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The Impact of War on Resource Allocation: "Creative Destruction," Patenting, and the American Civil War

> *"War among civilized peoples, equal in number, is a contest of Science and Wealth."*
>
> *New York Times* (1862)

The relationship between war and technology has long attracted scholarly debate between those who argue that armed conflict boosts economic activity and those who maintain that wars have a deleterious effect. Sombart, who originated the concept of "creative destruction," provided the classic exposition of the idea that wars stimulate industrialization and technological change. Charles and Mary Beard presented their own version of this thesis when they argued that the American Civil War promoted the economic prosperity of the Northern economy. More recently, Parker attributed the "triumph of the West" to an aggressive and technologically innovative military tradition. By contrast, Nef proposed that wars had negative consequences that extended beyond the obvious costs of mortality and injuries, or the opportunity cost of mobilizing labor and other resources for the military. He highlighted the drawback of war-time technologies, which

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tended to be based on well-worn ideas, diverting the attention of inventors and innovators from more productive endeavors and inhibiting progress. Despite a plethora of research, significant aspects of this issue have not been subjected to empirical assessment; the key contentions remain unresolved. It is surprising that none of the many books and articles written about the Civil War provides a systematic analysis of the technological changes that it fostered.[1]

The American Civil War is widely regarded as a watershed in military technique and technology, a transition from the (literally) more regimented European precedent toward modern strategies that placed a premium on the tools of warfare. John Ericsson, an eminent patentee, advised President Lincoln that the Union's "cause [would] have to be sustained, not by numbers, but by superior weapons. By a proper application of mechanical devices alone will you be able with absolute certainty to destroy the enemies of the Union ... if you apply our mechanical resources to the fullest extent, you can destroy the enemy without enlisting another man." The Civil War heralded the advent of a more capital-intensive approach to armed conflict and a quest for superior innovations to transform untutored recruits into formidable adversaries.

Historians have produced extensive case studies of specific technologies and innovations that were introduced during the war, encompassing repeating firearms, breech-loading rifles, explosives, hand grenades and underwater torpedoes, aeronautics and aerial reconnaissance, pontoon bridges, ironclad battleships, manned submarines, trench warfare, and the military use of telegraphy and rail transportation. Economists, however, have paid little attention to wartime technology, preferring instead to investigate such issues as the direct and opportunity costs of the war, the efficacy of naval blockades, the experience of veterans, and links to financial

1 Werner Sombart's *Krieg Und Capitalismus* (Munich, 1913) remains untranslated into English. For an explication of his views, see Waldemar Kaempffert, "War and Technology," *American Journal of Sociology*, XLVI (1941), 431–444. Kaempffert declares that the discovery of gunpowder "did quite as much as the invention of movable types and the steam engine to change the structure of society ... and to lay the foundations of engineering and mass production" (432). Charles Beard and Mary Beard, *The Rise of American Civilization* (New York, 1927); Geoffrey Parker (ed.), *The Cambridge Illustrated History of Warfare: The Triumph of the West* (NewYork, 1995); John U. Nef, *War and Human Progress: An Essay on the Rise of Industrial Civilization* (Cambridge, Mass., 1950).

markets. Despite the lack of systematic analysis about the technological changes that came as a result of the Civil War, few would question that the spirit behind the nineteenth-century "republic of technology" owed as much to militarization as it did to industrialization.[2]

The Confederacy was especially unprepared for the advent of modern warfare. In an 1895 article, Josiah Gorgas, the Confederate Chief of Ordnance, noted, "In the winter of 1861–'62, while McClellan was preparing his great army near Alexandria, we resorted to the making of pikes for the infantry and lances for the cavalry; many thousands of the former were made at the various arsenals, but were little used. No access of enthusiasm could induce our people to rush to the field armed with pikes." One of the first acts of the Confederate Congress was to introduce a patent system. *Scientific American*, IV, 20, (18 May 1861), reported that Jefferson Davis alerted the Congress of the Confederate States on April 29 to the need for legislation about patents, which were averaging "about seventy per month" (317). *Scientific American*, however, was dismissive of the notion that "inventive talent has suddenly sprung up among the Southern people." The analog of the "intellectual property clause" in the U.S. Constitution appears as Art. 1, Sec. 6, Cl. 8 of the Confederate Constitution: "To promote the

2 Ericsson designed the ironclad *Monitor,* which was involved in the encounter with the *Merrimac* early in 1862. The *Monitor* incorporated the patented inventions of other inventors, such as Theodore Timby's revolving gun turrets. For an excellent survey of the historiography about the technologies introduced during the war, see Alex Roland, "Technology and War: A Bibiographic Essay," in Merritt Roe Smith (ed.), *Military Enterprise and Technological Change* (Cambridge, Mass., 1985), 347–379. For a small sample of economists' work, see Ralph Andreano (ed.), *The Economic Impact of the American Civil War* (Cambridge, 1962); Stanley L. Engerman, "The Economic Impact of the Civil War," *Explorations in Entrepreneurial History*, III (1966), 176–199; Claudia D. Goldin and Frank D. Lewis, "The Economic Costs of the American Civil War: Estimates and Implications," *Journal of Economic History*, XXXV (1975), 299–325; David T. Gilchrist and W. David Lewis (eds.), *Economic Change in the Civil War Era* (Greenville, 1965); Patrick O'Brien, *The Economic Effects of the American Civil War* (London, 1988). For classic economic-history studies of European wars and technology, see Carlo Cippola, *Guns, Sails and Empires: Technological Innovation and the Early Phases of European Expansion, 1400–1700* (New York, 1965), which attributes European dominance to its command of superior military technologies; David S. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present Day* (Cambridge, 1969); William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (Chicago, 1982), which highlights the way in which technology and the state combine to create centralized power; Clive Trebilcock, "Spin-off in British Economic History: Armaments and Industry, 1760–1914," *Economic History Review*, XXII (1969), 474–490.

progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."[3]

In economic terms, the Civil War was a large exogenous shock to American society that affected labor and capital markets, aggregate demand, the distribution of expenditures, and national income. The war also altered the set of opportunities, creating incentives for entrepreneurs to take advantage of the potential for supranormal monetary returns. Such indirect micro-economic effects of large-scale armed conflict are not simple to measure or interpret, but they warrant examination if we seek a better understanding of the more subtle costs and consequences of wars. For instance, some scholars have approached the study of war in terms of its "totality," defined as the degree of centralization, mobilization, and federal control. Yet, such organizational factors are neither necessary nor sufficient to explain the impact of war on a society as a whole. When enough private individuals were extremely responsive to new incentives during a war, substantial changes in the allocation of resources could occur even within a decentralized structure with little federal control and low labor participation in the military.[4]

The existing body of research leaves many questions unexplored. How did the Civil War affect patterns of patenting and comparative advantage in inventive activity across regions? Which individuals, or types of individual, were most likely to take advantage of the opportunities that the American Civil War afforded? Were contributions to the war made primarily by individual entrepreneurs who radically changed their orientation, or did the major response emanate from those who were already specialized in weaponry during the antebellum period? As Nef pointed out, it

3 For a reprint of Gorgas' article, see Chad E. Fuller and Richard D. Steuart, *Firearms of the Confederacy* (Huntington, W. Va., 1944), 117. See also Frank E. Vandiver, *Ploughshares into Swords: Josiah Gorgas and Confederate Ordnance* (Austin, 1952). Ericsson cited in Robert V. Bruce, *Lincoln and the Tools of War* (Indianapolis, 1956), 68.

4 Stig Förster and Jörg Nagler (eds.), *On The Road to Total War: The American Civil War and the German Wars of Unification, 1861–1871* (New York, 1997); Engerman and J. Matthew Gallman's article in this volume—"The Civil War Economy: A Modern View" (217–248)—defines total war by the degree of a population's economic mobilization for war and the amount of centralized direction imposed by the state. By this measure, they find that the claim for total war was greater in the South than in the North. The French version of Nef's work (n.1) was titled "the road to total war"—*La Route de la Guerre Totale* (Paris, 1949).

is important to consider whether wars created new technologies or simply diverted existing inventive resources into the military sector. Arguably, technological creation tends to have greater re-allocative effects than does technological diversion. Finally, this linking of military innovation to returns on entrepreneurial activity requires exploring whether war-responsive inventors enjoyed disproportionate changes in their wealth relative to inventors in other sectors or to the overall population.

The analysis herein is based on patents filed between 1855 and 1870, as well as on a sample of individuals who engaged in inventive activity during this period. It focuses successively on patterns of patenting in the nineteenth century, and during the Civil War era in particular; the responsiveness of inventors to war needs; and the returns to entrepreneurial enterprise as a function of this responsiveness. The discussion of resource re-allocation centers on occupational change, geographical mobility, and commercialization during the war. The patentees in this study first entered the market for invention during the Civil War or filed their first military invention during this period.

PATENTING DURING THE CIVIL WAR The U.S. Constitution was the first such document in history to incorporate a specific clause to protect the discoveries of inventors; the patent system that it authorized was widely acknowledged to be the most successful of the nineteenth century. Secure property rights, an efficient legal system, effective mechanisms for the diffusion of information, and transparent rules and standards created an environment that was extremely favorable to investments in inventive activity. Thus, when improvements in transportation networks and increases in national output brought about market expansion and the prospect of higher expected returns during the antebellum period, patenting began to surge. Patentees in general tended to be located in commercialized urban and metropolitan areas, but rural residents became more attracted to the market for inventions when formerly isolated areas became more integrated into the regional economy. These new entrants tended to be ordinary individuals eager to take advantage of new potential opportunities for profit. Research about "great inventors" shows that the patenting record was by no means limited to trivial gadgets; it also contained technologically and economically important inventions. The majority of

the great inventors exhibited a high propensity to patent their discoveries, and inventors from humble backgrounds benefited disproportionately from the security that such property rights offered. Well-enforced patent rights increased the effectiveness of markets in invention by creating tradable assets that helped relatively disadvantaged inventors to gain returns by selling their rights rather than by trying to raise capital through personal sources or through financial markets.[5]

Nineteenth-century inventors were especially anxious to secure their rights through patenting. It is not a mere coincidence that President Lincoln was a patentee and former patent lawyer, his secretary of war a patent lawyer, his secretary of the treasury a commissioner of the Patent Office, and his chiefs of navy ordnance and military engineering eminent inventors. President Lincoln's State of the Union Address in 1861, after the outbreak of the war, made a point of mentioning the condition of the Patent Office. Moreover, even with all the pressures of a bitter and divisive conflict, Lincoln was daily involved in personal communications with inventors and in tests of their military innovations. Patent rights might have been even more valuable during the war because patent portfolios could serve as a signal of reputation and reliability that gave an advantage to bidders for military contracts. For example, in 1866, more than 80 percent of those on the surgeon general's list of approved suppliers of prosthetic devices that the federal government funded had secured patents on these products. Patents were also beneficial because they differentiated products, at a time when poor quality in such equipment as artillery or explosives could result in large negative consequences. Hence, the idea that changes in the patterns of

