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DO PATENT POOLS ENCOURAGE INNOVATION? EVIDENCE FROM THE 19TH-CENTURY SEWING MACHINE INDUSTRY

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ABSTRACT

Members of a patent pool agree to use a set of patents as if they were jointly owned by all members and license them as a package to other firms. Regulators favor pools as a means to encourage innovation: Pools are expected to reduce litigation risks for their members and lower license fees and transactions costs for other firms. This paper uses the example of the first patent pool in U.S. history, the Sewing Machine Combination (1856-1877) to perform the first empirical test of the effects of a patent pool on innovation. Contrary to theoretical predictions, the sewing machine pool appears to have discouraged patenting and innovation, in particular for the members of the pool. Data on stitches per minute, as an objectively quantifiable measure of innovation, confirm these findings. Innovation for both members and outside firms slowed as soon as the pool had been established and resumed only after it had dissolved.

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On the eve of the United States' entry into World War I, the aeronautics industry was in disarray. While the Wright Brothers owned a patent on the plane, Glenn Curtiss held overlapping patents that were crucial for improving the design, engines, and controls of even the most basic planes.[1] Since the Wright Brothers' patent covered any aircraft using these improvements, they were able to block Curtiss from producing planes.[2] Faced with the need to purchase planes from Europe to participate in a European war, Congress created a committee to address the problem. This Committee, headed by Franklin D. Roosevelt, recommended that Curtiss and the Wright Brothers form a patent pool: an arrangement in which "two or more parties agree to pool their respective technologies and license them as a package."[3] The Manufacturers' Aircraft Association, formed on 12 July, 1917, combined all patents that were needed to build a plane and made them available for licensing. Three weeks later, the United States entered World War I; U.S. production soared from 83 aircraft in 1916 to 1,807 in 1917 and 11,950 in 1918.[4]

Almost one hundred years later, patent pools have re-emerged as a remedy for industries that are plagued by litigation and patent blocking, which occurs when owners of competing patents prevent the commercialization of new technologies.[5] Since July 2008, UNITAID, an international drug purchasing facility, has been developing a patent pool to facilitate the development of improved treatments for HIV and AIDS.[6] In February 2009, the pharmaceutical company GlaxoSmithKline (GSK) announced its

[1] Dykman, "Patenting Licensing"; and Heller, *Gridlock Economy.*

[2] Bittlingmayer, "Property Rights." In the example of the airplane pool, patents were "one-way blocking." Wright's patent could block the use of Curtiss' improvements, but Curtiss could not prevent the Wright Brothers from producing planes, as long as they did not include his improvements. See Gilbert, "Antitrust," for a detailed discussion of blocking patents.

[3] Gaule, "Towards Patent Pools"; and Merges, "Contracting into Liability Rules."

[4] Stubbs, "Race," p. 133.

[5] See, e.g. Shapiro, "Navigating the Patent Thicket."

[6] See http://www.stopaidssocieties.org.uk/2008/07/patent-pool-plans-progress/.

support for a pool to develop treatments and cures for "neglected" diseases, including malaria and cholera. In addition, four parties holding key patent applications related to the development of SARS vaccines expressed their willingness to form a pool.[7] Pools have also been suggested as a means to advance diagnostic testing for breast cancer.[8] These plans follow the formation of four successful pools in the IT sector during the 1990s: the MPEG-2 pool, the 3G platform and two DVD pools.[9] In 2001, the value of U.S. goods produced under pooling agreements exceeded $100 billion.[10] Antitrust authorities in the United States favor pools because they "provide procompetitive benefits by integrating complementary technologies, reducing transaction costs, clearing blocking positions, and avoiding costly infringement litigation."[11]

Theoretical models of patent pools predict that pools encourage innovation. Specifically, the prospect of a patent pool increases firms' incentives to invest in R&D because lower risks of litigation and improved licensing schemes increase expected profits for participating firms.[12] The prospect of a patent pool may also increase the

