data suggest that experienced and committed, rather than uniquely gifted, individuals were the principal source of important inventions.

Few of the great inventors are eligible cases of serendipity or a single lucky finding. Table 2 also shows that the career of a great inventor from first to last patent typically spanned many years: nearly two-thirds had careers of over a decade, and over 45 percent were active for more than 20 years. Even among the 14 percent whose inventive careers (as gauged from their patenting records) were limited to one year or to one invention, there seem to be few good candidates for the lucky strike hypothesis. William Crompton, for instance, was a textile worker who identified two defects in the structure of looms. The cams restricted the number of warp harnesses that could be used, and they had to be changed every time a new pattern was woven. Crompton solved these problems by using an endless-chain feature in his widely adopted loom; he also incorporated a motion of the warp that put less strain on the threads.[10] An example of the two-thirds who made useful discoveries for more than a decade is James Bogardus, who patented successful inventions for a clock, ring flyer, sugar mill, bank note plates, gas meter, and cast-iron supports for buildings over a 20-year period.

ENTREPRENEURIAL BEHAVIOR BY GREAT INVENTORS

Far from being haphazard or unsystematic, great inventions generally appear to have been the outcome of investments in inventive activity directed at salient needs manifested through the market. One way to illustrate this is through the relation between occupation and inventions. Part of the argument that significant inventions are unrelated to demand is frequently expressed in terms of an insider/outsider dichotomy: "Reflective students of economic and engineering history must be struck by the curious circumstance that revolutionary inventions are usually conceived not within but without an industry."[11] However, when one considers the relationship between first major invention (as inventors frequently switched their occupation afterward) and previous

[10] This is not to say that luck was not involved. However, though it is true that many inventors proceeded by trial and error, that merely describes the *method* of discovery; it does not imply that their *objective* was random or haphazard. Charles Goodyear's discovery was the outcome of a sustained investment directed toward the invention of such a process. Several others, such as Nathaniel Hayward, were making similar experiments, induced by the large market for durable rubber products.

[11] Kaempffert, "Systematic Invention," p. 2010. Also see Gilfillan, *Sociology of Invention*.

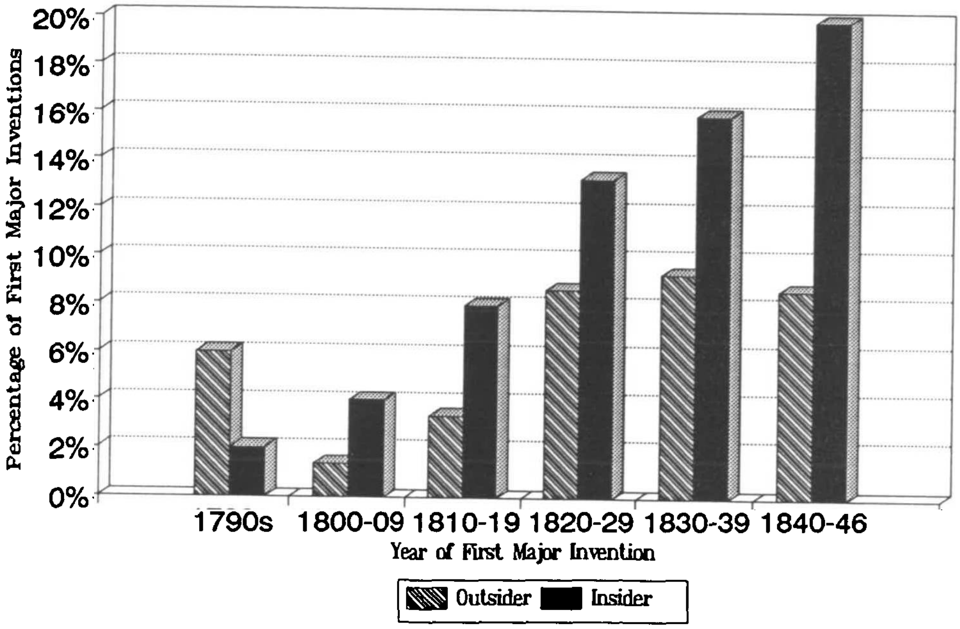

FIGURE 2

OUTSIDERS AND INSIDERS: THE RELATION OF FIRST MAJOR INVENTION TO PRIOR OCCUPATION

Notes and Sources: The first major invention of an insider was related to his previous occupation, whereas outsiders produced inventions that were unrelated. See the text and Appendix for sources.