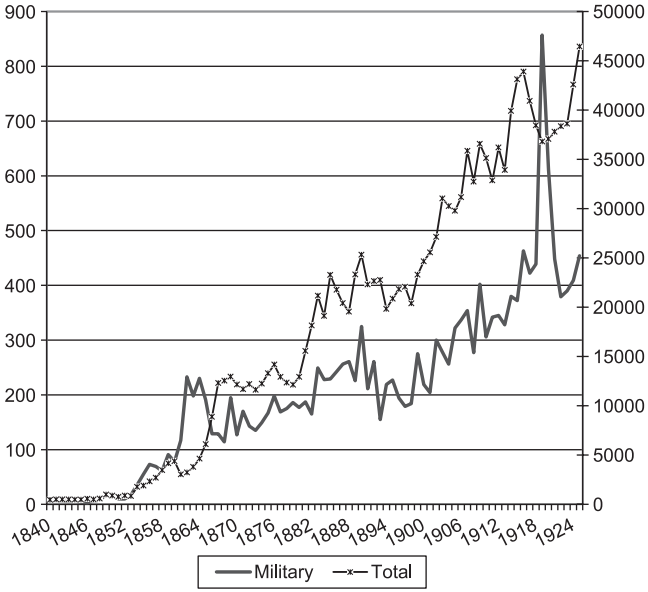
5 Khan, *The Democratization of Invention: Patents and Copyrights in American Economic Development* (New York, 2005). For evidence of the responsiveness of antebellum inventors to changes in market demand, see Kenneth L. Sokoloff, "Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790–1846," *Journal of Economic History*, XLVIII (1988), 813–850. Sokoloff and Khan, "The Democratization of Invention during Early Industrialization: Evidence from the United States," *ibid.*, L (1990), 363–378. For information about means of appropriating returns, see *idem*, "Institutions and Technological Innovation during Early Economic Growth: Evidence from the Great Inventors of the United States, 1790–1930," in Theo Eicher and Cecilia Garcia-Penalosa (eds.), *Institutions and Economic Growth* (Cambridge, Mass., 2006), 123–158; Naomi R. Lamoreaux and Sokoloff, "Market Trade in Patents and the Rise of a Class of Specialized Inventors in the 19th-Century United States," *American Economic Review*, XCI (2001), 39–44.

patenting during this period were representative of inventive activity in general, and of military inventions in particular, is more than plausible.[6]

At the most aggregate level, the data support Nef's contention that wars frequently retard inventive activity. On the eve of the Civil War, the United States was poised for rapid growth in innovation and industrialization. Patenting was increasing at an annual average rate of 19 percent, well in excess of population growth. As Figure 1 shows, the immediate after-effect of the Civil War was a fall in patent grants, from 4,363 in 1860 to 3,040 in 1861 and 3,781 in 1863. Patenting recovered to some extent in the following two years, but it jumped significantly at the end of the war; more than 12,300 patents were recorded in 1867. Table 1, which shows the broad geographical patterns in patenting before, during, and after the war, indicates that the war did not significantly alter regional comparative advantages; per capita patenting was notably resilient in all localities. As might be expected, the South and the Confederate states experienced a sharp decline in patenting during the war for which filings in the Confederate Patent Office could not compensate. The Northern states saw variation in relative positions between 1861 and 1865. For instance, Pennsylvania lost ground, and New York increased its share to a degree. The share of patents in frontier regions of the Midwest and West increased, whereas patenting in Illinois grew from 3 percent to almost 7 percent.

6 For Lincoln's interactions with hopeful military inventors, see Bruce, in *Lincoln and the Tools of War*, who notes that "the secretaries gave Lincoln at least three times as large a proportion of inventors' letters as they did of other kinds" (77). Lincoln approved the founding of the National Academy of Science in 1863 in part to provide the federal government with ready access to new discoveries. Congress concerned itself as late as March 1861 with patent business, producing the second major overhaul of the law in the century. The propensity to patent (patents filed per domestic resident) was significantly higher during the nineteenth century than during the past three decades, possibly due to the nature of technology, which at the time was fairly easy to duplicate; to industrial composition; to differences in the organization of firms; and to greater imperfection in capital markets. Edwin Stanton, "Artificial Limbs Furnished to Soldiers," 39th Congress, 1st Session, Ex. Doc. No. 108, House of Representatives. As of May 11, 1866, the government had provided prosthetics for 6,075 amputees, at a cost of $357,728. An article in the *South Danvers Wizard*, 1 June 1864, about the Salem Leg Company, one of the approved suppliers, described the company as "regularly organized and in possession of all the patents of the inventor" and its product as so superior to "all other [such] inventions, that the company can have no lack of orders, especially from those who have suffered amputation in the army, as this invention has the sanction and recommendation of the government, which pays the expense of furnishing the limbs" (2, 4).

Fig. 1 Patents for Weapons and Total Patents Granted, 1840–1925



NOTE AND SOURCE *Weaponry* is defined as an invention falling within patent classes 42 (firearms); 86, 102, and 149 (ammunition and explosives); 89 (ordnance); and 124 (mechanical guns), according to the U.S. Patent Office *Annual Reports*.

However, these developments are not inconsistent with the trends in technological change during the entire nineteenth century. The tremendous surge in patenting everywhere immediately after the war suggests that the conflict may have delayed the emergence of certain new technologies.[7]

Within the general stagnation in total patents, inventors responded disproportionately to the stimulus that the war provided. Changes in the distribution of patents across sectors were minor, but a sharp and marked increase in military inventions occurred. At the start of the war, the "belligerent arts" were underdeveloped. Combatants received muzzle-loading muskets with minimal range and accuracy, unreliable fuses, paper cartridges that dissolved in

7 The decrease in patent grants was not due to a lag in processing applications; the patent application series follows the patents granted closely. During the Civil War period, 63% of all patent applications were granted, approximately the same as the average for the period from 1860 to 1880. Between 1861 and 1865, 20,779 patents were granted out of 33,291 applications.

Table 1 Patenting and Population, 1830–1900

	PRE-1861	EVE OF WAR	CIVIL WAR	POSTWAR	1870S	1880S	1890S
New England							
Patents per capita	102.1	*260.1*	*308.1* (484.4)	*746.3*	725.3	820.2	698.4
Total patents (%)	28.0	*23.8*	22.8	*22.5*	19.8	17.8	15.8
Total pop. (%)	10.0		9.5		8.8	8.2	7.9
Middle Atlantic							
Patents per capita	70.4	*212.4*	*236.5* (346.7)	*506.5*	561.3	626.4	547.0
Total patents (%)	45.9	*41.1*	42.3	*37.4*	38.9	35.7	33.3
Total pop. (%)	23.7		23.4		22.3	21.6	21.3
East North Central							
Patents per capita	19.9	*114.6*	*124.0* (212.7)	*340.3*	317.0	417.3	409.4
Total patents (%)	12.0	*17.9*	21.2	*24.5*	22.5	24.7	25.8
Total pop. (%)	22.0		22.9		22.8	22.5	22.1
West North Central							
Patents per capita	6.1	*72.7*	*53.6* (102.6)	*171.9*	204.0	277.9	269.2
Total patents (%)	1.2	*2.4*	3.0	*4.4*	6.2	8.4	9.5
Total pop. (%)	6.9		8.3		9.8	11.4	12.3
West							
Patents per capita	5.0	*83.3*	*90.9* (175.8)	*193.6*	367.7	464.2	504.6
Total patents (%)	0.3	*1.0*	1.9	*1.8*	3.0	4.1	5.6
Total pop. (%)	2.0		2.2		2.6	3.3	3.9
South							
Patents per capita	3.0	*46.5*	*18.5* (41.9)	*65.0*	91.5	107.0	107.6
Total patents (%)	12.7	*12.2*	4.4	*6.2*	9.5	9.3	10.0
Total pop. (%)	35.4		33.7		33.6	32.9	32.5
United States	36.4	*130.6*	*129.5* (202.4)	*316.2*	322.1	379.1	349.8

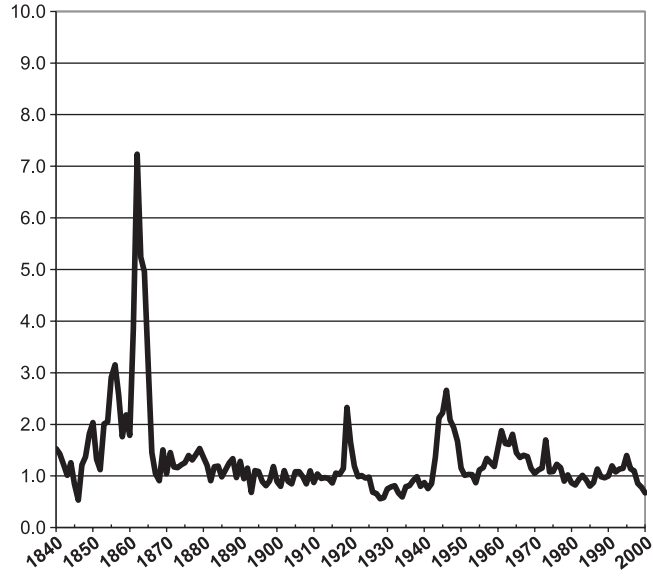
NOTES AND SOURCES The data around the Civil War period derive from a random sample of 1,074 patents filed on the eve of the war (1855, 1857, 1859, and 1860), 2,070 patents filed each year between 1861 and 1865 (inclusive), and 1,990 patents filed in the immediate postwar period (1866 and 1867). Data for total patents during the other years were computed from the *Annual Report of the Commissioner of Patents for 1891*. Population data are from the Census of the United States, computed at the decadal midpoint by exponential interpolation. Patents per capita are per million residents; the entries are inflated to the decadal total. Hence, the italicized per capita figures for the Civil War period refer to the total if the war pattern had lasted for the entire decade, whereas the figures in parentheses show the actual per capita figures for the 1860s.