[7] Simon et al., "Managing Severe Acute Respiratory Syndrome (SARS) Intellectual Property Rights."
[8] Verbeure et al., "Patent Pools."
[9] See e.g., Merges, "Institutions." These pools combine complementary patents that form a technological standard.
[10] Clarkson, "Objective Identification."
[11] U.S. Federal Trade Commission and Department of Justice, "Antitrust Guidelines." Regulators have even credited pools with making it possible to produce inventions that would otherwise be blocked by overlapping patent grants: "The pooling of the patents, licensing all patents in the pool collectively, and sharing royalties is not necessarily an antitrust violation. In a case involving blocking patents, such an arrangement is the only reasonable method for making the invention available to the public" (International Mfg. Co. v. Landon, 336 F.2d 723, 729, 9th Cir. 1964).
[12] Lerner and Tirole, "Efficient Patent Pools"; Choi, "Patent Pools"; Gilbert, "Antitrust"; Shapiro, "Navigating the Patent Thicket"; and Merges, "Institutions." Industry experts echo this expectation. For example, one of the founding members of the 2005 radio frequency pool, Stan Drobac,writes that "If you're a licensee, you need to negotiate with five entities to get five licenses, instead of negotiating with 20 to get 20 licenses" (*RFID Journal*, 10 April, 2008). Pools that combine complementary patents lower licensing fees for outside firms because they avoid "royalty stacking," when the same product is covered by multiple patents (e.g., Lemley and Shapiro, "Patent Holdup"; Shapiro, "Navigating the Patent Thicket"; and Lerner and Tirole, "Efficient Patent Pools").

speed of innovation: If the number of patents needed to form the pool is limited, firms may race to develop the technologies that are included in the pool.[13]

A lack of contemporary data, however, has made it difficult to establish these effects empirically. Existing empirical work has sharpened our understanding of institutional characteristics, such as the types of licensing deals that pools offer to non-members and rent-sharing agreements among pool members.[14] Nevertheless, there has been little empirical evidence on the effects of patent pools on innovation, mostly because such analyses require much longer time series of data than are available for contemporary pools. Moreover, pools that resolve conflicts about overlapping patents have been extremely rare in recent history.[15]

This paper uses the example of the first patent pool in U.S. history, the Sewing Machine Combination (1856-1877), to examine whether patent pools encourage innovation.[16] One key advantage of the historical setting is that we can observe an industry from its birth to technical maturity, including more than 30 years of data to analyze the long-term effects of a pool.[17] Another advantage is that the sewing machine pool operated in the complete absence of regulation, which allows us to examine how pools behave when regulators give them free reign.[18]

[13] Dequiedt and Versaevel, "Patent Pools."
[14] Layne-Farrar and Lerner, "Patent Pool Participation"; and Strojwas, Lerner, and Tirole, "Design."
[15] Bessen, "Imperfect Property Rights." The only recent example of a pool intended to resolve overlapping patents is the laser surgery pool, which was accused of price-fixing in 1998 (Clark et al., "Patent Pools"). This pool was formed between Summit and VISX, the only two firms with FDA approval to license photorefractive keratectomy (PRK) laser equipment for vision disorders. Based on an FTC antitrust complaint, the two firms eventually made their patents available for non-exclusive licensing to third parties. Bessen, "Imperfect Property Rights," argues that pools of overlapping patent rights are less likely to form because prospective members do not know what share of expected profits will accrue to them.
[16] See Thomson, "Path," for a detailed history of the sewing machine industry and, in particular, the industry's importance to the mechanization of shoe manufacturing.
[17] See e.g., Clark et al., "Patent Pools"; and Heller and Eisenberg, "Can Patents Deter Innovation?"
[18] The first major antitrust case regarding patent pools was *E. Bement & Sons v. National Harrow Co.* 186, U.S. 70, 91 (1902). Six different firms had formed the National Harrow to end crippling litigation. Their

In the first step of the analysis, we use data on litigation and on patenting to test the predictions of existing theoretical models of patent pools. Litigation data confirm that pools lowered litigation risks for pool members.[19] They also substantiate the prediction that the prospect of a pool encourages patenting among prospective members.[20]

Interestingly, however, the data suggest that pool members patented less while the pool was active, and only began to patent more aggressively again after the pool dissolved in 1877. Non-members, which account for the vast majority of patents, appear to have been similarly affected by the creation of the pool; patenting increases immediately after 1856, but declines soon afterwards and remains at low levels until the pool dissolves in 1877. These results are robust to the inclusion of time- and firm-fixed effects, as well as alternative controls for demand and the Civil War.