occupation among the great inventors, this "outsider hypothesis" is not sustained. As Figure 2 shows, most of the great inventors active in the 1790s could be deemed outsiders, but this was largely because of the predominance of merchants in the early cohorts of inventors. With the decline in the prevalence of the commercial class over time, the pattern shifted. Over the entire period from 1790 through 1846, 64 percent of the first major inventions were produced by men within the respective industries.

In contrast to the paradigm of the technically adept outsider revolutionizing an industry, our sample appears to be composed primarily of entrepreneurial inventors who contrived "schemes of practical utility."[12] Insiders, who perhaps had stronger incentives to invest in inventive activity and better information about the state of the market, were the norm. A typical experience was that of Michael Simpson, an importer of wool that frequently arrived full of burrs. He recognized the need for a cost-reducing method of combing out the particles and patented a device in 1837, the British rights of which were sold for £10,000. He then turned to the manufacture of this and other textile-related machinery.

This entrepreneurial response to perceived need was dramatically

[12] Bishop, *American Manufactures*, vol. 2, p. 512.

demonstrated during wars and interruptions in foreign trade. For example, Daniel Treadwell took advantage of the shortage of screws brought about by the embargo of 1807 by inventing a screw machine, which he operated until the peace following the War of 1812. The record of invention during the Civil War provides a further case study of entrepreneurial flexibility. Then the magnitude of the stimulus to invention was so great that insiders increased their investments in inventive activity, and outsiders were induced to redirect their efforts. Military-related invention engaged the abilities of one-third of the 41 inventors in our sample who were still active in 1861—a major shift in focus for the majority. No one demonstrates this point better than the legendary Richard Gatling, who had previously specialized in farm machinery. Yet others like Benjamin Babbitt, whose most recent invention had been in the medical area, were equally adaptable. These great inventors produced some 81 inventions relating to cartridges, guns, ordnance, and war vessels between 1858 and 1865, or 70 percent of all their military-related inventions since 1790. The substantial shift in the direction of inventive activity among great inventors paralleled a change in the orientation of ordinary patentees: whereas a total of 47 patents for firearms were granted from 1790 through 1846 (or fewer than one a year), 84 firearm patents were recorded in 1865 alone.

Another method of gauging entrepreneurial orientation among great inventors is to examine two additional dimensions of flexibility: occupational and geographical mobility. If these inventors were entrepreneurial, then one would expect to observe considerable mobility directed at promoting the commercial exploitation of their inventions. The data from the sample indicate that this was indeed the case. As we have noted, nearly two-thirds of the great inventors produced inventions related to their trade, so were already in a position to appropriate some of the returns. Furthermore, roughly 42 percent changed their occupation afterward to one that would allow a more ready pursuit of economic advantage. When other methods of extracting returns from the invention—such as royalties, licensing fees, and sales of patent rights—are taken into account, the overwhelming majority of great inventors was actively seeking income derived from inventive activity.

Some individuals showed such a remarkable degree of flexibility in their pursuit of material gain that it might be termed fluidity. Josiah Warren, originally a music teacher and orchestra leader, invented a lard-burning lamp, which he profitably produced for a while. After he devised a printing press, however, he started a journal and received other patents related to printing. Inventors like William Mason were not so mobile across trades, but were no less inclined to adapt to circumstances. An apprentice in a cotton factory, Mason manufactured power looms from 1832 to 1833 after obtaining a patent. He then went on to invent and manufacture a ring frame and his famous self-acting mule before shifting his focus to the production of textile goods rather than capital equipment. His firm eventually produced furnaces, rifles, printing presses, and locomotives.

