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'SCHEMES OF PRACTICAL UTILITY': ENTREPRENEURSHIP AND INNOVATION AMONG 'GREAT INVENTORS' IN THE UNITED STATES, 1790-1865

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ABSTRACT

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 not exceptional 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 towards districts conducive to invention.

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A central and longstanding 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 which are influenced, like any other investment, by an assessment of potential financial returns. In this view, circumstances which enhance the expected net return to inventive activity, such as the characteristic expansion of markets during the initial stages of industrialization, tend to stimulate higher rates of invention and technical change.[2]

In order to better evaluate the sources of important technological advance, this paper examines a set of detailed information about the lives and careers of 'great inventors' who were active in early industrial America. Instead of establishing that technologically significant discoveries were independent of demand conditions, the evidence indicates that they were like ordinary patents in being pro-cyclical and in originating disproportionately from geographic areas linked to extensive markets. Moreover, the 'great inventors' were not exceptionally well-endowed in terms of formal education or technical skills. Rather, they were distinguished by entrepreneurial abilities, for they were responsive to perceived demand and economic

incentives, systematically invested in inventive activity rather than engaging in noneconomically oriented tinkering, and actively pursued the returns to their discoveries. Overall, the experience of the 'great inventors' lends strong support to the view that the expansion of markets during early American industrialization induced a broad segment of the population to raise their commitments of resources to inventive activity and, in so doing, increased the rate of technical change.

I

The sample of 'great inventors' consists of 160 individuals credited with an important invention between 1790 and 1846 by biographical dictionaries and histories of technology.[3] The data set includes complete patent histories through 1865, as well as information on place and date of birth, schooling, occupation before and after major inventions, efforts to extract income from their discoveries, and other variables. The 150 'great inventors' who were also patentees received 1178 patents, or somewhat less than 2 percent of the total awarded over the period.

One of the salient features of the great inventors is how similar their patterns of patenting were to those of ordinary patentees. Most significant, perhaps, is the finding that important inventions resembled patents in being strongly and positively associated with the extent of markets. Like patentees in general, the great inventors were disproportionately concentrated in the Northeast, and especially in Southern New England and New York, where low-cost transportation networks had facilitated a rapid expansion of commerce early in the antebellum period. This geographic distribution was characteristic of where they filed their patents (see Table 1) as well

TABLE 1

Regional Shares of Patents, Great Inventor Patents, and Population: 1790-1865

	1790-1825	1826-1845	1846-1865
N. New England			
Patents	6.0%	8.4%	4.1%
G.I. Patents	11.4	6.0	2.7
Population	9.2	6.7	4.5
S. New England			
Patents	24.4%	19.4%	20.1%
G.I. Patents	43.4	30.9	27.0
Population	11.8	7.2	6.1
New York			
Patents	30.3%	32.5%	28.8%
G.I. Patents	15.4	37.3	35.2
Population	12.9	14.5	12.7
Pennsylvania			
Patents	14.9%	13.1%	11.7%
G.I. Patents	10.9	6.7	5.1
Population	11.2	10.2	9.5
S. Middle Atlantic			
Patents	12.6%	7.0%	6.6%
G.I. Patents	10.3	8.7	15.2
Population	10.3	6.0	5.0
Other U.S.			
Patents	11.9%	18.3%	26.5%
G.I. Patents	8.6	9.0	14.5
Population	44.7	55.4	62.2
Foreign			
Patents	0.1%	1.5%	2.2%
G.I. Patents	0.0	1.5	0.3
Population	-	-	-