One potential problem with using patent data to measure innovations is that firms may have used patents strategically to negotiate a more advantageous position in the pool, or to protect themselves from litigation by the pool.[21] To address this issue, we construct an alternative measure of innovation that objectively measures improvements in the performance of sewing machines. Specifically, we use information in company

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pool combined 85 patents for float spring tooth harrows – a tool to soften top soil for cultivation. National Harrow grew to include 22 firms that covered over 90 percent of the market. Bement was a licensee who sued the pools over the terms of the license, which required licensees to adhere to a uniform price schedule. In 1902, the Supreme Court decided that the pool's licensing terms were lawful, arguing that the benefits it conferred - preventing litigation over patent scope and validity - outweighed the costs that price-fixing created for the industry (Gilbert, "Antitrust," pp. 2-3).

[19] See e.g., Choi, "Patent Pools"; and Shapiro, "Navigating the Patent Thicket."

[20] Dequiedt and Versaevel, "Patent Pools."

[21] See Cohen et al., "Protecting Their Intellectual Assets"; Moser "Why Don't Inventors Patent"; and Hall and Ziedonis, "Patent Paradox."

records, including trade cards, advertising, and internal records to measure the number of stitches per minute that a sewing machine was able to perform.[22]

Data on sewing speeds confirm the results of the patent data: Innovation slowed soon after the pool had been established and did not recover until the pool had been dissolved. Thus, data on annual patenting and innovation suggest that theoretical models should be extended to capture the *ex post* effects of patent pools on their members, and incorporate effects of pool on other, non-members, which appear to play an important role as drivers of innovation for the entire industry.

The data suggest two ways in which the sewing machine pool may have discouraged innovation. First, by creating a more formidable opponent in court, the pool may have intensified the threat of litigation for outside firms, which lowered expected profits and discouraged innovation. Consistent with this idea, litigation data show that non-members were at a greater risk of being sued while the pool was active; pool members acted as plaintiffs in most of these cases. Second, the existence of a pool that aggressively defended patents may have shifted innovation by non-members towards substitute technologies that were not covered by the pool. In the case of the sewing machine industry, outside firms shifted both patenting and innovation (as measured by firm entry with new models of sewing machines) towards an inferior stitching mechanism, that was not covered by the pool.[23]

[22] Measuring effects on innovation, in addition to effects on patenting, is particularly important if innovations differ systematically from patents. Data on innovations at 19th century world's fairs indicate that inventors' propensity to patent varies significantly across industries and over time (Moser, "Why Don't Inventors Patent?").

[23] For a detailed analysis of the potential effects of patent pools on the direction of technical change see Lampe and Moser, "Patent Pools and the Direction of Technical Change."

The rest of this paper is organized as follows. Section II presents a short history of the sewing machine industry and its patent pool. Section III describes data on litigation, patents, and sewing speed as an alternative measure of innovation. Section IV and V test predictions of existing theoretical models, and Section VI concludes.

THE EARLY SEWING MACHINE INDUSTRY, 1846-1885

On 10 September 1846, Elias Howe was granted U.S. patent No. 4750 for "Improvements in the Sewing Machine" – the lock-stitch. Although the patent was initially contested, Howe began to charge a hefty license fee ($25, almost 50 percent of the average price) as soon as the court had upheld his patent in 1853.[24]

The Sewing Machine "Wars" (1846-1856)

Despite its high price, Howe's license did not cover all parts that were needed to build a functional sewing machine. Mirroring the experience of the early 20th century aircraft industry, manufacturers soon filed suits to assert their rights to different parts of the sewing machine. Litigation during the "sewing machine wars" threatened to stop production and sales.[25] For example, the I. M. Singer Company warned consumers not to buy sewing machines from Wheeler & Wilson, or Grover & Baker:

> The unparalleled success of our Sewing Machines has induced several fraudulent imitations of them, besides numerous infringements of our patents-of which we own sixteen. Suits for the infringement of our patents have recently been decided in the U.S. Circuit Courts in N.Y. and New Jersey. In the suit the great principle of HOLDING DOWN THE FABRIC TO BE SEWED TO THE SURFACE OF THE MACHINE, BY A YIELDING PRESSURE, which is used in all Sewing Machines-has been fully established. The Wheeler & Wilson, and the Grover & Bakers Sewing Machines, as we allege, each infringe three distinct patents owned by us.-We have suits against them in several of the U.S. Courts, which will soon be tried. We

[24] Bays, *Encyclopedia*, p. 15.
[25] Cooper, *Sewing Machine.*

hereby caution the public not to buy infringing Machines, as they can be compelled by law to stop using them, and to pay costs and damages (*Daily Scioto Gazette*, 25 October, 1856).