the rain, cannon that exploded after several rounds, and projectiles with unpredictable trajectories. Inventors quickly turned their attention to remedying these routine defects. The *New York Times* reported that "the war has so stimulated the inventive Yankee brain that the Office at Washington fairly groans (we believe that is the figure) under the weight of instruments of destruction, and Gen. McClellan has but to adopt any one out of ten thousand patent kill-alls to utterly annihilate the rebels' 'grand army of the Potomac.'" Patents for improvements to cannon, projectiles, small arms, cartridges, and tents increased from 128 in 1860, to 345 in 1862, and 403 the following year. However, the greatest relative increase was in improvements to small arms and their cartridges, which promised the largest market. As the Commissioner of Patents noted, "Whatever improvements tend to the perfecting of the weapons of the private soldier must have a great value in warfare, where, as is usually the case, masses of men are marshaled to oppose collected masses."[8]

Figure 2 presents a time series involving the ratio of weaponry to total patents filed between 1840 and 2000. The results are striking, since this proportion was twice as high during the Civil War as it was during World Wars I and II. The size of the wartime effect during the nineteenth century relative to that during the twentieth century might be due to greater responsiveness among nineteenth-century inventors, or to the more diffuse nature of military technologies during the twentieth century. Patentees were responsive to other dimensions of conflict beside the need for overt military technologies. A significant number of them turned their attention to improving war-related accessories, including knapsacks, tents, groundsheets, ambulances, and military flares. William B. Johns, an army captain from Georgetown, obtained patents in 1861 for saddle leggings "very well adapted to army use, not only for mounted officers, but for general cavalry use" (patent no. 33,996); for an "improved military equipment" invention that could be converted from a sheet into a knapsack, tent, or military cloak (patent no. 33528); and for portable fireplaces that "thus take up but little of the most valuable room, while the property of retaining the heat thus gained renders it peculiarly desirable for keeping the

8 *New York Times*, 6 Dec. 1861, 4; *Annual Report of the Commissioner of Patents for 1863* (Washington, D.C., 1864).

Fig. 2 Weaponry as a Percentage of U.S. Total Patents, 1840–2000

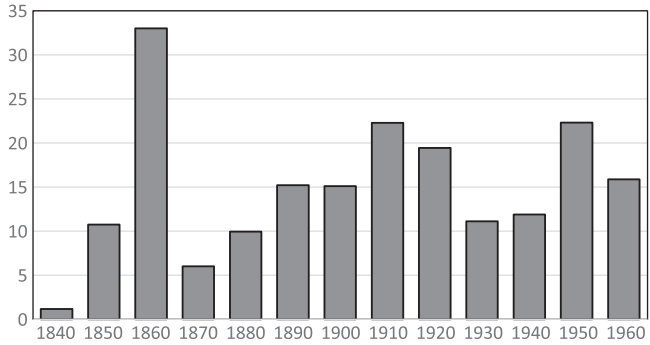


NOTE AND SOURCE *Weaponry* is defined as an invention falling within patent classes 42 (firearms); 86, 102, and 149 (ammunition and explosives); 89 (ordnance); and 124 (mechanical guns), according to the U.S. Patent Office *Annual Reports*.

tent comfortable during the great part of cold nights, so that it thereby becomes very useful for an army in winter quarters" (patent no. 33,995).

Prosthetics comprised an especially poignant category of war-related inventions, demonstrating the sensitivity of inventors to potential returns. Figure 3 shows the pattern for prosthetic inventions, which jumped from 25 in the previous decade to 104 during the 1860s. In his *Annual Report* for 1865, Commissioner of Patents Thomas C. Theaker recorded a fall in "warlike implements" but noted the "multitude of inventions to supply the place of amputated arms and legs." About 20,559 (8.1 percent) wounded Civil War soldiers underwent amputation, the incidence of which was higher during the Civil War than previously partly because of the increased range of rifles and artillery. Anesthetics also helped to increase soldiers' survival rates during the Civil War; so a large number of soldiers who suffered amputations required artificial limbs. Patents for improvements in prosthetics declined toward

Fig. 3 Prosthetic Patents per Capita, 1840–1960



SOURCE U.S. Census and Patent Office *Annual Reports*.

the end of the war but grew rapidly after Congress decided in 1866 and 1870 to continue underwriting the cost of artificial limbs provided to disabled soldiers.[9]

ENTREPRENEURSHIP AND INVENTION AMONG PATENTEES Some of the inventors who filed patents for military inventions during the Civil War may have had purely patriotic motives, but many of them were attempting to exploit the opportunity for financial gain. The experience of inventors of weaponry and war-related patents, compared to that of the white male population at large and to patentees of other kinds of invention, yields insights into the relationship between war and technology. An investigation of the characteristics associated with a military orientation among inventors, including career patterns and commitment to patenting, allows us to gauge the effects of the war by considering how occupational and geographical mobility before and after the war differed for patentees with more inventive capital relative to that of the general population.

9 *Weaponry* is defined as the set of patents that fall within patent classes 42 (firearms); 86, 102, and 149 (ammunition and explosives); 89 (ordnance); and 124 (mechanical guns). See Robert H. Meier, in *idem* and Diane J. Atkins (eds.), *Functional Restoration of Adults and Children with Upper Extremity Amputations* (New York, 2004); Susan Provost Beller, *Medical Practices in the Civil War* (Cincinnati, 1992); Katherine Ott, David Serlin, and Stephen Mihm (eds.), *Artificial Parts, Practical Lives: Modern Histories of Prosthetics* (New York, 2002).

The analysis is based on a stratified random sample of 1,359 inventors who filed at least one patent between 1855 and 1870—720 patentees of general inventions and 639 of military inventions. From 1855 to the Civil War, 255 of the inventors filed patents—673 from the Civil War period and 431 from the postbellum period through 1870. The full patenting record during the lifetime of the sample amounts to a total of 8,542 patents. The patentees were matched across manuscript censuses in 1860 and 1870 to capture changes that occurred in their individual circumstances before and after the war. The linkage to manuscript censuses yields information about age, place of birth, residence, migration, occupation, real-estate wealth, personal wealth, and military status (veteran or not). The control sample consists of 1,712 white native-born males drawn from the Integrated Public Use MicroData (IPUM) census, traced between 1860 and 1870.[10]

During the war, both ordinary and "great inventors" dramatically changed the rate and direction of their activities toward military technologies, as well as toward other areas where markets were expanding, such as cotton substitutes. Table 2 provides more information about the occupational distribution of inventors before and after the war. As might be expected, a number of the inventors of weaponry and war-related devices were eminent military men, such as Henry M. Naglee, a West Point graduate and Brigadier-General in the Union Army, who in 1863 devised an apparatus for locating and exploding submarine torpedoes. For the most part, however, inventors were artisans, farmers, laborers, and professionals without particular technical skills. Among the less distinguished veterans was John Oliphant, a laborer from Uniontown, Pennsylvania, who filed a patent in January 1863 for a safety catch on firearms. The patent specification (no. 37,406) attributed Oliphant's motivation to "the custom in the army, for the purpose of preventing accidents of this nature, to require the soldiers to march with empty guns, they not being permitted to load until they are in the immediate presence or neighborhood of the enemy, thus constantly running the risk of being suddenly surprised by an ambuscade with

10 Southerners are oversampled because of an attempt to trace the inventors of all 269 patents that were filed in the Confederate Patent Office during its term of existence. For further information about the sample, see the notes to Table 2. Joseph Ferrie generously provided access to the IPUM data.

Table 2 Characteristics of Inventors in the Sample

AGE AT TIME OF FIRST INVENTION (PERCENTAGE)

	GENERAL INVENTIONS		WEAPONRY		WAR-RELATED INVENTIONS		ALL	
AGE	ALL	CIVIL WAR	ALL	CIVIL WAR	ALL	CIVIL WAR	ALL	CIVIL WAR
Less than 20 years	0.6	0.7	0.7	1.0	0.0	0.0	0.6	0.8
20–29 years	19.5	14.9	21.2	19.9	13.0	10.8	19.7	16.8
30–39 years	38.9	43.3	36.1	37.8	42.0	43.2	38.0	40.7
40–49 years	25.1	22.7	23.6	25.6	26.0	27.0	24.6	24.6
50–59 years	13.3	14.2	13.4	13.5	14.0	13.5	13.4	13.8
60 years and over	2.3	3.9	1.1	0.3	3.0	4.5	1.9	2.3
Average age	38.7	39.5	37.9	37.8	40.0	40.2	38.5	38.8
Number	710	281	517	301	98	73	1,325	655

OCCUPATIONS IN 1860 AND 1870 (PERCENTAGE)

	GENERAL INVENTIONS		WEAPONRY		WAR-RELATED INVENTIONS		ALL	
	1860	1870	1860	1870	1860	1870	1860	1870
Artisans	20.3	16.3	17.7	12.8	17.8	16.8	19.1	15.0
Blacksmiths	2.8	2.4	1.9	1.1	1.0	0.0	2.3	1.7
Engineers	2.4	1.5	3.9	3.9	0.0	1.0	2.8	2.4
Inventors	1.0	5.4	1.7	4.3	1.0	0.0	1.3	4.6
Machinists	9.4	9.2	10.8	6.5	7.9	3.0	9.9	7.7
Farmers	11.9	12.6	5.8	4.8	6.9	4.0	9.1	8.9
Medical	2.8	1.5	5.2	3.5	12.9	6.9	4.5	2.7
Merchants	2.6	1.7	3.9	3.4	4.0	3.0	3.2	2.4
Manufacturers	8.5	15.8	9.9	11.9	10.9	25.7	9.2	15.0
Military	0.1	0.1	5.2	4.8	1.0	2.0	2.2	2.1
Professionals	5.6	5.7	5.9	5.2	7.0	7.0	5.8	5.6
Laborers	10.1	9.6	6.5	3.9	5.0	2.0	8.3	6.8
Traders	5.1	6.5	4.8	3.2	6.9	6.0	5.2	5.2
None	5.7	2.8	2.2	2.0	0.0	1.0	3.9	2.4
Unknown	11.7	9.0	14.7	28.6	17.8	22.8	13.3	17.7
Number	720	720	538	538	101	101	1,359	1,359

INVENTORS BY TOTAL NUMBER OF PATENTS FILED OVER LIFETIME (PERCENTAGE)

	GENERAL INVENTIONS	WEAPONRY	WAR-RELATED INVENTIONS	ALL
One patent	31.3	28.6	46.5	31.4
2–4 patents	32.0	27.9	29.7	30.2
5–9 patents	21.8	21.4	11.9	20.9
10–19 patents	9.5	12.8	9.9	10.8
20 patents and above	5.4	9.3	2.0	6.7
Average patents	6.0	7.2	3.9	6.3
Total inventors	720	538	101	1,359

Table 2 (Continued)

INVENTORS BY LENGTH OF PATENTING CAREER (PERCENTAGE)				
One year	32.9	31.1	49.5	33.4
2–4 years	11.4	7.3	3.0	9.1
5–9 years	10.4	13.2	18.8	12.2
10–19 years	22.9	20.5	15.8	21.4
20 years and above	22.4	27.9	12.9	23.9
Average career	11.3	12.8	7.6	11.6

NOTES The data comprise a stratified random sample of 1,359 inventors who filed at least one patent between 1855 and 1870, and who could be traced in the 1860 and/or the 1870 manuscript censuses. The strata include 720 patentees of general inventions and military inventors—538 patentees of weaponry and 101 patentees of war-related inventions. The source for 255 of the patentees were patents filed from 1855 to the Civil War; 673 of them came from the Civil War period; and 431 came from the postbellum period through 1870. The patents for all of the individuals in the sample were traced throughout their lifetime. The inventors in the sample filed a total of 1,842 military patents and 8,542 total patents during their lifetimes. "General inventions" refer to patents that are unrelated to war or the military. "Weaponry" includes patents for firearms, cannon, ordnance, and explosives. "War-related inventions" comprise miscellaneous patents, other than weapons, that mentioned war and the military in the specifications or that were incidental to the war (such as uniforms, knapsacks, tents, canteens, shields for warships, artificial limbs, and military signals). The length of an inventor's patenting career was measured by the difference between the first and last patent filed plus one year.