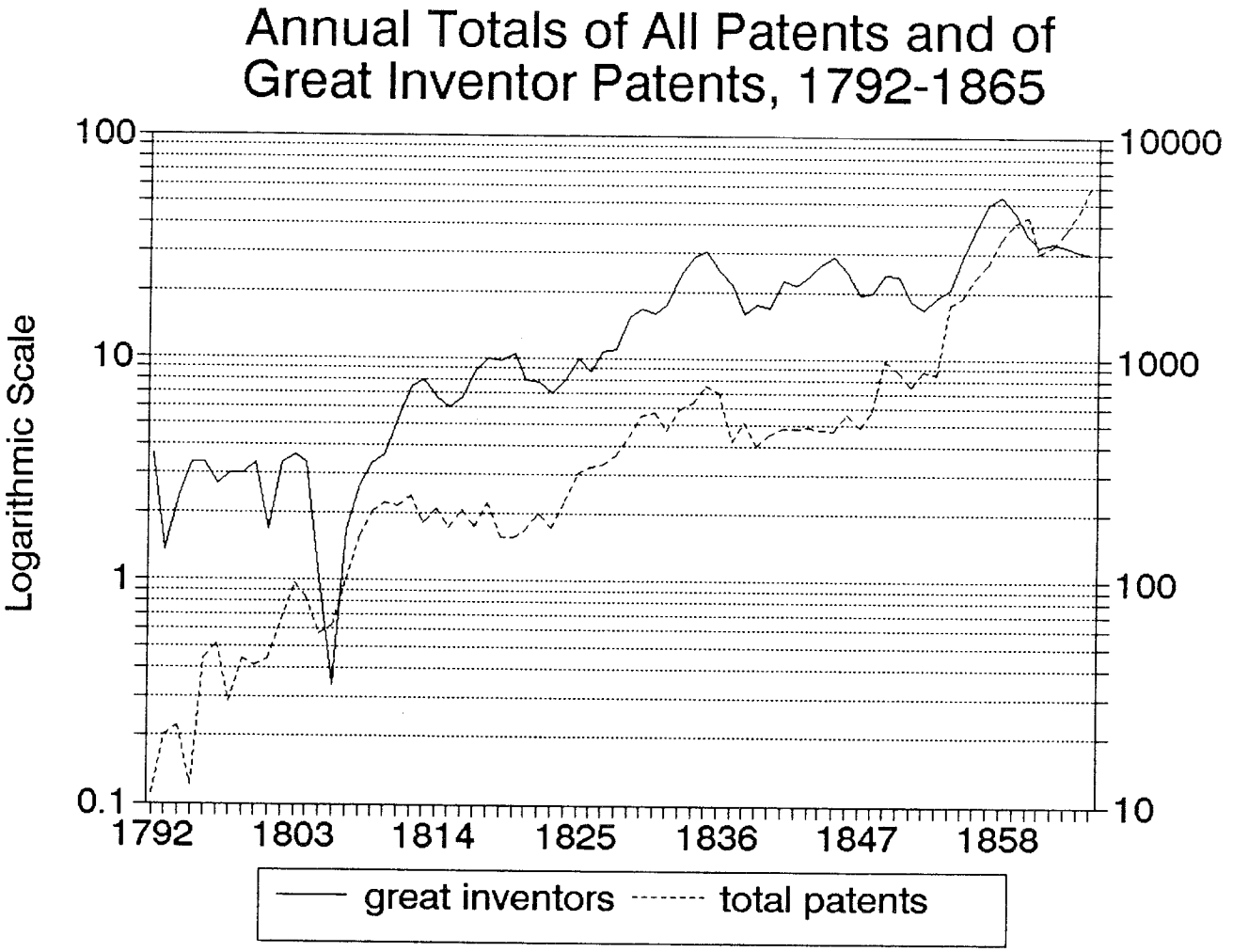
Notes and Sources: See the Appendix. The population figures were interpolated for the midpoints of the respective time periods.

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 pro-cyclicality 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 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 argued that both the pro-cyclicality 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 shown in Table 2, higher education was hardly a necessary prerequisite for important inventions. Nearly half of the sample had little

Figure 1



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

or no formal schooling, while less than a quarter attended college.[6] The latter were certainly over-represented relative to the general population, but tended to be merchants or professionals with credentials in law or the arts rather than in engineering or scientific fields. The shares of great inventor patents were even more weighted towards those with limited schooling, since 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 sub-regions, with patentees from the South and foreign countries providing 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 over-represented relative to the general population, but they were outnumbered by those from commercial, artisanal, professional and other less technical occupations.[8] As seen in Table 2, the occupational distribution for great inventors exhibits a similar pattern. Roughly one-third of our sample was comprised of machinists, engineers and full-time inventors. The majority, however, consisted of merchants, manufacturers, farmers, and others whose jobs did not require exceptional technical skills; artisans from traditional crafts accounted for the remainder. As in our earlier study, one is impressed with how broad a 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

TABLE 2

Personal Characteristics of the Great Inventors

Educational Background

Primary	- 76	47.5%
Secondary	- 22	13.8%
College	- 38	23.8%
Unknown	- 24	15.0%

Occupational Class at First Invention

Artisan	- 24	15.0%
Farmer	- 8	5.0%
Eng/Mach/Inventor	- 53	33.1%
Merchant/Prof.	- 36	22.5%
Manufacturer	- 37	23.1%
Other/Missing	- 2	1.3%

Age at First Invention

< 20 Years	- 8	5.0%
20-29	- 42	26.3%
30-35	- 42	26.3%
36-40	- 25	15.6%
41-45	- 12	7.5%
46-55	- 22	13.8%
> 55 Years	- 9	5.6%