The Albany Agreement

To resolve such litigation, Singer, along with Wheeler & Wilson, Grover & Baker, and Elias Howe formed a patent pool on 24 October, 1856 (*Albany Agreement,* Singer Papers, Box 225).[26] Their pool combined nine complementary patents that were necessary to build a sewing machine. (See Appendix A for a list of the pool patents.) It survived for the duration of all original patents; no additional patents were added after 1856.[27] After Howe's lock stitch patent expired in 1867 the pool continued on the strength of Wheeler and Wilson's patent on the "four-motion" feeding mechanism and Singer's patent on the horizontal surface until 8 May 1877, when the last patent expired.[28]

Consistent with theoretical predictions, the sewing machine pool lowered license fees, especially for pool members and in comparison with Howe's original fees.[29] From 1856 onwards, pool members paid $5 per machine and other firms paid $15 while the

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[26] Searches of the *New York Times,* Chicago Tribune, and *Scientific American* yielded no indication that the pool was anticipated by the members. As the first patent pool is U.S. history it is unlikely that the pool was anticipated. In fact, Grover & Baker did not contribute any patents to the pool but was included because its president, Orlando Potter, devised the idea of a patent pool. The settlement of the sewing machine wars (out of court) was announced after the pool had already been established: "Sewing Machines-To the Public-The undersigned hereby give notice that all suits and controversies in relation to the infringement of patents upon sewing machines between the Wheeler & Wilson Manufacturing Company, I. M. Singer & Co and the Grover & Baker Sewing Machine Company have been amicably arranged and settled. WHEELER & WILSON Manf'g Co., I. M. SINGER & CO., GROVER & BAKER, S. M. Co. (*New York Herald*, 22 November, 1856).

[27] More formally, the sewing machine pool did not incorporate a *grantback* clause, which requires any additional patents that are granted to pool members after the agreement to be offered to other pool members for licensing without fees (Layne-Farrar and Lerner, "Patent Pool Participation," p. 10).

[28] Wheeler and Wilson's four-motion feed was "so superior but few first-class machines are made without it" (Knight, *American Mechanical Dictionary*, p. 2102) and made the firm "several million dollars" (*New York Times*, 26 January, 1875). It was renewed twice and expired in 1873. The great feature of the Singer (Bachelder) patent "was the production of a sewing machine in which the cloth to be sewn is supported horizontally, and is fed through the machine perpetually. His machine was the first sewing machine in which the cloth was supported horizontally and advanced by an automatic feed of any kind. It is scarcely possible to estimate sufficiently the importance of such an invention in the art of sewing by machinery" (*Potter et al. v. Braunsdorf*, F. Cas. 1132 1869; Knight, *American Mechanical Dictionary*, p. 2102. Singer had purchased this patent from John Bachelder (Cooper, *Sewing Machine*, p. 23).

[29] E.g., Shapiro, "Navigating the Patent Thicket"; and Gilbert, "Antitrust."

average sewing machine cost $65.[30] The pool further reduced license fees when Howe's patent was renewed in 1860: licensing fees decreased to $1 for members and $7 for other firms. After Howe's patent expired in 1867, the pool abolished fees for its members and further reduced fees for other firms to $5.[31] Despite their lower levels, differences across members and outside firms may, however, have lowered expected profits for outside firms, and thereby discouraged innovation by outside firms relative to members. The pool licensed freely to

> …any manufacturer who had a meritorious machine that was not an offensive imitation of the machine of some other licensed manufacturer (Frederick Bourne, President of the Singer Company, 1883 to 1905, from Depew, *One Hundred Years*, p. 530).

In fact, Elias Howe, who did not produce sewing machines, demanded that the pool patents should be licensed to at least 24 licensed manufacturers at any given point in time.[32] Once outside firms had bought a license, the pool placed no restrictions; most importantly, licensees were able to set prices without intervention by the pool.[33]

The pool agreement, however, stipulated that part of the license fee was to be set aside to support its litigation fund, which was to be maintained above $10,000, approximately a quarter million 2007 dollars, exceeding the annual sales of most small