Entrepreneurial flexibility was no less evident in a willingness to migrate to more promising markets, or geographical mobility in general. The antebellum period witnessed the rise of new centers of manufacturing and invention in townships such as Troy, Lowell, Waterbury, and Trenton, as well as the national expansion westward. Among an extremely mobile population, the great inventors stood out as especially inclined to take advantage of opportunities by moving—the most mobile tending to be the most prolific patentees. Individuals like Jacob Perkins, Richard Gatling, and Cyrus McCormick readily relocated when it was useful for the commercial development of their ideas. Overall, 70 percent of all great inventors migrated to two or more states over their career. More than 80 percent at some point filed a patent in a state other than that of their birth; over 10 percent filed in three states. A number of inventors, including Samuel Colt, Joseph Saxton, and John Howe, even traveled to Europe to take advantage of opportunities there. The data thus suggest that great inventors were markedly more geographically mobile than the general population.[13]

Figure 3 illustrates this exceptional mobility in terms of the distribution of great inventor patents by subregion and migratory status (defined by whether the patent was filed in a state other than the inventor's state of birth). Migrants clearly dominated patenting in all subregions except Southern New England and the Southern Middle Atlantic. The record for Southern New England is particularly interesting, because it implies that the technological leadership of this region was based on natives to the area, as opposed to centers like New York City that attracted inventors from distant and disparate locations. Table 2 allocated great inventor patents by subregion of birth and migratory status. Combined with Figure 3, it suggests that the net flow of great inventors was from subregions with less commercial development and economic opportunity (like Northern New England or the Southern Middle Atlantic) toward areas with more extensive markets (like New York or Southern New England) or those undergoing rapid expansion (the Midwest). Even though a substantial share of great inventors born in Southern New England did ultimately migrate to New York, this movement from one highly commercialized location to another is consistent with the interpretation that these men were acting entrepreneurially to increase the returns to their inventive activity.

Further evidence of the relationship between patenting, migration, and entrepreneurial motives is provided by Table 3. The first panel

[13] According to the 1860 census, 24.8 percent of the native free population had emigrated from their state of birth, typically relocating in states adjacent to their state of origin (U.S. Census Office, *Statistics*, pp. xxxiii–xxxiv).