Of the inventors in the sample, 1,177 were traced in the 1860 census, 1,120 in the 1870 census, and 974 in both censuses. In the first group, the name of the patentee was matched to the residence of the patentee, as given in the patent records, with entry in at least one of the censuses. Matches across the decade were made on the basis of name, birth date, birthplace, and the identities of family members (only if the patentee had a family). The likelihood of a match increased with proximity of the patenting year to the census. Information retrieved from the censuses include birth year and birthplace, occupation, residence, migration, real-estate wealth, and personal wealth. The sample includes 147 inventors who were identified as veterans of the Civil War, 745 who did not appear in war records, and 467 whose status as veterans could not be determined.

empty guns in their hands." Oliphant may have belonged to the 5th Pennsylvania Infantry regiment in 1861.

Although farmers accounted for the single largest occupational category in the general population, the majority of inventors fell into three basic categories—workers and artisans, comprising farm laborers, bakers, carpenters, and jewelers; a more elite class of professionals, including such technical and white-collar inventors as bookkeepers, engineers, and physicians; and market-oriented manufacturers and traders (merchants, salesmen, retail, and wholesale dealers.) A substantial number of patentees attempted to capitalize on their invention by manufacturing it themselves resulting in an even larger share of occupations (18.2 percent) for manufacturers,

Fig. 4 Notice of Jewett's Patent

JEWETT'S

Patent Artificial Legs !

OFFICE OF THE JEWETT PATENT LEG CO., Washington, D. C.

THESE limbs are manufactured by the Patentee, under a special contract with the Government, and supplied to the soldiers free of charge.

The Patentee claims for them a superiority over all other patents, for their STRENGTH, DURABILITY, LIGHTNESS, PERFECT FINISH, SIMPLICITY OF CONSTRUCTION, and ease with which those parts liable in all artificial limbs to become worn or disarranged can be replaced and adjusted, without the trouble, expense, and very great inconvenience of sending the limb back to the manufactory for repair.

Soldiers and Sailors who have lost their limbs in the service are entitled to one without charge, and all information regarding the mode of proceeding will be cheerfully given by applying at the office, or by letter directed to

GEO. B. FOSTER,
33 Tremont St, Boston.

sep 28 1mdis*

SOURCE *Hartford Daily Courant*, 30 Sept. 1865, 3.

after the war. The increase was especially evident among inventors of war-related patents, among whom manufacturers increased from 10.9 to 25.7 percent. For instance, the link between patent records and manuscript censuses reveals that George B. Jewett, who had been a clergyman in Salem, Massachusetts, before the war, filed six patents for an improvement in artificial limbs during the war; by 1870, he was manufacturing prosthetics (see Figure 4).[11]

About half of all inventors filed their first patent during the Civil War. Women increased their patenting markedly during this period, from only seventy-two patented inventions in the entire period before the war to eighty-six during the war years alone. Many of their inventions were related to the war effort and to women's participation in production outside the home. For instance, in 1864, Mary Jane Montgomery of New York obtained

11 For patenting activities of "great inventors," see Khan and Sokoloff, "'Schemes of Practical Utility': Entrepreneurship and Innovation among 'Great Inventors' during Early American Industrialization, 1790–1865," *Journal of Economic History*, LIII (1993), 289–307; *idem*, "Entrepreneurship and Technological Change in Historical Perspective: A Study of Great Inventors during Early Industrialization," *Advances in the Study of Entrepreneurship, Innovation, and Economic Growth*, VI (1993), 37–66.

a patent for a "war vessel." Sarah J. A. Hussey, a Quaker from Cornwall, New York, noted in her 1865 patent specification that her invention was inspired by her "long experience as a nurse in the United States army hospitals." Many of these patents were widely marketed—a notable example being the $20,000 that Martha J. Coston received by authority of Congress on June 5, 1862, granting the U. S. Navy the rights to her chemical flares. Coston founded a company and manufactured the signals at cost for the military during the war.[12]

The patterns of new entrants differed significantly according to their military orientation. Approximately 40 percent of general inventors (281) were new entrants during the Civil War, whereas 58.2 percent of the creators of improvements in weapons (301) and 74.5 percent of war-related inventors (73) were first-time filers. Hence, inventors of military innovations appear to have been more responsive than general patentees to the prospects that the war offered. The average age of inventors at the time of first patenting was an experienced forty. Those who entered this field for the first time during the Civil War tended to be older than the average inventor, and certainly older than the average age of the general population. Only 10.8 percent of these war-related first-timers were younger than thirty, whereas 20.3 percent of all inventors were younger than thirty, probably because most of the men in this demographic had been pressed into military service.

Telling information about the identities of those who were making contributions to technological change during the war comes from data about career patents (Table 3). The inventors of weaponry differed from those who created miscellaneous devices that were incidental to the war. Almost one-half of the war-related inventors produced a single patent and had brief careers; only 12.9 percent had careers of twenty years or more.

12 Khan, "'Not for Ornament'"; *idem*, "Married Women's Property Laws and Female Commercial Activity: Evidence from United States Patent Records, 1790–1895," *Journal of Economic History*, LVI (1996), 356–388. Patent No. 41167, January 5, 1864; patent No. 47831, May 23, 1865, for an "improved table for hospitals." Sarah Hussey was buried in 1898 with military honors in her hometown. Reports of Committees, Report No. 622 of the Committee of Patents, 48th Congress, 2nd Session of the Senate, May 17, 1880. The Bureau of Navigation of the Navy noted, "No lights or other symbols for making night signals in fleets or squadrons have been found . . . *in any degree comparable to those known as Coston Night Signals*" (2, emphasis in original).

Table 3 Lifetime Patents and Average Number of Patents per Inventor, by Type of Invention, Region, and Occupation

		MILITARY INVENTIONS		GENERAL INVENTIONS		
	NUMBER	BEFORE WAR	CIVIL WAR	BEFORE WAR	CIVIL WAR	LIFETIME INVENTIONS
Veterans	147	0.20	0.66	0.61	1.09	5.40
Nonveterans	745	0.18	0.38	3.48	1.17	6.23
Occupation before war						
Artisan	290	0.16	0.40	7.01	1.06	4.33
Farmer	124	0.16	0.19	0.53	0.73	3.07
Technical	172	0.24	0.49	1.62	1.52	9.12
Manufacturer	125	0.62	1.02	1.90	1.93	11.62
Professional	187	0.31	0.95	1.27	1.74	6.67
Trader/ merchant	114	0.06	0.69	0.98	1.44	6.54
Laborer	113	0.10	0.40	0.54	0.88	4.39
None	53	0.02	0.26	0.40	0.96	6.19
Unknown	181	0.23	0.45	0.59	0.77	5.91
Region of birth						
New England	468	0.32	0.61	5.30	1.43	7.21
Middle Atlantic	408	0.19	0.60	0.89	1.31	6.04
East North Central	84	0.04	0.41	0.58	0.95	5.92
West North Central	7	0.43	0.43	0.43	0.71	3.86
South	101	0.21	0.41	0.73	0.73	4.64
Foreign	274	0.16	0.50	0.63	1.11	5.76
Unknown	17	0.24	0.35	0.71	0.59	8.12
Region of patenting						
New England	415	0.30	0.60	5.67	1.41	6.62
Middle Atlantic	458	0.21	0.67	1.11	1.38	6.61
East North Central	256	0.12	0.31	0.62	0.98	4.73
West North Central	50	0.02	0.34	0.12	0.76	3.80
South	115	0.32	0.60	0.91	1.02	5.09
West	28	0.03	0.29	0.14	0.71	5.21
Other	17	0.06	0.30	0.06	0.42	2.76
Unknown	20	0.65	1.10	0.75	1.50	6.25
All inventors	1,359	0.22	0.55	2.32	1.27	6.29
Total patents		304	749	3,147	1,677	8,542

By way of contrast, the 538 patentees of weapons tended to have longer careers and to hold more patents; more than 22 percent of them filed ten or more patents—a profile consistent with the greater specialization of weapon inventors. The war may well have attracted new entrants into the area of miscellaneous war-related inventions (technological creation), but the invention of new weaponry per se was more likely to come from existing patentees who had changed their orientation (technological diversion) because of the prospects that the war offered.

Table 3 shows average patenting per inventor and patents granted throughout inventors' entire lifetime, across regions and occupations. Career patenting was highest in the well-developed markets of the Northeast and otherwise uniformly distributed across regions. Although they lagged in terms of average patents per inventor, the West and the West North Central frontiers accounted for large surges in war-time patenting, indicating a widespread response to the anticipated growth in the market for military inventions. Inventors born in the Mid-Atlantic States and outside the United States were especially responsive to the technological exigencies of the conflict. As might be expected, war veterans, who were responsible for fewer lifetime patents than was the case for the average inventor, were disproportionately likely to produce military inventions. However, among general inventors, the commitment to patenting fell sharply among artisans and New England residents, groups that may have suffered disproportionately from the war.