[30] Bays, *Encyclopedia*, p. 15.
[31] Five dollars per machine is the amount that the Florence Sewing Machine Co. paid to the pool in 1869. Some licensees may have paid even lower fees; Florence sued because the pool appeared to have extended more favorable terms to another firm. Its complaint, however, was dismissed (*Florence Sewing Machine Co. v. Singer Manufacturing Co.*, 9 F.Cas. 302, 1870).
[32] Cooper, *Sewing Machine.*
[33] Hounshell, *American System*, p. 68; and Depew, *One Hundred Years*, p. 530. Archival materials suggest that the pool may have attempted to limit the supply of its licensees. For example, the original *Albany Agreement* stipulated that licensees should not produce more than 1,000 machines per year. Licensing data, however, suggest that licensees were able to exceed their allotted quota without punishment. For example, Ladd & Webster produced 1,788 machines in 1859.

manufacturers.[34] This litigation fund more than sufficed to protect the pool's patents, and members divided remaining funds between each other.

THE DATA

To examine the pool's effects on innovation, we have constructed a rich new data set, which combines annual data on patents by pool members, licensees and other non-members with data on improvements in sewing speeds as an objectively quantifiable measure of innovation. Legal records on litigation, as well as alternative measures for changes in the demand for sewing machines complement these data.

Sewing Machine Patents by Pool Members, Licensees, and Other Firms

To measure changes in inventive activity over time, we count the number of U.S. patents for sewing machines per year, distinguishing patents of pool members from patents of other firms (Figure 2). Patent data are drawn from *Knight's Mechanical Dictionary* (1877) and the *Annual Reports of the United States Patent Office*.[35]

Data on sewing machine manufacturers, along with their age and other information are drawn from collectors' manuals for antique sewing machines. One hundred and seventy new manufacturers entered the industry between 1845 and 1885.[36] Entry and exit dates are available for 135 of these firms, nearly 80 percent; few companies, however, survived for more than ten years.

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[34] Using the Consumer Price Index, $10,000 in 1856 is worth $252,240.88. Other indicators place the value of the litigation fund between $191,841 and $34,443,798 (Williamson, "Six Ways").

[35] *Knight's Mechanical Dictionary* is a useful complement to the records of the United States Patent Office because Knight divides sewing machine patents for 1842 and 1874 into nine functional categories: (1) sewing machines making the chain-stitch, (2) sewing machines making the lock-stitch, (3) sewing machines for sewing leather, (4) feeding devices, (5) button-hole sewing, (6) miscellaneous parts, (7) attachments, (8) tables and stands, and (9) motors. We exclude data for "table and stands."

[36] Cooper, *Sewing Machine.*

Patents are matched to firms based on firm names (e.g. Wilson, A. B. of Wheeler and Wilson) as well as information on other inventors who assigned patents to a firm (e.g. patents assigned by Edward Clark to the Singer Manufacturing Co.). Thirty-five firms licensed the pool's patents between 1853 and 1877, 27 percent of 129 total entrants.

To measure the timing of inventions, we record the grant dates for all patents; filing dates, as an alternative measure, are only available after 1873.[37]

Improvements in Sewing Speed

One potential problem with using patents as a measure of innovation is that inventors may use patents strategically, so that changes in patenting do not accurately reflect changes in innovation. For example, prospective pool members may patent existing innovations more aggressively prior to the pool because they want to improve their negotiating position relative to other members. Similarly, non-members may patent more aggressively after the pool has formed to protect themselves from litigation.[38]

To address this issue, we construct an alternative measure of innovation that quantifies improvements in the performance of sewing machines for member and non-member machines. Specifically, we examine changes in the speed of sewing machines, as measured by the number of stitches that a machine can perform within one minute.[39]

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[37] Grants typically occurred six months to a year after an inventor applied for a patent (e.g., Thomson, "Learning by Selling," p. 435), depending on the complexity of applications and the workload of examiners (Popp et al., "Time in Purgatory"). To measure this lag for 19th-century sewing machines, we compared application and grant dates for a random sample of 100 sewing machine patents between 1873 and 1875. In this sample the average patent was granted roughly six months (140 days) after the application. These data corroborate the standard assumption that sewing machine patents were issued about six months after the application date (e.g,, Thomson, "Learning by Selling," p. 435).

[38] See, e.g. Hall and Ziedonis, "Patent Paradox"; and Shapiro, "Navigating the Patent Thicket."

[39] A major benefit of this measure is that speed can be quantified objectively. In comparison, alternative measures, such as the number of known stitch types, would be significantly more subjective. *Knights Mechanical Dictionary*, lists 68 distinct stitch types in 1874 (Knight, *American Mechanical Dictionary*, pp.