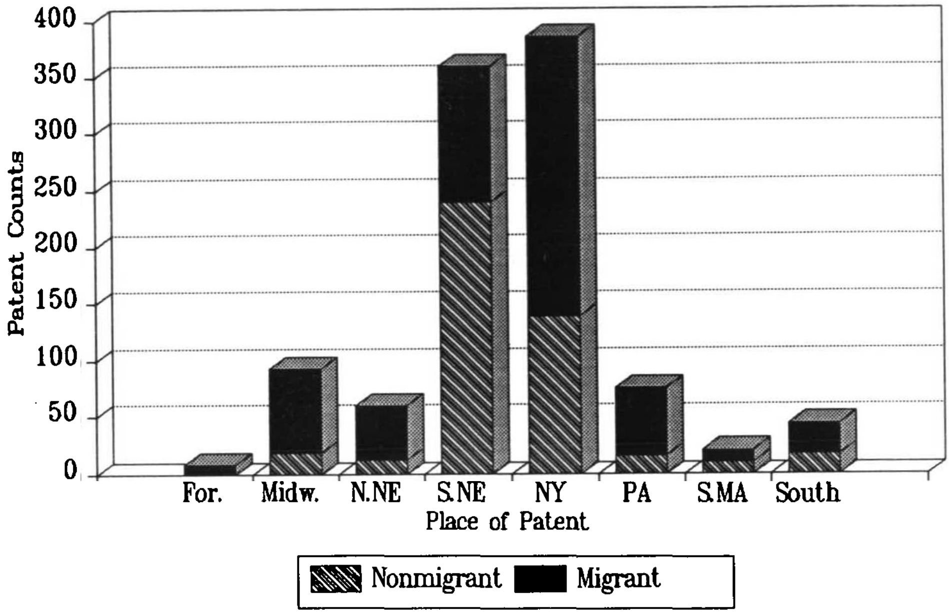

FIGURE 3

DISTRIBUTION OF GREAT INVENTOR PATENTS BY REGION AND MIGRATORY STATUS

Notes and Sources: The counts are the number of patents filed by residents of the specified geographic regions. A patent is filed by a migrant if the patentee was born in a state other than the one in which the patent was filed. See the Appendix for sources and further information.

classifies great inventors by their county of birth and residence at first patent; the second panel does the same for their patents—residence at time of patent obviously varying with each patent. The counties are grouped as follows: "High-Patenting Metropolitan," comprising major urban centers that in 1825 had had rates of patenting per capita at least twice the national average; "High-Patenting Nonmetropolitan," which met the patenting rate standard but were not major urban centers; and a residual "Other" category. Given that the first two classes of counties averaged about 4 and 6 percent, respectively, of the national population over the 1790 to 1865 period, both distributions demonstrate that great inventors were disproportionately concentrated in, and drawn to, counties that had achieved high patenting rates early in the process of industrialization—as judged by either their place of birth (25.6 percent of great inventors, according to the first panel) or places of patenting (53.8 percent of their first patents).[14] The technological leadership of

[14] Sokoloff, "Invention, Innovation, and Manufacturing Productivity," found that firms in high-patenting counties also had higher levels of productivity, suggesting that these localities were at the same time centers of patenting, invention, and technical change. For an assessment of progress in manufacturing productivity in the antebellum period, also refer to Sokoloff, "Productivity Growth."

TABLE 3
DISTRIBUTIONS OF GREAT INVENTORS AND OF GREAT INVENTOR PATENTS BY COUNTY OF BIRTH AND COUNTY OF PATENTING

Place of Birth	High-Patenting Nonmetropolitan	High-Patenting Metropolitan	Other	Total
	Distribution of Great Inventors (by First Patent)			
High-patenting nonmetropolitan				
N	16	6	7	29
Row %	55.2	20.1	24.1	—
Column %	57.1	10.3	9.5	18.1
High-patenting metropolitan				
N	0	8	4	12
Row %	—	66.7	33.3	—
Column %	—	13.8	5.4	7.5
Other				
N	12	44	63	119
Row %	10.1	37.0	52.9	—
Column %	42.9	75.9	85.1	74.4
Total				
N	28	58	74	160
%	17.5	36.3	46.3	
	Distribution of Great Inventor Patents			
High-patenting nonmetropolitan				
N	113	44	28	185
Row %	61.1	23.8	15.1	—
Column %	40.5	9.9	6.2	15.7
High-patenting metropolitan				
N	10	31	9	50
Row %	20.0	62.0	18.0	—
Column %	3.6	7.0	2.0	4.2
Other				
N	156	370	417	943
Row %	16.5	39.2	44.2	—
Column %	55.9	83.2	91.9	80.1
Total				
N	279	445	454	1,178
%	23.7	37.8	38.5	

Notes and Sources: The top panel reports the cross-tabulation of great inventors by their county of birth and the county in which their first patent was filed. The bottom panel reports the cross-tabulation of all of the great inventor patents by the inventor's county of birth and the county in which the respective patent was filed. The counties are classified by how their patenting rates of 1825 compared with the national average and by whether the county contained a major urban center. A high-patenting county had a patents per capita rate of twice the national average between 1816 and 1825; a major urban center had a population of 50,000 by 1850. See the text and Appendix for sources and further information.