Migration—both international and internal—has long been part of the American experience; Americans remained "restless in the midst of their prosperity." Geographical mobility is a key indicator of resource re-allocation, signaling the flexibility necessary for entrepreneurial success. Since investments in human capital are usually associated with higher mobility, holding other things constant, patentees might be expected to exhibit greater mobility than their less inventive counterparts. Inventors from other countries were disproportionately attracted by the opportunities that this country offered. In 1860, more than 20 percent of patentees were immigrants to the United States; 7.6 percent of those in the sample were from Britain and 5.3 percent from Germany. Native-born inventors were clustered in states where per capita patenting was especially high—New York, Massachusetts,

and Connecticut accounting for 18.7 percent, 12.3 percent, and 8.6 percent of the inventors in the sample, respectively.[13]

The dataset observes the residence of patentees at each point of patenting; and a measure of migration that takes into account any recorded change in residence yields rates of interstate migration that are exceedingly high for all inventors, military or otherwise. Table 4 defines migration more conservatively, however, in order to enable comparison with the general population. Lifetime migration through 1870 simply indicates any change that occurred across birthplace, location in the 1860 census, and location in the 1870 census. The middle of the 1850s saw a rapid increase in the rate of international immigration into the United States. The 1850 census recorded that less than 10 percent of the population were immigrants but, by 1860, 13.2 percent of the population was foreign-born, and in 1870 the proportion of foreign-born residents was 14.4 percent.[14]

Table 4 shows that, relative to the general population, individuals who possessed inventive capital exhibited significantly greater movement across states, by any measure of geographical mobility. Since the U.S. population sample is restricted to native-born residents, the last row in the table presents the results for native-born inventors. By 1870, 42.3 percent of the U.S. population had moved from their birthplace to another state, but both military inventors and total inventors experienced higher mobility (53.4 percent and 52.8 percent, respectively). As shown in other research co-authored with Sokoloff, their destinations tended to be places with greater commercial opportunities. Although inventors exhibited higher rates of mobility during their careers than did the general population, the war retarded the likelihood that they would switch locations. Between 1860 and 1870, their rates of geographical mobility, and the distance between old and new

13 Alexis de Tocqueville regarded American mobility as pathological: "It is strange to see with what feverish ardor the Americans pursue their own welfare, and to watch the vague dread that constantly torments them lest they should not have chosen the shortest path which may lead to it." See Tocqueville, *Democracy in America* (New York, 1899; orig. pub.1840), 144. Regarding investment in human capital, see, for instance, Robert A. Margo, *Race and Schooling in the South, 1880–1950: An Economic History* (Chicago, 1990); Aba Schwartz, "Migration, Age and Education," *Journal of Political Economy*, LXXXIV (1976), 701–719.

14 See Series C89-119, *Historical Statistics of the United States, Colonial Times to 1970* (Washington, D.C., 1975), I.

Table 4 The Geographical Mobility of the U.S. Population and of Inventors

	MIGRATION BETWEEN 1860 AND 1870									LIFETIME MIGRATION THROUGH 1870			
	U.S. POPULATION			MILITARY INVENTORS			ALL INVENTORS			MILITARY INVENTORS		ALL INVENTORS	
		MIGRANT=1			MIGRANT=1			MIGRANT=1		MIGRANT=1		MIGRANT=1	
RESIDENCE IN 1860	ALL	ROW %	COL %	ALL	ROW %	COL %	ALL	ROW %	COL %	ROW %	COL %	ROW %	COL %
East North Central	25.1%	19.8	32.2	12.4%	22.9	18.0	19.7%	13.6	18.4	93.8	18.5	82.7	26.9
	N=430			48			191						
Middle Atlantic	25.2%	11.4	18.6	35.5%	11.0	24.6	31.7%	11.4	24.8	56.2	31.7	51.8	27.0
	N=432			137									
New England	14.4%	13.4	12.5	36.5%	14.2	32.8	34.0%	14.9	34.8	49.7	28.8	48.6	27.2
	N=246			141			329						
South	25.5%	13.4	22.2	10.4%	25.0	16.4	9.2%	21.4	13.5	77.5	12.8	66.3	10.0
	N=436			40			89						
West	2.0%	27.9	3.7	2.3%	33.3	4.9	1.9%	22.2	2.8	100.0	3.7	100.0	3.1
	N=35			9			18						
West North Central	7.8%	21.6	10.9	2.8%	18.2	3.3	3.6%	22.9	5.7	100.0	4.5	97.1	5.8
	N=133			11			35						
Total %	100%	—	15.4%	100%	—	15.8%	100%	—	14.6%	—	63.0	—	60.7%
Total *N*	1,711	—	264	386	—	61	969	—	141	386	243	969	588
Native born only													
Total %	100%	—	15.4%	100%	—	16.6%	100%	—	14.9%	—	53.4%	—	52.8%
Total *N*	1,711	—	264	307	—	51	790	—	118	307	164	790	409

NOTE The table defines migration conservatively, in order to enable comparison with the general population. Lifetime migration through 1870 simply indicates any change that occurred across birthplace, location in the 1860 census, and location in the 1870 census. Since the U.S. population sample is restricted to native-born residents, the last row in the table presents the results for native-born inventors.

locations, were approximately the same as that of the resident white male population. The war may have lowered expected benefits or increased the risks and costs of migration disproportionately for those with higher investments in inventive capital.[15]

Individuals often move for personal reasons but, in many instances, migration is tied to job search. Geographical and occupational mobility are often a function of similar individual characteristics—age, inherent ability, the accumulation of investments in human capital, and access to information over time. Responses to an exogenous shock like the Civil War would have varied depending on these individual characteristics. Although labor-market theory does not offer a basis for predicting the direction of change, it suggests that the share of individuals at risk for change might be negatively related to investments in human capital, because of a fall in the set of occupations that might lead to greater returns as education and skill increases.[16]

Table 5 presents the distribution of occupations in 1860 and 1870 for a sample drawn from the general population, as well as all inventors and inventors of military patents. Approximately 60 percent of the U.S. population remained in the same broad job category during the war, relative to 63 percent of all inventors. Persistence, or no transition across occupational classes, was the norm for the majority of inventors as well as for the population in general, but occupational persistence for war-related inventors was higher (almost 70 percent). As theory predicts, inventors in higher-status occupations experienced greater persistence relative to the population. Inventive capital helped to avoid downward mobility; inventors show a special tendency to remain in skilled and white-collar occupations.

In the general population, about one-half of all men in market-oriented occupations (the commercial class) remained there after

15 See Khan and Sokoloff, "Schemes of Practical Utility."

16 The argument about similar characteristics for the two types of mobility is based on broad occupational categories corresponding to general skill levels. Persistence in these categories does not rule out rapid entrepreneurial within-class changes, such as a manufacturer of soap shifting to the production of lathes after he patents an improvement for the latter product. Khan and Sokoloff, "Schemes of Practical Utility," found that such occupational re-orientation was standard among inventors of the time. For studies of occupational mobility during this period, see, for instance, Ferrie, "Up and Out or Down and Out? The Occupational Mobility of Immigrant Non-Persisters in the Nineteenth Century U.S," *Journal of Interdisciplinary History,* XXVI (1995), 33–55. For the labor-market theory, see Schwartz, "Migration, Age and Education."

Table 5 Occupational Mobility among U.S. Population and Inventors between 1860 and 1870 (Percentage Of 1860 Occupational Class in 1870 Occupational Class)

OCCUPATIONS 1860 AND 1870	U.S. POPULATION (WEIGHTED)	ALL INVENTORS	MILITARY INVENTORS
Commercial, commercial	49.8	72.4	76.5
Commercial, farmer	17.8	3.8	6.2
Commercial, skilled	6.8	10.8	6.2
Commercial, white collar	19.6	10.8	11.1
Commercial, worker	6.0	2.2	0.0
N (1860, 1870)	(105, 171)	(185, 257)	(81, 110)
Farmer, commercial	4.9	19.8	20.8
Farmer, farmer	76.6	60.4	58.3
Farmer, skilled	3.8	9.4	8.3
Farmer, white collar	2.3	3.8	8.3
Farmer, worker	12.4	6.6	4.2
N (1860, 1870)	(656, 682)	(106, 104)	(24, 27)
Skilled, commercial	13.2	19.6	18.2
Skilled, farmer	18.0	4.2	2.6
Skilled, skilled	48.8	61.9	68.2
Skilled, white collar	7.5	9.3	8.4
Skilled, worker	12.5	5.0	2.6
N (1860, 1870)	(256, 195)	(378, 299)	(154, 124)
White collar, commercial	19.1	11.1	9.9
White collar, farmer	13.7	2.2	2.5
White collar, skilled	4.1	9.6	8.6
White collar, white collar	58.5	73.3	77.8
White collar, worker	4.7	3.7	1.2
N (1860, 1870)	(101, 125)	(135, 165)	(81, 89)
Worker, commercial	11.0	14.4	24.2
Worker, farmer	33.5	15.6	6.9
Worker, skilled	11.3	24.4	17.2
Worker, white collar	3.9	7.8	6.9
Worker, worker	40.3	37.8	44.8
N (1860, 1870)	(306, 247)	(90, 69)	(29, 19)
Total	1,421	894	369

NOTES Commercial occupations include traders, merchants, and manufacturers; skilled occupations include machinists, engineers, artisans, and mechanics; white-collar occupations include such professionals as physicians and bookkeepers; workers include farm laborers and unskilled individuals. The data set includes only those individuals for whom occupational information was available in both years and excludes those who had no occupation or who were not located in one of the years. The percentages refer to the first-mentioned occupational class (commercial, farmers, skilled, white-collar, and workers) in 1860 that fell within the adjacent class in 1870. Joseph Ferrie's Integrated Public Use MicroData (IPUM) census sample for the U.S. population includes only white native-born adult males (letters A through C) who were linked in both years, and the weights adjust Ferrie's sample observations to the national proportions for birthplace, region, and occupation. The sample of inventors is unweighted.

the war. Patentees were not only significantly more likely to remain in commercial occupations; they were also more likely to switch to such occupations after the war, arguably demonstrating greater entrepreneurial abilities by so doing. Inventors were able to move up from unskilled worker to skilled or white-collar occupations to a greater extent than those without inventive capital. Workers in the general population who made the transition to another occupational class were more likely to become farmers (33.5 percent of all laborers in the general population, compared to 7 percent of war-related inventors), rather than progress to skilled or commercial pursuits. Moreover, farmers in the general population were twice more likely than inventor-farmers to fall into the laborer category. Farmers and workers who persisted in the same occupation had less of both real estate and personal wealth, regardless of whether or not they possessed inventive capital.