We have constructed data on sewing speeds for 1845 to 1900 from 19th-century issues of the *Scientific American*, company records, trade cards, and reports from international technology shows, such as the Crystal Palace Exhibition of 1851.[40] For example, a description of work in a clothing factory provides data on sewing speed for Wilcox & Gibbs and Wheeler & Wilsons in 1889.

> The linings are made by a Wilcox & Gibbs machine, the topping is done by a two needle Union machine which runs at the rate of about 2220 stitches per minute, the closing is done by a Weed feed machine, and the other work is done by Wheeler & Wilson's machines which run at the rate of about 1000 stitches per minute (Tullidge, *Tullidge's Histories*, p. 368).

Litigation between Pool Members and Outside Firms

Litigation data are drawn from *Westlaw's* pre-1945 federal courts database. Westlaw combines reports from the series *Federal Cases* (district and circuit court decisions decided before 1880, compiled in 1892), the *Federal Reporter* (district and circuit court decisions from 1880 onwards), the *Supreme Court Reports* and *United States Reports* (decisions of the Supreme Court).[41] Westlaw reports 100 patent disputes

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2123-4), but it is difficult to establish how distinct, or useful these stitches are from each other. For example, Knight's data include several embroidery stitches, but these stitches may not be as distinct from each other (or as useful) as two stitches to work with leather versus cloth.

Because the type of a stitch that a sewing machine performs influences its sewing speed, we focus on lock-stitch machines, which were known to produce the most durable stitch. Machines producing single thread stitches, such as Wilcox and Gibbs chain stitch machines were generally faster than lock-stitch machines, but a single stitch proved so much less durable that all but a few firms eventually abandoned it (James, *Upholstery Tips*, p. 86). Among the pool members, Singer and Wheeler & Wilson had focused on lock-stitch machines from the start (Bays, *Encyclopedia*), while Grover & Baker manufactured double thread chain-stitch machines until 1875, when they sold to a competitor who switched production to lock-stitch machines (Depew, *One Hundred Years*, p. 528). Improvements in the design of shuttles and the adoption of cranks in drive mechanisms (instead of springs and cams) are the most likely sources of improvements in the speed of sewing (Thomson, *Path*, p. 148). Although Singer introduced a machine with an attached electric motor in 1889, the foot-powered treadle remained the most effective drive mechanism throughout the 19th century (Depew, *One Hundred Years*, p. 534).

[40] A special report in the *Thirteenth Annual Report of the Commissioner of Labor* (*Hand and Machine Labor)*, contains comparisons of sewing machine and hand productivity for 1895. Unfortunately, these data cannot be linked to earlier years or specific sewing machines.

[41] We search for cases that include the terms "sewing machine" and "patent infringement." Broader search terms, such as "patent" or "sewing," did not produce additional cases.

regarding sewing machines between 1850 and 1885.[42] As a robustness check for the Westlaw data, we also searched William Robinson's *Law of Patents*, which includes two cases that were omitted from Westlaw. These data indicate that the pool (as a whole) engaged in 19 cases; pool members (acting independently) engaged in another 23 disputes.[43]

A potential concern with litigation data is that they only capture cases that were decided in court and may therefore underestimate the real risk of litigation. For example, outside firms may have been more willing to settle and less likely to initiate legal action because they were afraid to face the pool in court.[44]

Potential Sources of Bias and Measurement Error

Most importantly, the firm-level data are subject to survivorship bias, because 19th-century data on entry and exit are more likely to be available for larger and more successful firms. Collectors' manuals record entry and exit dates for 40 percent of all manufacturers in the U.S. census in 1860 (29 of 74 firms), 63 (21 of 49 firms) in 1870, and 36 percent (36 of 101 firms) in 1880. Since missing firms are more likely to be small, our data may underestimate the number of small, outside firms before and after the