these districts may initially have been based on their access to low-cost transportation to major markets. Yet their primacy endured through 1865, after two decades of railroad construction that enormously expanded and facilitated market access. These long-standing geographic centers for invention were the birthplaces of a disproportionate share of great inventors and would have had high patenting rates regardless, but the data reveal that they also drew a substantial net inflow of great inventors. Indeed, migrants were quantitatively significant in accounting for the degree of geographic clustering in patenting, especially in urban centers. These systematic patterns at the county level contradict the idea that great inventions were generated randomly, but they are not inconsistent with the view that location-specific variables influenced the propensity of individuals to make important advances in technology. The most striking implication of these data, however, is that men of great inventive potential who were not already located in centers of high patenting activity tended to migrate to them. Although they may also have offered other conditions conducive to invention, these centers were probably attractive for their array of commercial and entrepreneurial opportunities.

GREAT INVENTORS AND THE APPROPRIATION OF ECONOMIC RETURNS

The entrepreneurial inclinations of inventors can also be discerned from their attempts to appropriate returns from their inventions. Their efforts encompassed a variety of methods, including direct use of the invention in production, assignment or sale of rights, licensing, and litigation. The typical great inventor combined ingenuity in invention and in commercial exploitation, proving to be a shrewd entrepreneur who promoted his inventions for profit. Indeed, few failed to secure rewards from their inventions.[15]

The assignment or sale of patent rights could prove profitable when the invention was demonstrably useful and when the inventor had reputational capital to draw on. Some inventors maintained long-term relationships with enterprises, as did Henry Burden with the Troy Iron and Nail Factory, which paid him a retainer of $10,000 per year for the rights to his spike machine. Alternatively, the decision to license involved the patentee in a measure of risk taking, but the difference in payoff could be significant. Christopher Scholes assigned his typewriter patent rights to the Remington Company for $12,000, but his partner opted for royalties and subsequently received over $1,500,000. Almost 40 percent of those who simply assigned the rights or licensed the patent were from the merchant/professional class. Those who chose this strategy were in the minority, because 85 percent of the inventors for whom information is available were directly involved in commercial

[15] Only two inventors are recorded as receiving no benefits. However, as it is likely that many of the 20 inventors for whom no record of income exists also did not receive substantive returns, we chose the conservative route of including them in the "no income" category. An upper estimate is thus that 14 percent of inventors, who accounted for less than 10 percent of all great inventor patents, gained minimal returns.

TABLE 4
DISTRIBUTION OF GREAT INVENTOR PATENTS BY SOURCE OF INCOME AND OCCUPATION

Occupation	Sources of Income from Invention				
	Royalty	Manufacturing	Both	None	Total
Artisan					
N	5	73	55	2	135
%	3.7	54.1	40.7	1.5	
Full-time inventor					
N	45	27	69	19	160
%	28.1	16.9	43.1	11.9	
Engineer/machinist					
N	60	150	110	26	346
%	17.3	43.4	31.8	7.5	
Merchant/professional					
N	22	35	135	56	248
%	8.9	14.1	54.4	22.6	
Manufacturer					
N	5	39	165	7	216
%	2.3	18.1	76.4	3.2	
Farmer/other					
N	5	27	30	0	62
%	8.1	43.6	48.4	—	
Total	142	351	564	110	1,167

Notes and Sources: This table reports the distribution of great inventor patents by the principal occupation of the inventor over his career as well as by the methods he employed to secure returns to his inventions. Hence, each of an inventor's patents is classified in the same manner. The categories of methods by which inventors realized returns to their invention are royalties (inclusive of the licensing or sales of the rights to the patented inventions), manufacturing (inclusive of manufacturing that used the inventions), both royalties and manufacturing, or none. In general, no information was available on those inventors whose patents were classified in the "none" category. See the text and Appendix for sources and further information.

exploitation of their invention through manufacture, or through both manufacture and licensing.