Length of Career-From First to Last Invention

0-5 years	- 45	28.1%
6-10	- 11	6.9%
11-20	- 34	21.3%
21-30	- 39	24.4%
> 30 Years	- 31	19.4%

Place of Birth and Migratory Status - Weighted by Patents

N. New England	92 patents	87.0% by out-migrants
S. New England	537	55.5%
New York	213	34.7%
Pennsylvania	45	64.4%
S. Middle Atlantic	118	91.5
South	48	64.6%
Other U.S.	34	44.1%
Foreign	91	100.0%

Notes and Sources: See text and Appendix. Migrating status is defined with respect to whether the state of residence at time of patent is different from state of birth.

observation that great inventors in Southern New England were markedly less well-educated and less inclined towards 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 their resources towards 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 this 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 made their first significant invention before the age of 30. As seen in Table 2, the distribution of age at first patent indicates that middle-aged and older men were predominant in inventive activity. Great inventors on average were older than the general working population, and more than 25 percent were in their 40s or 50s. Since a dominant role for genius would presumably be reflected in an age distribution more skewed towards 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 nearly 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 which could be used, and had to be changed everytime a new pattern was woven. Crompton solved these problems by using an endless-chain feature in his widely adopted loom, and also incorporated a motion of the warp which 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, banknote plates, gasmeter, and cast-iron supports for buildings over a twenty-year period.

II

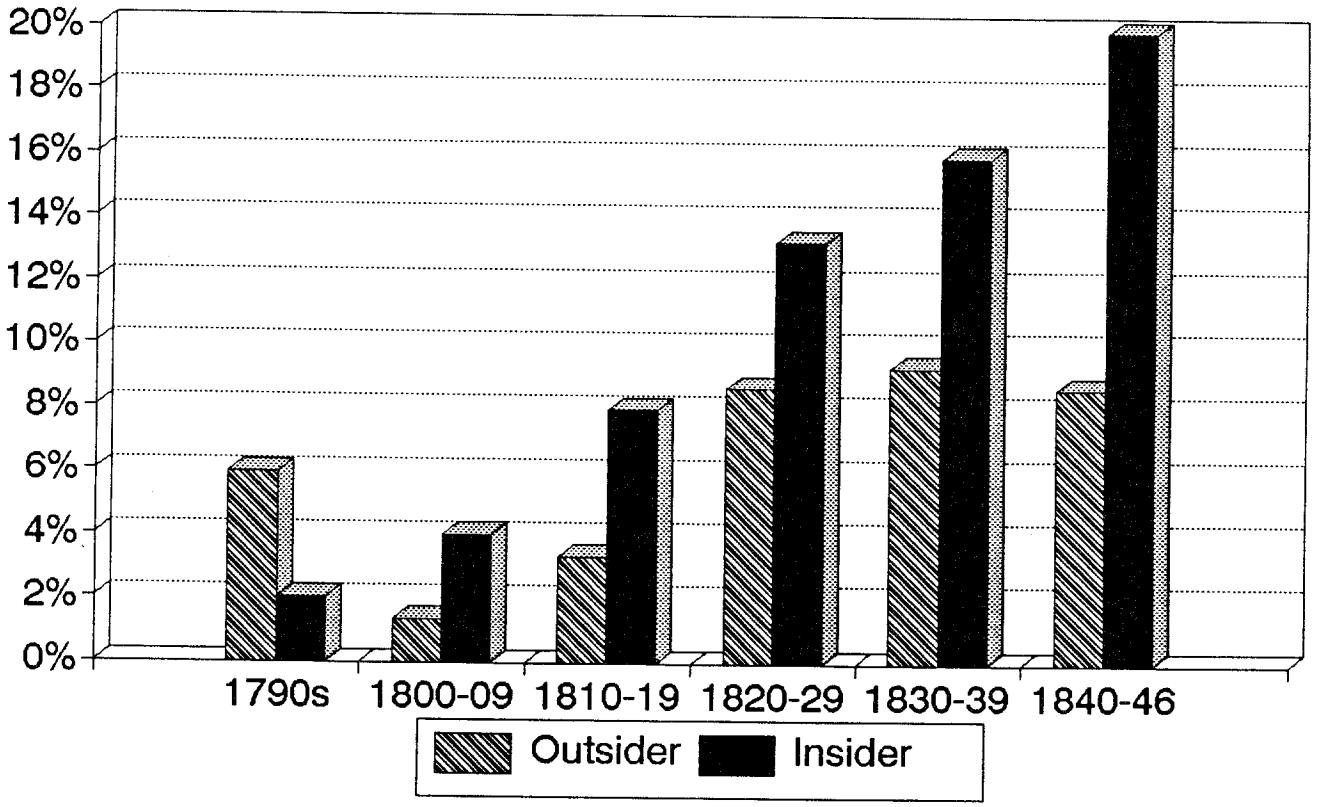
Far from being haphazard or unsystematic, great inventions generally appear to have been the outcome of investments in inventive activity directed at salient needs manifested through the market. One illustration of this is through the relation