To what extent did inventors who responded to the war differ from inventors without a military orientation? Table 6 presents the results of regressions that control for a number of the possible correlates of patenting. The first two regressions show the factors that influenced variation in the number of military patents that were filed during the war, and the next two concern the characteristics that were associated with high numbers of military inventions between 1855 and 1870. In general, military inventions were more numerous in New England and the South, but inventors who responded to the war came from all regions of the country. Unlike the entire population of inventors, military patentees tended to be geographically immobile, but those who switched occupations obtained higher numbers of patents. Surprisingly, technical expertise did not yield greater numbers of military inventions; instead, manufacturers and the professional class of physicians, lawyers, and other white-collar workers filed the greatest number of military inventions. Other things being equal, the poorer segments of the population who owned less than $100 in total wealth in 1860 filed the bulk of military patents, though not during the Civil War.[17]

17 Regressions that control for wealth as a continuous variable (run by author but not reported herein) show that its effect was minimal in explaining inventive orientation.

Table 6 Negative Binomial Regressions of Military Patenting among Inventors, 1855–1870

	MILITARY PATENTS DURING WAR		TOTAL MILITARY PATENTS	
Intercept	−3.66***	4.04***	−1.30*	−.85*
	(23.1)	(19.0)	(4.17)	(4.99)
Age	0.05	0.06	−0.04	0.06*
	(2.52)	(2.78)	(2.65)	(3.53)
Age squared	−0.00	−0.00	−0.00	−0.00
	(0.00)	(1.65)	(1.71)	(2.36)
Region				
Midwest	0.08	0.02	0.34	0.23
	(1.25)	(0.00)	(0.68)	(0.24)
Middle Atlantic	0.26	0.15	0.58	0.47
	(0.40)	(0.11)	(2.42)	(1.00)
New England	0.18	0.07	0.67*	0.59
	(0.18)	(0.03)	(3.19)	(1.54)
South	0.63	0.45	0.81*	0.65
	(2.04)	(0.85)	(4.28)	(1.71)
Occupation				
Technical	−0.17	−0.07	0.07	0.18
	(1.16)	(0.18)	(0.27)	(1.41)
Trader	0.10	0.17	0.43***	0.53***
	(0.40)	(0.89)	(7.98)	(10.14)
Manufacturer	0.36**	0.44***	0.38***	0.49***
	(5.18)	(6.23)	(6.97)	(8.38)
Professional	0.60***	0.59***	0.60***	0.65***
	(19.75)	(14.56)	(22.0)	(19.98)
Farmer	−0.43	−0.40	−0.30	−0.31
	(3.00)	(2.48)	(2.17)	(2.07)
Mobility				
Migrant	0.04	−0.03	0.09	−0.02
	(0.14)	(0.07)	(0.87)	(0.05)
Occupational	−0.25***	−0.18	−0.29***	−0.22**
Persistence	(6.29)	(3.00)	(10.83)	(4.89)
Urbanization				
Rural	−0.73***	−0.66***	−0.45***	−0.26
	(14.31)	(9.97)	(7.62)	(3.74)
Urban	−0.52***	−0.48***	−0.25***	−0.18*
	(24.03)	(16.72)	(6.82)	(2.75)
Time period				
Antebellum	0.73***	0.88***	−0.41***	−0.36
	(9.88)	(10.5)	(5.32)	(3.17)
Civil War	2.02***	2.14***	0.41***	0.51***
	(145.9)	(104.55)	(16.15)	(17.04)
Military orientation				
Log (career patents)	0.53***	0.50***	0.64***	0.62***
	(109.51)	(75.82)	(209.18)	(148.21)

Table 6 (Continued)

	MILITARY PATENTS DURING WAR		TOTAL MILITARY PATENTS	
Log (prewar patents)	−0.10***	−0.10***	−0.14***	−0.14***
	(19.47)	(15.07)	(39.19)	(29.86)
Log (military pats. pre-war)	0.16 ***	0.15***	0.40***	0.41***
	(24.25)	(18.28)	(162.93)	(131.0)
Wealth				
Poor	—	0.11	—	0.31***
		(0.68)		(6.16)
Wealthy	—	0.13	—	0.08
		(0.88)		(0.32)
Pearson Chi-sq	1,133.8	989.0	1,308.8	1,122.3
N	1,279	1,091	1,279	1,091

*$p < 5$ percent level.

**$p < 1$ percent level.

***$p < 0.1$ percent level.

NOTES Negative binomial regressions are linear exponential models that are applied to dependent variables that comprise nonnegative integer counts. This model allows for a distribution that is left-skewed because of zero values in the dependent variable. The negative binomial model belongs to the class of generalized Poisson models but allows for over-dispersion or instances in which mean counts differ from their variance. The model was estimated using maximum likelihood methods. The estimated coefficients are interpreted as percentage changes in the dependent variable given a unit change in the independent variable. Absolute values of Chi-square statistics are in the parentheses. Alternative models, including logistic and OLS regressions, yield essentially the same results. "Urban" is a dummy variable for counties with populations between 25,000 and 50,000; "rural" refers to counties with populations below 25,000. "Military" patents are granted for weapons and war-related inventions such as tents and knapsacks. "Poor" is a dummy variable for inventors with less than $100 in total wealth; "wealthy" represents those with over $5,000 in total wealth. The excluded regional variable is West and foreign, and the time period is relative to the postwar period. Career patents are the total patents filed during an inventor's lifetime.

The regressions attempt to measure unobserved heterogeneity among inventors directly. A significant source of heterogeneity is likely to be the difference in technological or inventive capabilities among individuals. Some of these abilities are subject to improvement through learning by doing, but others point to invariant characteristics. A possible way to model this inherent ability is through fixed effects that capture individual inventors' patent history (their stock of patents). After conditioning on inventive ability, we can better determine the process that gave rise to higher numbers of military patents during the war. The regression results show that individuals who

responded to the war by filing patents for weaponry and war-related items had previously submitted a military invention. Given that the coefficient on their total patenting in the antebellum period is negative, and the coefficient on their pre-war military invention is positive, they appear to have specialized in military technology.

When markets first expanded during the antebellum period, the new inventors were more often than not ordinary people without much technical training who responded to perceived needs by filing job-related patents. Similarly, the change in market demand during the Civil War attracted a number of general inventors. Logit regressions (not reported herein) concerning those who first patented during the war show them to have held significantly fewer patents throughout their lifetimes than did more experienced patentees and to have had shorter careers. Even though we cannot know whether they would have invented anything in the absence of the war, weapons patentees who were active for the first time during the war were not likely to have done so. Newcomers to weapons invention were usually newcomers to invention per se and not much interested in patenting after the war. However, the regressions in Table 6 demonstrate that those who filed the larger numbers of military patents during the war were already specialists in military invention. Although the war temporarily diverted a number of individuals with considerable human and financial capital from other activities into military production, the greatest numbers of patents came from manufacturers and professionals who had already committed to this type of activity. The social returns to such re-allocation are debatable, but we can be more specific about the *private* returns by examining whether a military orientation was associated with greater additions to personal wealth by the end of the 1860s.

WEALTH AND MILITARY INNOVATION For many people, war was associated with pain, displacement, and death; for others, however, war promised prosperity. Profits signal the most highly valued allocation of resources; in the absence of data about profits, changes in wealth can serve as a rough proxy for the re-allocation in resources that the conflict permitted. For instance, Daniel B. Wesson, the famous manufacturer of the Springfield rifle and inventor of the Smith & Wesson revolver, experienced an increase in wealth from $1,000 in 1860 to $350,000 in 1870. Wesson's was undoubtedly an extreme case; the degree to which other military

patentees could emulate him depended in part on the market for new innovations.[18]

The patent records indicate a rapid increase in inventive activity directed toward military improvements, but it is useful to know what and whether new technologies were actually adopted during the Civil War. The conflicting views that researchers hold about the extent to which innovation was pervasive during this period reflect those prevalent among major participants in the war. Some of them were enthusiastic about innovations, whereas others pointed to the need for standardization and centralization in times of large-scale mobilization. Among the skeptics was James W. Ripley, Chief of Army Ordnance, who in June 1861 referred to the "vast variety of the new inventions . . . each having its own advocates," as a "great evil." He recommended that it "be stopped by positively refusing to answer any requisitions for or propositions to sell new and untried arms, and steadily adhering to the rule of uniformity of arms for all troops of the same kind." The testing of new equipment was undoubtedly costly and risky at both ends of the supply and demand chain. It not only led to the possibility of hold-ups by either party; it also created the potential for corruption in the requisitions process. Innovations in manufacturing inputs or final products might reduce the future cost of production and increase military productivity, but some officials were more concerned that they might divert funds away from current production.[19]

18 Wartime demand for Smith & Wesson revolvers far exceeded the firm's ability to supply them. The firm earned more than $1 million in gross income between 1862 and 1868 (See Bill S. No. 273, January 11, 1870, Senate Ex. Doc. 23, 41st Congress, 2d Session.) The Smith and Wesson factory in Springfield was located close to the federal armory in Springfield, the largest in the country; it produced more than 800,000 rifles during the war. It grew rapidly from 700 employees in June 1861 to 2,600 employees by January 1865. See Mark Wilson, "The Business of Civil War: Military Enterprise, the State and Political Economy in the United States, 1850–1880," unpub. Ph.D. diss. (Univ. of Chicago, 2002), 533.

19 Engerman and Gallman, "Civil War Economy," contend that "the North fought a technologically modern war but organized around traditional assumptions and limitations" (247). According to Cochran, "By modern standards, the Civil War was still unmechanized." See Thomas C. Cochran, "Did the Civil War Retard Industrialization?" in Andreano (ed.), *Economic Impact*, 167–179. A large number of monographs about individual technologies in the cavalry, infantry, navy, and even an incipient "airforce" of balloonists highlight the proliferation of innovations during the war. Charles D. Ross, *Trial by Fire: Science, Technology, and the Civil War* (Shippensburg, Penn., 2000), finds a number of war commanders, such as George B. McClellan and P. G. T. Beauregard, to have been ahead of their time in their support of new technologies. However, others, like Joseph G. Bilby, *Civil War Firearms: Their Historical*

Nonetheless, McClellan, J. E. B. Stuart, Ambrose E. Burnside, and a substantial number of other military leaders were successful patentees. Others—like Benjamin F. Butler, major general of volunteers—were enthusiastic about new technologies and quick to adopt promising innovations. Stephen V. Benet, chief of ordnance, refers (in a letter of March 6, 1875 to the secretary of war) to the Statute of 1854 10 Stat., 579, appropriating $90,000 for the purchase of breech-loading rifles. "The effect of this measure was to stimulate the ingenuity of inventors in devising and perfecting methods of operating arms at the breech; and the records of the Patent Office show, in the number of patents issued for breech-loading arms about this time, that it is here properly that the era of breechloaders in this country begins." However, not much of the money was spent because the army selected only carbines for the cavalry. Initially, Burnside's patented rifle was selected because it used metallic cartridges, but the order for it was later canceled. The money was spent instead on carbines from Benjamin F. Joslyn and on rifles by the more established patentees Samuel Colt, Edward Maynard, and Christian Sharps. Suppliers had substantial leeway in fulfilling their obligations; contracts were so vague that their terms could be widely interpreted.[20]

Background and Tactical Use (Conshohocken, Pa., 1996), feel that the degree of innovation was overstated, at least until the later years of the war, especially within the Confederate ranks. Guy Hartcup, *The Wars of Invention: Scientific Developments, 1914–1918* (London, 1988), considered World War I to be "the first major technological war in history," although he does not appear to have taken much account of the American Civil War in reaching that conclusion (vii). Ripley cited in Bruce, *Lincoln and the Tools of War*, 69.