Entrepreneurs are normally credited with transforming the invention into a usable product, and such innovation is often associated with the greatest potential return. For instance, Cyrus McCormick received $20 to $35 in royalties per reaper, but he gained an estimated unit profit of $80 through manufacturing.[16] Before 1825, half of all great inventor patents were filed by individuals who manufactured the product in question and were presumably directly affected by the growth of markets. Subsequent to the rapid industrial expansion of the 1820s and 1830s, it became increasingly common for these inventors to license as well as manufacture. Because patent assignments or licenses could be restricted to specific locations, that practice often made it possible to exploit a larger market than if the inventor had chosen the manufactur-

[16] Hutchinson, *Cyrus McCormick*, vol. 1, pp. 278, 292.

ing strategy alone. Table 4 indicates that over 76 percent of all patents by manufacturers were due to those who chose this dual route to appropriating returns, as compared with 42 percent of patents by great inventors in other occupations. Although the joint strategy was preferred, unless inventors benefited from learning by doing their licensees and assignees could become competitors on expiration of the patent. This may be one reason why multiple patenting was so prevalent among inventors who had their own manufacturing enterprises. Their establishments tended to incorporate the latest technology, including developments by other inventors. Inventor-manufacturers like Hiram Pitts, Cyrus McCormick, Horace Day, Richard Hoe, George Esterly, and George Bruce aggressively acquired the assignment rights to patents and designs that they employed in their operations. Many of their companies became virtual monopolies because of their superior policies of innovation.[17]

Great inventors thus attempted to appropriate returns from their inventions, and for the most part succeeded. However, entrepreneurs operate within an environment of rules and regulations that may either foster or inhibit their progress. In his first address to Congress, George Washington urged the delegates to encourage "the exertion of skill and genius" by introducing a national system of patenting, for it was felt that this exertion was best induced by offering inventors the right to appropriate returns on their efforts. To defend their claims, inventors were advised to seek patent protection. Not all new inventions are patentable, however; and of those that qualify, not all are patented. Under some circumstances, inventors may choose to appropriate returns from their discoveries through other means (such as maintaining secrecy) or may abandon their rights to the public. However, the first half-century of the patent system witnessed a remarkable growth in patenting, indicating that many inventors during early industrialization were clearly interested in securing the property rights to their ideas.

If the propensity to patent typifies economic men motivated by expected profit, then virtually all of the great inventors fall within this category: only 10 of our 160 failed to secure patents for their discoveries. Some "patent Dissenters" like Thomas Rogers—who provided specifications for his improvements in locomotives to the Patent Office but did not obtain a patent, "to ensure their being public property"—apparently objected to the individual accumulation of profit on ethical grounds. Rogers was amply remunerated, nonetheless, by producing locomotives for which a ready demand existed, based on his excellent reputation among railroad owners. Three machinists—Gridley Bryant,

[17] Many of the great inventors were noted for their successful manufacturing enterprises, accounting for half of all great inventor patents. We regarded an inventor as a successful manufacturer if he appeared in the Index of Manufacturers of Malone, *Dictionary of American Biography*, or was listed as such in Bishop, *American Manufactures*.

Sylvanus Brown, and Isaac Dripps—made unpatented improvements that transformed the productivity of the enterprises in which they were employed. Thomas Kingsford relied on secrecy rather than patents to protect his process for making cornstarch. However, when it became apparent that others were replicating his results, Kingsford switched to edible cornstarch, for which he obtained a patent in 1863. It is noteworthy that all these individuals produced job-related inventions. Most were thus able to obtain some return from their efforts, either through enhanced reputations, which led to greater remuneration, or through manufacturing. Although these inventors were able to extract returns without patents, the vast majority of great inventors did not run the risk. That only a few individuals chose to bypass the patent system was due to the readily duplicable nature of technology and to the degree of competition in antebellum product markets.[18]