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 (since inventors frequently switched their occupation afterward) and previous 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 apears to be primarily composed 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, who was an importer of wool which frequently arrived imbedded with burrs. He recognized the need for a cost-reducing method of combing out these 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.

Figure 2

Distribution of First Major Invention by Relation to Prior Occupation: Outsiders and Insiders, 1790-1846



Notes and Sources: The first major invention of the insider was related to his previous occupation, while outsiders produced inventions which were unrelated. See text and Appendix.

This entrepreneurial response to perceived need was dramatically 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 and invented 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. Here 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 the sample who were still active in 1861, involving 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, but 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 from 1858 to 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 the change in orientation by ordinary patentees: whereas a total of 47 patents for firearms were granted from 1790 through 1846 (or less 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 the great 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 discussed above, nearly two-thirds of the great inventors produced inventions which were related to their trade, and were accordingly already in a position to appropriate some of the returns. Furthermore, roughly 42 percent changed their occupation afterwards to one which would allow a more ready pursuit of economic advantage. When other methods of extracting returns from the invention are taken into account, such as royalties, licensing fees, and sales of patent rights, the overwhelming majority of great inventors were actively seeking income derived from their inventive activity.

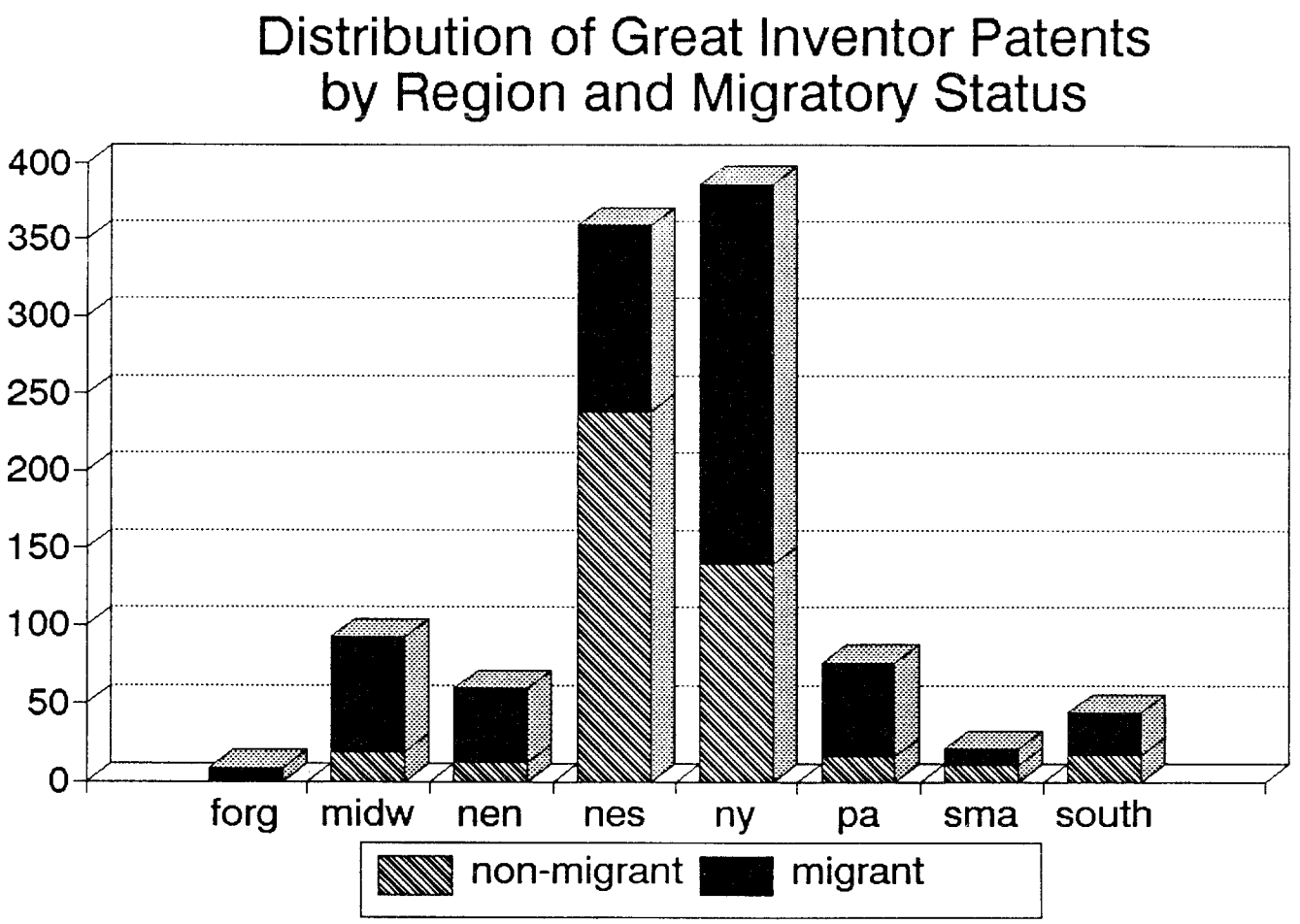
Some individuals showed such a remarkable degree of flexibility in their pursuit of material gain that it might be termed fluidity. Josiah Warren was originally a music teacher and orchestra leader who invented a lard-burning lamp, which he profitably produced for a while. After he devised a printing press, however, he started a journal, and received other patents related to printing. Inventors like William Mason were not as 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 terms of 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 Ilion, Lowell, Waterbury and Trenton, as well as the national expansion westward. Amongst an extremely mobile population, the great inventors stood out as especially inclined to take advantage of opportunities by moving - with the most mobile tending to be the most prolific in terms of numbers of patents. 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, with over 10 percent filing in three states. A number of inventors, including Samuel Colt, Joseph Saxton, and John Howe even travelled to Europe to take advantage of the 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 sub-region and migratory status (where the latter refers to whether the patent was filed in a state other than the inventor's state of birth). Migrants clearly dominated patenting in all sub-regions except Southern New England and the Southern Middle Atlantic. The record for Southern New England is particularly interesting, since it implies that the technological leadership of this region was based on natives to the area, as opposed to centers like New York City, which attracted inventors from distant and disparate locations. Table 2 allocated great inventor patents by sub-region of birth and migratory status. When combined with