[42] These reports publish the date of the decision but do not include the filing date. Anecdotal evidence suggests that decisions were made up to two years after filing. For example, Walter Hunt, who claimed to be the rightful inventor of the lock-stitch, appealed against the Commissioner of Patents on 24 May, 1854. This case was decided in Howe's favor in the Circuit Court of the District of Colombia in February 1855. See *Hunt v. Howe*, 12 F. Cas. 918 (1855). A similar case that Howe filed against William Bradford by Howe between 1850 and 1851 was decided in 1852 (*Scientific American*, 1852, p. 356).
[43] The Combination was a plaintiff in one additional case (*Potter v. Hicks,* 19 F. Cas. 1154, Mossoff, "Stitch," p. 40, no dates are available). Ten of these 102 cases were retrials and appeals. The records list an additional case (*Potter v. Stewart*, 7 F. 215) in 1881, four years after the pool dissolved, when pool members sued for past infringement of Bachelder's patent (USPTO patent 6,439).
[44] Another source of bias is that historical case data are based on contributions of individual reporters, rather than a centralized system, which may create bias toward general interest decisions. Khan, "Property Rights," p. 94.

pool relative to pool years, which implies that we may overestimate innovation by outside firms during the pool.[45]

In addition, patent data, especially when electronically collected, are subject to measurement error. For example, optical character recognition cannot always distinguish the 19th-century script for letters R from B, P from F, and U from J. To address this issue, we hand-checked random samples of the data and replicated every search with the corresponding misspelled letters (e.g., "Singee" for Singer).

Measures for the Intensity of the Civil War and Changes in Demand

Across industries, disruptions as a result of the Civil War (1861 to 1865) may have discouraged innovation. For the sewing machine industry, however, the war may have also encouraged innovation, as it increased demand for machine-made uniforms.

> Before 1861 the U.S. Army manufactured its own uniforms and was reluctant to experiment with machine-made clothing, fearing that the product would be inadequate for combat duty, especially under rough frontier conditions. The sewing machine was initially confined, therefore, to stitching caps and chevrons. With the outbreak of war, the contracts signed for military clothing did not specify a method of manufacture. Suppliers soon turned increasingly to machine-made apparel to assure standard quality and to meet contract deadlines (Whitten and Whitten, *Handbook*, pp. 91-92).

In addition to increasing its demand for machine-made clothing, the war department placed direct orders for machines:

> the Civil War brought a demand by the War Department for a million uniforms. The government contracted for thousands of sewing machines; these were loaned free to sewing circles which worked on the making of uniforms (Crow, *Great American Customer*, p. 205).

[45] Small sewing machine manufacturers that are missing from the data produced between 500 and 1000 firms over their lifetime (Bays, *Encyclopedia*). As an alternative check of the data, we also examined city directories for Philadelphia (1850, 1855, 1860, 1870, 1880, and 1890) and New York (1850, 1851, 1860, 1869, 1880, and 1890). In the New York directories, most entries are manufacturers, and the data closely match the information in Cooper (*Sewing Machine*). In comparison with the New York directories, the Philadelphia directories include a large number of sewing machine agents (e.g., Edward Jones, and Henry Co. in 1860).

Thus, 19th-century accounts suggest that the Civil War resulted in a significant positive demand shock, which may have encouraged innovation in sewing machines.[46] To measure the size of changes in demand we include data on increases in the size of the Union Army between January 1861 (16,267 soldiers) and January 1865 (959,460 soldiers, Figure 4).[47] Most of our estimations focus on increases in the number of Union soldiers; Confederate uniforms were rarely machine-stitched and both sides reused uniforms.[48] Results, however, are robust to alternative measures of the intensity of the war, including the number of Confederate soldiers.

To control for alternative sources of changes in demand, we include data on population growth and real GDP, which serve as proxies for demand by individual families.[49]

EMPIRICAL RESULTS

Did the Pool Reduce Litigation?

Theoretical models of patent pools predict that pools lower the threat of litigation for their members.[50] In the case of the sewing machine, the pool's prospective members had engaged in crippling litigation, which was ended by the pool.[51] Between

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[46] See e.g., Schmookler, "Invention"; and Sokoloff, "Inventive Activity."
[47] Long and Long, *Civil War.*
[48] Drew and Snow, *Eagle's Talons*, p. 113. The daughter of Mrs. Robert M. Patton of Florence, Alabama, remembers "I was just through college, and I made, together with my mother and a serving woman she had employed, uniforms, underwear, and several overcoats, so heavy that we had to work on them while lying on a table. Every stitch was done with our fingers. We had no machines until 1869, when my father bought me one" (Andrews, *Women*, p. 427).
[49] *United States Census Bureau, 1850-1890*, and Johnston, "*U.S. GDP." Godfrey,* International*, p. 125, notes that ``the majority of the American sewing machine firms were concerned mainly with producing small domestic machines for use in the home, while only a small number were engaged in building the heavier type of machine which could be used for industrial purposes."*
[50] See e.g., Choi, "Patent Pools."
[51] See e.g., Cooper, "Sewing Machine," p. 41.