Senator Jefferson Davis of Mississippi inserted a clause into the appropriations bill for the year ending June 1861: "No arms nor military supplies whatever, which are of a patented invention, shall be purchased, nor the right of using or applying any patented invention, unless the same shall be authorized by law and the appropriation therefore explicitly set forth that it is for such patented invention" (*ibid.*, 92). Cynics would point to Davis' decamping for the Confederacy shortly afterward as consistent with this attempt at technological destabilization. *The Annual Report of the Secretary of War for 1860* requested an appropriation of "$50,000 for experiments for the improvement of arms and military supplies," protesting the provision regarding the purchase of patented weapons (Benet, letter of March 6 1875 to the Secretary of War.) Davis' statute was quickly repealed. The unfavorable view of innovation is evident in a letter from H. K. Craig, chief of ordnance, to Joseph Holt, interim secretary of war, January 8, 1861: "The number of arms manufactured at the national armories during the last year was not as great at the available funds would have justified. This diminution is in a measure attributable to the diversion of armory operations from the manufacture of arms of the established model to the alteration of arms according to plans of patentees and to getting up models of arms for inventors" (Fuller and Steuart, *Firearms of the Confederacy*, 8.)

20 Fuller and Steuart, *Firearms of the Confederacy*, 88, 89.

Scattered evidence suggests that patentees did not labor entirely in vain, even in the South. The Confederate Congress offered subsidies as high as 50 percent to firms that established factories, which may have reduced the incentive to invest in other forms of appropriation. Although armories in the South employed more than 5,000 people, especially in Richmond and Fayetteville, the majority of Confederate firearms were purchased elsewhere. Nonetheless, at least some of the new patented inventions filed in the Confederacy went into production. According to Fuller and Steuart, "One of the first steps taken by the Confederate Government to obtain arms was to encourage home industries by subsidies. On January 13, 1862, Congress passed an Act providing for an advance of 50 percent of the capital of any firearms manufacturing company." Nathan T. Read manufactured his patented firearm at Keen, Walker & Co's establishment in his hometown of Danville, Virginia. Thomas Cofer's Confederate patent of August 12, 1861, was granted for a revolver that was manufactured in Portsmouth, Virginia. Despite the outbreak of hostilities, on May 14, 1861, the U.S. Patent Office granted Virginian Lorenzo Sibert Patent No. 32316 for his magazine rifle, which was produced in the Confederacy. The Confederate government also sent agents to Cuba and Mexico, and to Europe, for weapons; Jean Alexander LeMat of Louisiana received an order for 5,000 of his patented revolvers, which were manufactured in France. The Confederacy even smuggled arms from the North. Gorgas, the Confederate Chief of Ordnance, reported in 1864, "We have hitherto had no difficulty in importing arms through the blockaded seaports"; the greatest barrier that they faced was lack of funds.[21]

In the North, a number of the most successful patentees were career officers—Thomas J. Rodman, Robert P. Parrott, John A. Dahlgren (inventors of guns, projectiles, and ordnance), and Henry H. Sibley (the patentee of Sibley's conical tent, which saw extensive use in the army at the time). Others were experienced patentee/manufacturers—Edward Maynard, Samuel Colt, Christopher Spencer, Oliver Winchester, Christian Sharp, Eli Remington, and Simeon North. But the outside-contracting method meant that even small-scale producers were able to benefit from the military

21 *Ibid.*, 108, 157, 250, 263.

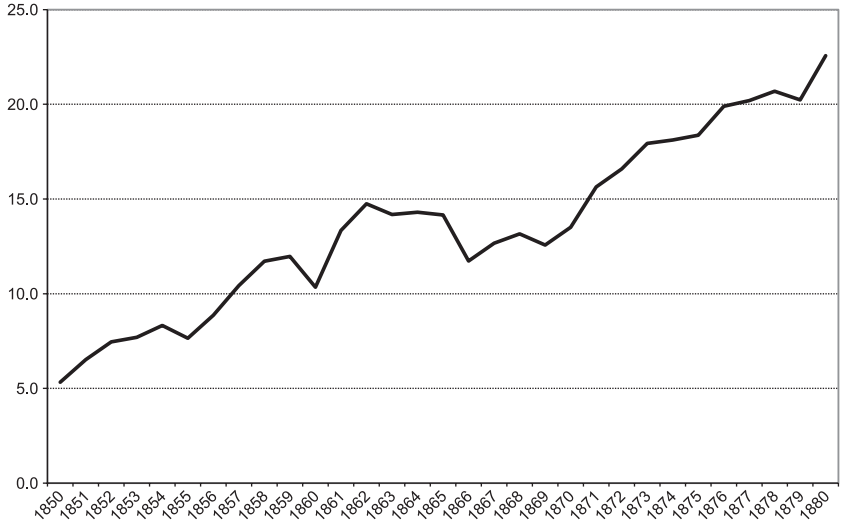
market. For instance, George W. Morse obtained orders for his patented breech-loading arms, which he manufactured during the war. Moreover, military commanders had significant discretion in placing orders for equipment with promising innovations, thus bypassing the formal requisitions process. Further evidence that a remarkably diverse array of patented items were in widespread use during the war can be gleaned from archaeological findings at prominent battlefields.[22]

Figure 5 provides more systematic information about the extent of innovation or applied invention during the war by showing the percentage of patents that were assigned (sold) when granted, calculated from the total record of patents filed in the United States. The general trend between 1850 and 1880 is positive; the proportion of patent assignments grew from 5.3 percent in 1850 to 22.6 percent in 1880. The Civil War boosted the sale of patent rights from 10.4 percent in 1860 to more than 14 percent during the entire period of the conflict. The rate fell from 14.2 percent in 1865 to 11.7 percent in 1866. What sorts of improvement were being sold at the time of patenting? Between 1861 and 1865, 48.1 percent of patents that the sample of inventors assigned were for military inventions. The market for inventions was thriving in the middle of a devastating conflict due to the allocation of inventive resources toward the war effort. Patented inventions may have been sold and presumably placed in action, and a number of patentees like Wesson amassed riches, but a key question is whether contributions to the war effort made a significant difference in the returns to the average inventor.[23]

22 According to Engerman and Gallman, "Civil War Economy," "the wartime procurement system left the Northern economy largely in the hands of small entrepreneurs who responded to market incentives rather than to government incentives" (243). Procurement of military equipment and provisions involved a mixed supply system with centralized government production, but with considerable out-sourcing to private firms. The most comprehensive account of military procurement and expenditures is Wilson, "Business of Civil War." For a discussion of the Northern navy's relationship with private firms, see William H. Roberts, *Civil War Ironclads: The U.S. Navy and Industrial Mobilization* (Baltimore, 2002). Fuller and Steuart, *Firearms of the Confederacy*, 91. Since many of orders were for alterations of existing weapons, patent innovations were not necessarily reflected in tallies of new production. Bruce, *Lincoln and the Tools of War*, identifies John Frémont, McClellan, and Butler as particularly active procurers of innovative items (72). See, for instance, www.civilwarartillery.com for archaeological evidence.

23 Peripheral war-related items were riskier to patent; only 5.9% of such patents in the sample were assigned. Farmers were the only group that had a significantly lower than average

Fig. 5 The Market for Inventions during the Civil War: Percentage of Patents Assigned at Issue, 1850–1880



SOURCE AND NOTE U.S. Patent Office *Annual Reports*. These data do not account for patents that were licensed, nor do they include patents that were assigned after the date of granting.

If technological improvements served to increase military productivity, greater returns and financial mobility for military inventors might be expected, holding other things constant. Both the 1860 and 1870 censuses include entries on real estate and personal wealth, which allow an examination of wealth directly before and after the war. Soltow found it "rather shocking" that in 1860, 57 percent of white men possessed no real-estate wealth and that 43 percent owned no personal estate, which still held true in both cases ten years later. The implications from Table 7 regarding the distribution of inventors' wealth by asset level are that on the eve before the outbreak of war, more than one-half of all inventors, like the rest of the white male population, held no real estate and that more than one-third recorded no personal wealth.

propensity to assign, and inventors without any wealth from every income class were slightly more likely to be assignees. The data regarding assignments are incomplete and unrepresentative because the sample includes only one patent per inventor at the time that he or she was selected. Note also that patents could be sold anytime during their term and that, after 1861, the life of a patent was extended from fourteen years from date of issue (with a possibility of renewal) to a single seventeen-year term (with no renewals).