Figure 3

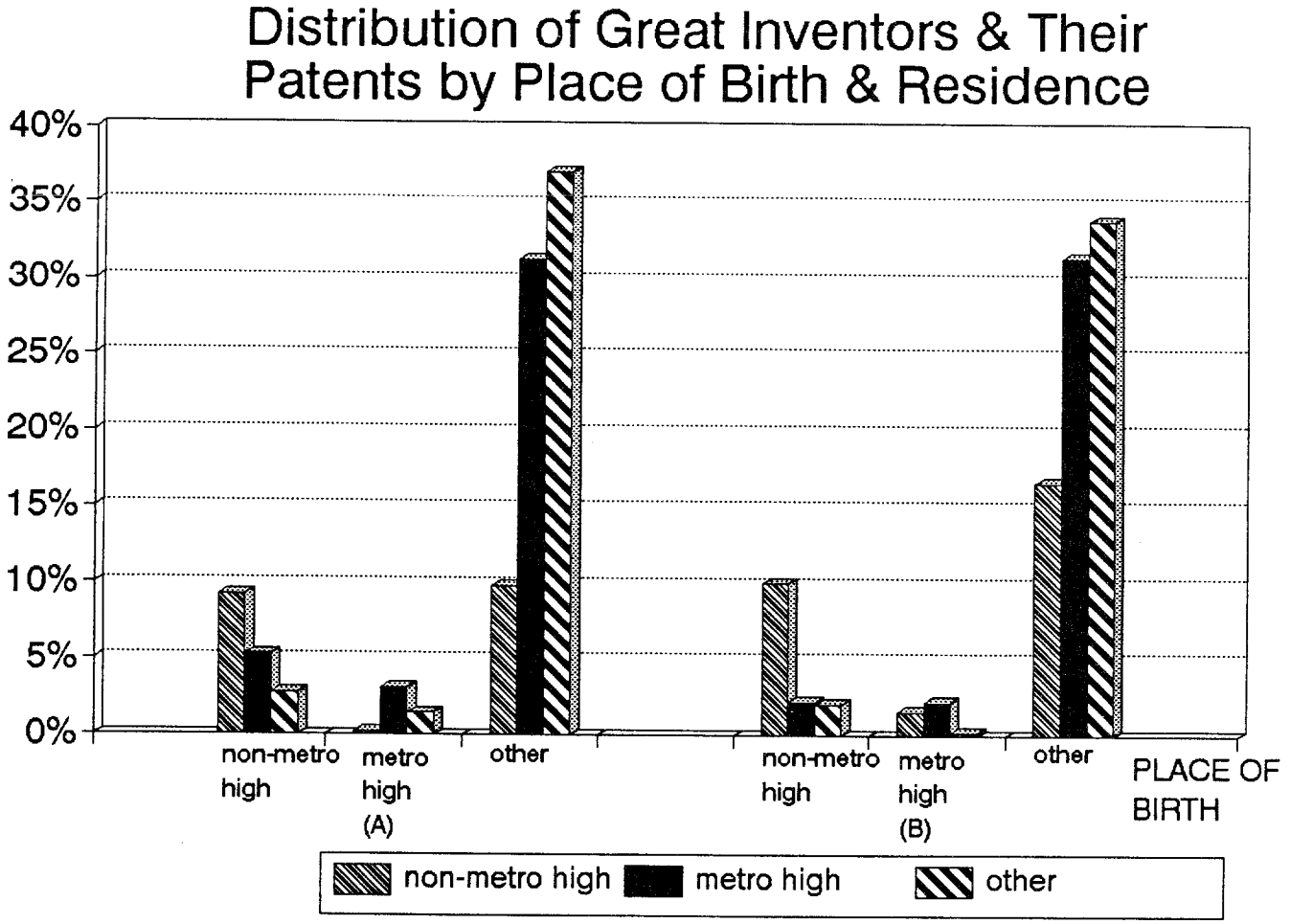


Notes and Sources: The totals refer to the number of patents filed from residents of the specified geographic areas. See Appendix.

Figure 3, it suggests that the net flow of great inventors was from sub-regions 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 migration and entrepreneurial motives is provided by Figure 5. Distribution A classifies great inventors by county of birth and residence at first patent, while Distribution B does the same for their patents, with residence at time of patent obviously varying with each patent. The 'metro high' category comprises major urban centers which had had rates of patenting per capita at least twice the national average in 1825, while the 'non-metro high' counties met the patenting rate standard, but were not major urban centers. For example, Distribution A indicates that roughly 9 percent of the great inventors were both born and filed their first patent in 'non-metro high' counties; just 5 percent were born in these counties but filed their first patent in an urban center with high patenting activity. The distributions reveal a substantive absolute and proportional (relative to the population) net flow of great inventors toward counties with high patenting rates. Such counties produced a disproportionate share of great inventors and would have had somewhat high patenting rates regardless, but the migrants were responsible for a

Figure 5



Notes and Sources: See text and Appendix. Distribution A presents the percentages of great inventors by place of birth and place at first patent. Distribution B presents the percentages of all great inventor patents by place of birth of the inventor and place of residence at time of patent. The counties of birth and residence are classified by their patenting rates as of 1825 and the presence of a major urban center.

large percentage of their patents, especially in major urban centers. These systematic patterns at the county level militate against the idea that important inventions were random, and instead suggest a common motive factor. Although consistent with the idea that location-specific variables stimulated individuals to make great inventions, the evidence also indicates that men of great inventive potential were inclined to migrate to particular centers of activity. These loci were likely attractive for the array of commercial opportunities available, as well as for other conditions conducive to invention.