Though a valid patent was helpful, it was no guarantee that an inventor would be able to appropriate the return on his invention. That ability depended, among other factors, on aspects of the legal system, such as the attitudes of the judiciary. Influenced by the frustrations experienced by Eli Whitney, Charles Goodyear, and Oliver Evans in the courtroom, some observers have questioned whether important inventions could be protected. Although there is some truth to the idea that the more significant the discovery, the greater the incentive for infringement, this does not imply that inventors were unable to realize substantial returns. Ithiel Town, an engineer and architect whose design simplified bridge structures, was readily able to identify infringers: he charged them double the price collected from more honest users. Nathaniel Wyeth filed over 14 patents dealing with cutting and shipping ice, but he ignored infringers in the domestic market because he was gaining large returns from shipping overseas.[19]

Fewer than one-fifth of all the great inventors (30) were ever involved in litigation, and only 3 percent of their patents (40) were at issue. For the 80 percent who never appeared in the courts, it is likely that their patent rights and reputation were sufficient to ensure out-of-court settlements, or that patent infringement was not critical because the inventors could appropriate returns through other means. At the same time, the per patent rate of litigation for great inventor patents was three times as high as the rate for ordinary patents, indicating that important patents had a higher probability of being litigated. One reason might be that inventors employed litigation as a strategy to maintain market share

[18] An example is Mathias Baldwin, a pioneer in American locomotive production, who gained access for half an hour to an imported locomotive and then returned to his workshop and reproduced it (see Bishop, *American Manufactures*, vol. 2, p. 538).

[19] The *DAB* lists Nathaniel Wyeth as an eminent trader and explorer rather than as an important inventor; he is therefore excluded from the sample even though his patented inventions allegedly revolutionized the ice-shipping industry.

and preempt rivals, both actual and potential. An example is Cyrus McCormick, who maintained a phalanx of lawyers full-time on his payroll. William Woodworth's wood-planing machine was similarly litigated in over 75 lawsuits throughout the country, resulting in a virtual monopoly over the industry.[20] The proportion of *cases* to total patents filed was 2 percent for all inventors but amounted to 10 percent for great inventors. As precedent was established in the first successful outcome, these plaintiffs may have been more interested in suppressing competition than in defending the patent per se. The litigation records are thus consistent with the other evidence we have presented, suggesting a strong concern with extracting an economic return.

CONCLUSION

Even if they agreed that "marginal inventions" might be market induced, many economic historians concerned with the sources of early inventive activity have viewed important inventions as largely haphazard and unresponsive to the prospect of material gain. This article argues that information from a sample of 160 great inventors does not support that perspective. Instead, the data indicate that, though not especially distinctive in terms of age, occupation, or education, inventors of the antebellum era were typically entrepreneurial and responded systematically to changes effected by the remarkable extension of markets. Far from being random, patenting by great inventors corresponded closely to the procyclical patterns observed for general patentees—and, like ordinary patentees, the great inventors were highly concentrated in districts with access to broad markets. Moreover, the great inventors took advantage of expanding opportunities by migrating in disproportionate numbers to areas with ready access to markets, as well as by changing occupations to exploit their inventions. They tended to make long-term commitments to inventive activity, and the overwhelming majority secured the property rights to and returns on their efforts. In sum, the experience of the great inventors seems to be entirely consistent with the idea that technical change during early industrialization was substantially due to increased investments in inventive activity, by individuals whose "schemes of practical utility" were stimulated by higher perceived returns, or by demand-side incentives in general.

Appendix

The main source of our sample was volumes 1 to 10 of the *Dictionary of American Biography* (*DAB*). This was supplemented by *Who Was Who in America, Historical*

[20] Although Woodworth's patent dominated the woodworking industry because of shrewd manipulation, he is not included in the sample as a great inventor.