Table 7 Distribution of Inventors' Wealth in 1860 and 1870 by Military Orientation, in Percentages

	REAL ESTATE					
	GENERAL INVENTORS		MILITARY INVENTORS		ALL INVENTORS	
	1860	1870	1860	1870	1860	1870
None	51.6	40.9	57.1	45.3	54.0	42.7
$1–$499	3.1	3.4	3.4	2.1	3.2	2.8
$500–$999	5.2	6.2	2.5	3.7	4.0	5.2
$1,000–$1,999	11.9	10.2	9.9	9.2	11.0	9.8
$2,000–$4,999	13.5	18.1	7.8	13.8	11.0	16.4
$000–$9,999	8.0	8.8	8.4	9.7	8.2	9.2
$10,000 and above	6.8	12.3	10.9	16.3	8.6	13.9
Average	4,158	5,710	7,552	8,716	5,641	6,908
Median	0	993	0	709	0	922
Std dev	40,000	22,501	31,195	28,249	36,438	24,980
N	616	657	493	435	1,012	1,092
	PERSONAL WEALTH					
	GENERAL INVENTORS		MILITARY INVENTORS		ALL INVENTORS	
	1860	1870	1860	1870	1860	1870
None	32.9	26.2	40.1	31.3	36.0	28.3
$1–$499	31.3	25.5	22.4	18.2	27.5	28.3
$500–$999	5.4	13.4	6.2	12.7	5.7	13.1
$1,000–$1,999	12.5	8.8	12.0	10.6	12.3	9.5
$2,000–$4,999	8.0	12.7	7.1	11.7	7.6	12.3

Table 7 (Continued)

	PERSONAL WEALTH					
	GENERAL INVENTORS		MILITARY INVENTORS		ALL INVENTORS	
	1860	1870	1860	1870	1860	1870
$5,000–$9,999	6.2	4.1	3.0	3.5	4.8	3.9
$10,000 and above	3.8	9.3	9.2	12.0	6.1	10.4
Average	1,948	4,316	4,063	6,246	2,873	5,019
Median	300	426	300	567	300	447
Std dev	6,558	20,215	16,276	22,268	11,871	21,067
N	578	656	493	434	1,012	1,090

	AVERAGE WEALTH, MALES AND WAR INVENTORS, 1860 AND 1870					
	REAL ESTATE WEALTH			PERSONAL WEALTH		
	1860	1870	CHANGE	1860	1870	CHANGE
Inventors' responsive to war						
First military invention	8,859	8,508	−287	4,071	5,954	1,630
Filed during war						
First invention	4,112	5,490	2,850	2,576	3,595	1,558
Filed during war						
U.S. pop (Soltow)	2,231	2,141	—	1,549	966	—
U.S. pop sample	1,521	1,712	734	892	880	−13
Median	0	709	0	200	355	55
Std dev	3,768	6,864	6,605	2,844	2,796	3,414

NOTES The computations exclude observations with missing values in either year. Wealth in 1870 is adjusted for inflation to obtain real values. The wealth statistics regarding the U.S. population derive from Lee Soltow, *Men and Wealth in the United States, 1850–1870* (New Haven, 1975).

Because poor inventors were more likely to assign their inventions, it is not surprising that many of them, unlike the general population, succeeded in acquiring assets within the decade. Inventors without property were more likely to file patents for military technology, perhaps because a military orientation was associated with significantly higher wealth on average. However, the evidence concerning the rewards for switching to military inventions is less clear-cut. Table 7 indicates that the average real-estate wealth for inventors with first-time military patents fell by $287 between 1860 and 1870, and the change in their personal wealth was below the average for all inventors. Thus, a focus on war-related inventions did not typically lead to higher returns relative to other types of inventions.[24]

Table 8 includes regressions of the factors associated with differences in personal wealth in 1870, after controlling for wealth in 1860. Within the white-male population (the first regression), manufacturers and artisans suffered a greater decline in prosperity during this period than did all other classes. As might be expected, the accumulation of wealth was positively related to age, and to prior stocks of assets. The regressions for the inventors show that their wealth varied little in terms of the geographical location of their patenting—possibly because they tended to move toward areas with better prospects, notwithstanding that the war reduced the tendency to migrate. Occupation played a significant role in explaining additions to wealth; job persistence was associated with higher returns. Unlike the rest of the white male population, inventors with a commercial orientation (traders and manufacturers) and those in more developed urban markets benefited the most throughout this decade. This finding is consistent with previous research about "great inventors" that attributed greater income to innovation than to inventive activity per se. Additions to personal

24 Richard H. Steckel and Carolyn M. Moehling, "Rising Inequality: Trends in the Distribution of Wealth in Industrializing New England," *Journal of Economic History*, LXI (2001), 160–183, attribute increases in wealth inequality during the nineteenth century to "luck, rents, and entrepreneurship." The censuses included information about real-estate wealth, exclusive of "liens or encumbrances," and personal estate comprising personal property "consist of what it may." These entries are not entirely accurate, because of missing values, left-censoring of observations around values of $100, and "clumping" around popular figures such as round hundreds. See Lee Soltow, *Men and Wealth in the United States, 1850–1870* (New Haven, 1975), 60. "Patterns [between 1860 and 1870] . . . were remarkably stable. The most striking finding was that this country harbored vast proportions of populations with no wealth" (*ibid.*, 61).

Table 8 OLS Regressions of Log of Personal Wealth in 1870 among Native-Born Population and Inventors

	U.S. POPULATION		INVENTORS	
Intercept	0.19	1.52	0.56	1.46
	(0.26)	(1.02)	(0.35)	(0.87)
Age	0.15	0.11	0.14	0.13
	(4.41)	(1.69)	(2.17)	(1.90)
Age squared	−0.002	−0.001	−0.002	−0.002
	(4.56)	(1.79)	(2.31)	(2.11)
Log (personal wealth in 1860)	0.25	0.20	0.21	0.20
	(8.41)	(5.14)	(5.13)	(4.82)
Regions				
Midwest	1.05	0.76	0.06	0.15
	(2.19)	(0.88)	(0.07)	(0.15)
Middle Atlantic	0.95	0.51	0.10	0.21
	(1.92)	(0.59)	(0.11)	(0.22)
New England	0.93	0.85	0.37	0.49
	(1.84)	(0.98)	(0.38)	(0.50)
South	0.52	0.54	−0.14	0.02
	(1.07)	(0.59)	(0.14)	(0.02)
Occupations				
Technical	0.13	0.30	0.37	0.33
	(0.20)	(0.82)	(1.02)	(0.89)
Trader	1.22	1.36	1.47	1.47
	(3.95)	(3.26)	(1.47)	(3.52)
Manufacturer	−1.09	1.63	1.60	1.56
	(1.44)	(3.85)	(3.79)	(0.86)
Professional	0.74	0.04	0.16	0.19
	(2.51)	(0.11)	(0.43)	(0.50)
Farmer	0.54	0.39	0.35	0.34
	(3.06)	(0.99)	(0.90)	(0.86)
Mobility				
Migrant	0.02	−0.30	−0.23	−0.15
	(0.13)	(1.16)	(0.88)	(0.59)
Occupational persistence	0.14	0.39	0.46	0.41
	(0.95)	(1.63)	(1.90)	(1.69)
Urbanization				
Rural	—	—	0.86	0.93
			(2.10)	(2.25)
Urban	—	—	1.22	1.25
			(4.23)	(4.31)
Career patents				
Log (Stock of patents before war)		—	—	0.19
				(1.93)
Log (Stock of patents during war)		—	—	0.03
				(0.38)

Table 8 (Continued)

	U.S. POPULATION		INVENTORS	
Response to war				
Antebellum patentee who shifted to military invention during war		—	—	−1.86 (2.97)
Antebellum patentee who did *not* shift to military during war		—	—	−0.48 (1.03)
New entrant during war who patented military inventions		—	—	0.25 (0.47)
New entrant during war who did *not* patent military inventions		—	—	0.44 (0.86)
Adjusted R^2	0.17	0.08	0.10	0.11
F-Stat	26.39	6.70	7.46	5.91
N	1711	923	898	896

NOTES Absolute value of *t*-statistics is in parentheses. All the *F*-statistics are significant at the .01 percent level. The dependent variable refers to the log of reported personal wealth plus one dollar. "Urban" is a dummy variable for counties with populations between 25,000 and 50,000; "rural" refers to counties with populations below 25,000.

wealth during the decade were associated with entrepreneurial responses to changes in the market.

The wealth regressions include fixed effects for technological capability, as discussed above. The stock of all patents accumulated *prior to* the war controls for inherent ability, whereas the stock of all patents filed *during* the war proxies for learning by doing. There is no evidence that inventors who learned by doing earned any returns, but more committed inventors (those who filed greater numbers of patents) were rewarded with higher returns. After controlling for heterogeneity across inventors, the regression considers the experience of those who responded to the war. New entrants to invention during the war, regardless of their military orientation, did not benefit much from their efforts. The regressions include variables to represent inventors who had filed a nonmilitary patent before the war and switched to military invention during the war, and those with prior experience as inventors who did not switch to military invention. Although both classes of inventors had lower returns, the coefficient on nonmilitary inventors with prior experience is not significant. However, the experienced patentees

who switched into military invention during the war were disappointed in their expectations, since they obtained significantly lower returns.

Although this finding might appear to have been driven by those in white-collar occupations who had higher opportunity costs and were less adept at innovation, the results for manufacturers are even more marked. A full explanation will have to await further research, but the results may well have something to do with the decentralized nature of war-time procurement that precluded the benefits normally associated with economies of scale. It also bears some relation to the experience of modern providers of military supplies and equipment, who similarly find that the risks of war-related production far outweigh the returns, typically leading to financial and real losses rather than to the abnormal returns often expected.

The effect of wars is often assessed from a macroeconomic perspective. Some microeconomic analysts simply assume that wars do not misallocate resources, because the tastes of the population change at the onset of armed conflict, and an affected population inclines naturally toward a demand for security, with a revealed preference to allocate scarce resources to investments in "regrettable necessities." The discussion herein presupposes instead that the objective of a well-functioning economic system is to offer the greatest possible consumption opportunities. In this respect, war represents a deviation from maximum welfare, diverting resources from higher-valued final goods to lower-valued "tools of war." Prices also tend to become misaligned under wartime procurement and to alter both supply and demand, whereas higher taxes and government subsidies produce further distortions that reduce the probability for resources to be optimally allocated. Moreover, even in war, the purchase of guns would be a misallocation if less costly means of achieving security, such as knives or even diplomacy, were available.

The empirical evidence in this study suggests that war resulted in a misallocation of technological resources. The American Civil War was a landmark event in the history of military technology; large numbers of individuals reoriented their attention to the expanding market for improved methods of destruction and to satisfy the needs of the military. The patent records show a distinct response to the advent of conflict that was uniform across every region, except the South. New entrants into nonmilitary invention

during the war tended to be impoverished and so less likely to possess the resources or the reputation to commercialize their product. The war reduced the tendency to migrate that was a feature of successful entrepreneurship and innovation during the antebellum and postbellum periods. Technological innovation yielded higher average returns to inventors prior to the war but not during the war, possibly because the exaggerated increase in military innovation drove down the marginal return. The plight of patentees who shifted into the market for military technology while the conflict was ongoing exemplifies the war's misallocation of resources. These people tended to be professionals, a class with arguably higher opportunity costs. Moreover, their attention to military invention did not carry over into the postwar period for good reason since, unlike other inventors, they experienced a fall in personal wealth.

Sheridan, evidently an optimist regarding the role of weapons technology, thought that "the improvement in the material of war was so great that nations could not make war, such would be the destruction of human life." Sombart similarly contended that the net outcome of wars on the economy and technology was positive. These observers were not correct but, fortunately, pessimists like Nef were equally incorrect in their view that wars destroyed the capacity for future technological progress. The most telling indicator of how wars affect the potential for improvements in material well-being comes not from the Civil War era but from the resilient and dramatic surge in inventive activity at its close. The outbreak of peace, not war, propelled the United States toward the higher trajectory of productivity and achievement that was to establish it as the foremost industrial nation of the twentieth century.