III

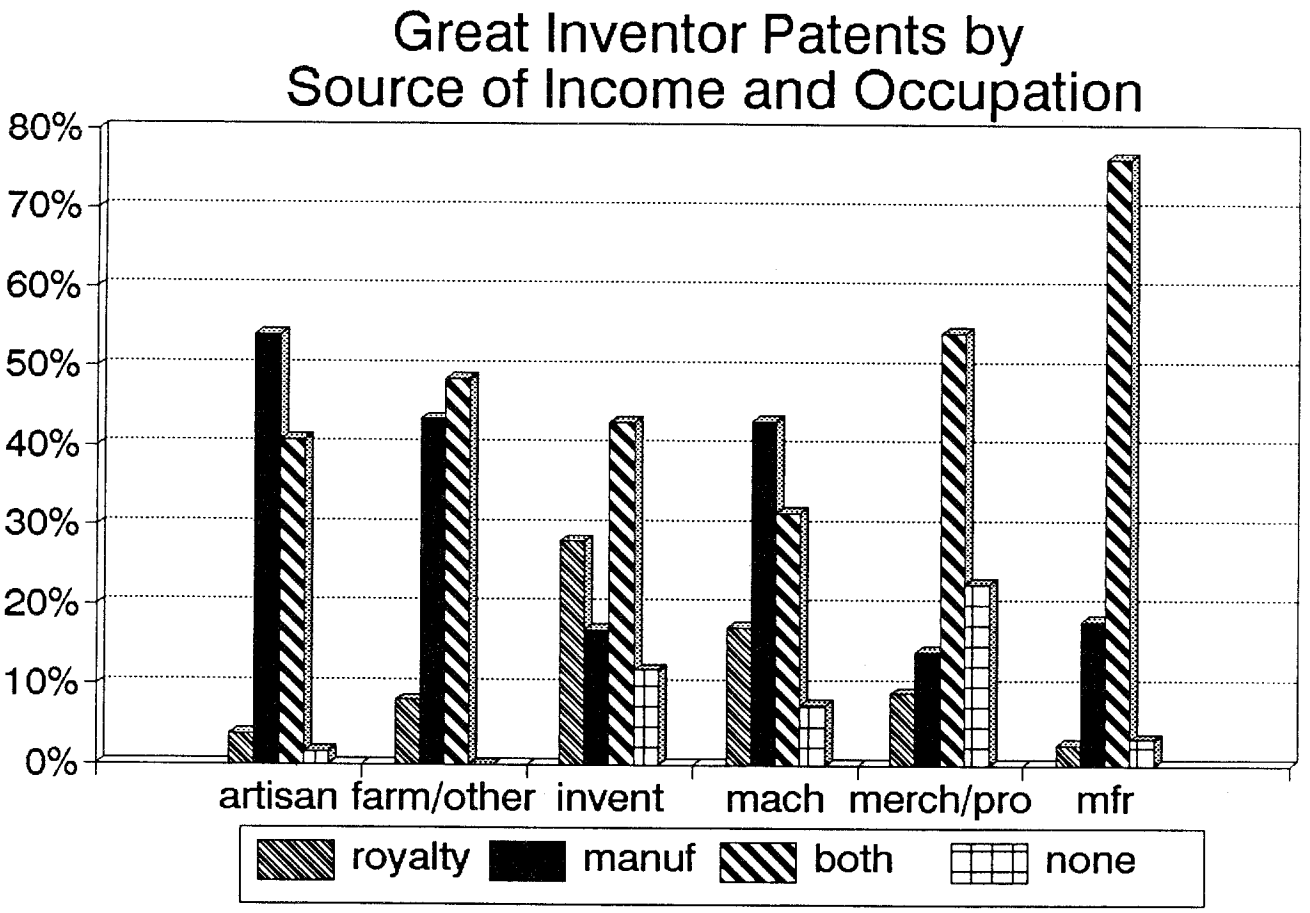
The entrepreneurial inclinations of inventors can also be discerned from their attempts to appropriate returns from their inventions. Such efforts encompassed a variety of methods, including direct use of the invention in production, assignment or sale of rights, licensing, and litigation. The typical great inventor combined ingenuity in both invention and commercial exploitation, proving to be a shrewd entrepreneur who efficiently promoted his inventions, motivated by a desire for profit. Few failed to secure rewards from their inventions.[14]

The assignment or sale of patent rights could prove to be 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, such as Henry Burden's 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, while 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, since 85 percent of the inventors for whom information is available were directly involved in commercial exploitation of their invention through manufacture, or 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 gained an estimated unit profit of $80 through manufacturing.[15] 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. Since patent assignments or licenses could be restricted to specific locations, such practices often made it possible to exploit a larger market than if the inventor chose the manufacturing strategy alone. Figure 4 indicates that 76 percent of all patents by manufacturers were due to those who chose this dual route to appropriating returns, as compared to 42 percent of patents by great inventors in other occupations. While the joint strategy was preferred, unless inventors benefited from learning by doing,

Figure 4



Notes and Sources: See text and Appendix. Categories of income are royalties and patent assignments, manufacturing (using the invention either as input or output), or both royalties and manufacturing. 'None' refers predominantly to observations for which no information was available regarding income.

their licensees and assignees could become competitors on the 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 which they employed in their operations. Many of their companies became virtual monopolies because of their superior policies of innovation.[16]

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, which may 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 to their efforts. In order to defend their claims, inventors were advised to seek patent protection. Not all new inventions are patentable, and of those which qualify, all are not 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 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 by producing locomotives for which a ready demand existed, based on his excellent reputation among railroad owners. Three machinists - Gridley Bryant, Sylvanus Brown and Isaac Dripps - made unpatented improvements which transformed the productivity of the enterprises where 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 of the above individuals produced inventions which were job-related. Most were 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. 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.[17]

While a valid patent was helpful, it was no guarantee that an inventor would be able to appropriate the return to 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 of 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 did 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, whom he charged 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.