Volume, 1607–1896 and *The National Cyclopaedia of American Biography*; additional details were obtained from a number of biographical sources. The sample comprises virtually all the best-known antebellum inventors who were first active in the field of invention between 1790 and 1846. Among the 160 "great inventors" whose first invention fell within this period were James Eads, Samuel Morse, Robert Stevens, Thomas Blanchard, Paul Moody, and John Roebling. The information we compiled includes their date and place of birth, father's trade, schooling, and age at first major invention. The classifications also cover inventive specialization (if any), occupations before and after the first major invention, whether the first major invention was related to their prior occupation, and whether their subsequent trade was related to the invention. We categorized occupational status as follows: merchants and white-collar professionals; machinists, engineers, and full-time inventors (mechanics were classed as machinists, and there were 14 full-time inventors); artisans; manufacturers; and farmers and others. The "first major invention" was determined by the *DAB*'s account, and the inventive career of the inventor was measured as the difference between his first and last patent. The *DAB* also provided details on the inventor's source of income, categorized as assignments and royalties from licensing, commercialization, both of these, or no income. The sample used for the comparison with "ordinary patentees" is described in Sokoloff, "Inventive Activity," and Sokoloff and Khan, "Democratization."

The U.S. Patent Office's *Annual Report of the Commissioner of Patents* for various years provided data on patents filed between 1790 and 1865 at both the aggregate and individual level. Patent records include date of issue, city of residence at time of patenting, and the subject matter of each patent. We classified each patent into its sector of final use and the county of patentee residence. Counties were categorized on the basis of per capita patenting rates computed in Sokoloff, "Inventive Activity." The subregions include Northern New England (Maine, New Hampshire, and Vermont); Southern New England (Connecticut, Massachusetts, and Rhode Island); Southern Middle Atlantic (Delaware, New Jersey, Maryland, and the District of Columbia); and the South (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia).

REFERENCES

Bishop, J. Leander, *A History of American Manufactures, from 1608–1860*, 3 vols. (Philadelphia, 1868).

Gilfillan, S. C., *Sociology of Invention* (Cambridge, MA, 1935).

Hutchinson, William T., *Cyrus Hall McCormick*, 2 vols. (New York and London, c. 1930).

Kaempffert, Waldemar, "Systematic Invention," *The Forum*, 70 (1923), pp. 2010–18, 2116–22.

Malone, Dumas, ed., *Dictionary of American Biography* (New York, 1937), vols. 1–10.

Mokyr, Joel, *The Lever of Riches: Technological Creativity and Economic Growth* (Oxford, 1990).

Schmookler, Jacob, "The Economic Sources of Inventive Activity," this JOURNAL, 22 (Mar. 1962), pp. 1–20.

Schmookler, Jacob, *Invention and Economic Growth* (Cambridge, MA, 1966).

Sokoloff, Kenneth L., "Productivity Growth in Manufacturing During Early Industrialization: Evidence from the American Northeast, 1820 to 1860," in Stanley L. Engerman and Robert E. Gallman, eds., *Long-Term Factors in American Economic Growth* (Chicago, 1986), pp. 679–736.

Sokoloff, Kenneth L., "Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790–1846," this JOURNAL, 48 (Dec. 1988), pp. 813–50.
Sokoloff, Kenneth L., "Invention, Innovation, and Manufacturing Productivity Growth in the Antebellum Northeast," in Robert E. Gallman and John Joseph Wallis, eds., *American Economic Growth and Standards of Living Before the Civil War* (Chicago, 1992), pp. 345–84.
Sokoloff, Kenneth L., and B. Zorina Khan, "The Democratization of Invention During Early Industrialization: Evidence from the United States, 1790–1846," this JOURNAL, 50 (June 1990), pp. 363–78.
The National Cyclopaedia of American Biography (New York, 1926), various volumes.
United States Census Office, *Statistics of the United States in 1860* (8th census, vol. 1), (Washington, DC, 1866).
United States Patent Office, *Annual Report of the Commissioner of Patents* (Washington, DC, various years).
Who Was Who in America: Historical Volume, 1607–1896 (Chicago, 1963).