Thirty, or less than one fifth of all great inventors were actually involved in litigation, while only 40, or 3 percent of their patents, 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 for this is perhaps that inventors employed litigation as a strategy to maintain market share 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.[17] The proportion of cases in relation to total patents filed was 2 percent for all inventors, but amounted to 10 percent for great inventors. Since precedent was established in the first successful outcome, these plaintiffs may have been more interested in suppressing competitors than in defending the patent per se. The litigation records are thus consistent with the evidence presented above in suggesting a strong concern with extracting an economic return.

IV

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 paper argues that information from a sample of 160 great inventors does not support this perspective. Instead, the data indicates that, although they were 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 pro-cyclical 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 and returns to 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 due to increased investments in inventive activity, by individuals whose "schemes of practical utility" were stimulated by higher perceived returns or demand-side incentives in general.

Appendix

The main source of the sample is the Dictionary of American Biography [DAB] (vols. 1-10), (NY, 1937). This is supplemented by Who Was Who in America, Historical Volume, 1607-1896 (Chicago, 1963) and The National Cyclopaedia of American Biography (various volumes, NY, 1926), while additional details were obtained from a number of biographical sources. The sample comprises virtually all of the best known antebellum inventors who were first active in the field of invention between 1790 and 1846. Featuring among the 160 'great inventors' whose first invention falls within this period are James Eads, Samuel Morse, Robert Stevens, Thomas Blanchard, Paul Moody and John Roebling. The information 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 prior occupation, and if their subsequent trade was related to the invention. We categorized occupational status as 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; farmers and others. The 'first major invention' was determined by the DAB's account, while 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, which were grouped in terms of 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 Annual Report of The Commissioner of Patents (Washington, DC, 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 county of patentee residence. Counties were categorized on the basis of per capita patenting rates which were computed in Sokoloff, "Inventive Activity." The sub-regions 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.)

FOOTNOTES

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

2. Schmookler, Jacob, Invention and Economic Growth (Cambridge, MA, 1966) and "The Economic Sources of Inventive Activity", Journal of Economic History, 22 (March 1962), pp1-20. See also Kenneth L. Sokoloff, "Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790-1846", Journal of Economic History, 48 (December 1988), pp. 813-850.

3. The sample is drawn from Malone, Dumas, ed., Dictionary of American Biography (vols. 1-10), (NY, 1937); refer also to Data Appendix.

4. An extended treatment appears in Sokoloff, "Inventive Activity", and Kenneth L. Sokoloff and B. Zorina Khan, "The Democratization of Invention during Early Industrialization: Evidence from the United States, 1790-1846", Journal of Economic History, 50 (June 1990), pp. 363-78. The number of great inventor patents in Figure 1 declines after 1846 relative to all patents, because of the bias introduced by the inclusion of only those inventors whose first invention occurred by that year.

5. Sokoloff, "Inventive Activity."

6. The terms 'primary' and 'secondary' are arbitrary, since the former refers to little or no education, while the latter indicates more years of schooling, but no college. Inventors for whom the extent of schooling is unknown seem likely to have had low levels of educational attainment.

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 were relatively more important in transportation. Although dominant in the South, they comprised a distinct minority in all 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," make the same argument for ordinary patentees. Our records indicated that high inventive activity was typically market induced, attracting a wider segment of the population to commit resources to invention and innovation.

10. This is not to say that luck was not involved. However, while it is true that many inventors proceeded by trial and error, this 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 at 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. Waldemar Kaempffert, "Systematic Invention", The Forum, 70 (1923), pp. 2010-2018 and 2116-2122. Also see S. C. Gilfillan, Sociology of Invention (Cambridge, MA, 1935).

12. J. Leander Bishop, A History of American Manufactures, from 1608-1860 (Philadelphia, PA, 1868), vol. 2, p. 512.

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 (Statistics of the United States in 1860 (8th Census, vol. 1), (Washington, 1866), vol. 1, pp. xxxiii-xxxiv).

14. Only 2 inventors are recorded as receiving no benefits. However, since 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.

15. William T. Hutchinson, Cyrus Hall McCormick, vol. 1, (NY and London, c. 1930), p. 278 and p. 292.

16. A large number of the great inventors were noted for their successful manufacturing enterprises, accounting for half of all great inventor patents. An inventor is regarded as a successful manufacturer if he appears in the Index of Manufacturers of the Dictionary of American Biography, or is listed as such in Bishop, American Manufactures.

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

18. Although the Woodworth patent dominated the woodworking industry because of shrewd manipulation, he is not included in the sample as a great inventor.