1856 and 1877, while the pool was active, it was a defendant in only 3 of 55 total legal disputes (Figure 7) all of which concerned the same complaint: The pool had granted a more favorable license to a competitor of the Florence Machine Company, and Florence sued to get its license fee reduced; the court decided in favor of the pool.[52] Singer was a defendant in two additional cases in 1859 and 1860.[53] Both were based on the complaint that Singer had patented another firm's invention and were decided in Singer's favor.[54]

Contrary to the results for member firms, litigation data suggest that the pool increased litigation risks for outside firms. Between 1856 and 1876 the pool initiated 15 legal battles, more than a quarter of all 55 sewing machine cases.[55] Pool members acting independently initiated another 9 legal disputes. Forty-nine of these 64 cases were directed at outside firms (Figure 6). Thus, the pool may have increased litigation risks for outside firms even as it lowered such risks for its members.

Did the Pool Encourage its Members to Patent More?

The most central prediction of the theoretical literature, however, is that patent pools encourage innovation by increasing expected profits for member firms and reducing the costs of licensing for outside firms.[56] To test this prediction, we examine

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[52] Two subsequent cases concerned payments by Florence to a judge and jurisdictional concerns (not all parties were resided in the same state). See *Florence v. Singer Manufacturing Co.*, F. Cas. 302 (1870), *Florence v. Singer Manufacturing Co.*, F. Cas. 310 (1871), and Case of the Sewing Machine Cos., 85 U.S. 553 (1873), and *Florence Machine Co. v. Grover & Baker Sewing Mach. Co.*, (1872), 110 Mass. 70.
[53] *Wickersham v. Singer*, F. Cas. 1134 (1859) and *Wilson v. Singer*, F. Cas. 217 (1860).
[54] In *Wilson v. Singer*, F. Cas. 217 (1860), Wilson sought the reissue of a patent that incorporated improvements which had been patented by Singer. Though the court initially ruled in Wilson's favor, his patent was ruled invalid in subsequent litigation (*Potter v. Dixon* (1863), 2 Fisher, 381).
[55] All but 2 of 15 disputes in which the pool was the plaintiff concerned Wilson's "four motion" feeding mechanism (USPTO patent 7,776).
[56] See e.g., Dequiedt and Versaevel, "Patent Pools."

whether patenting increased in the years leading up to the pool and continued at a higher level while the pool was active. While theoretical analyses focus on effects on pool members, we also extend the analysis to include effects on other firms, which accounted for the majority of patents and improvements.

If the prospect of a pool encourages a patent race among prospective members, firms that succeed in joining the pool should have a larger number of patents in the years leading up to the pool. These predictions are borne out in the data; in 1855, three members were granted a total of 10 patents, compared with an average of less than three patents per year for 1850 to 1854 (Figure 1). This increase in patenting, however, is also consistent with the alternative hypothesis that prospective pool members Singer, Wheeler & Wilson, Grover & Baker and Elias Howe patented more to protect themselves from litigation. Prospective members may also have patented existing innovations more aggressively to improve their bargaining positions in negotiations for the pool.[57] Thus, 9 of the 10 member patents in 1855 were granted to Singer, even though the company contributed no significant in-house inventions to the pool.[58]

Interestingly, these firms began to patent less as soon as the pool had been established, producing an average of three patents per year from 1857 to 1861 and only two patents per year from 1866 to 1870. Members continued to patent less until the pool dissolved in 1877, and quickly resumed patenting afterwards, producing five patents in 1878, nine in 1879, and eight in 1880.

Did the Pool Encourage Outside Firms to Patent More?

[57] Dequiedt and Versaevel, "Patent Pools."
[58] Singer purchased its key patent for the horizontal work surface from Bachelder (Cooper, *Sewing Machine*, p. 23).

In contrast to patents by members, patents by outside firms spiked *after* the pool had been established (Figure 2). Annual patents jump from 29 patents in 1856 to more than 100 patents in 1858.[59] Similar to the case of member patents, this spike in patenting may, however, represent a strategic response to a heightened threat of litigation with a more powerful opponent, rather than a true increase in innovation.[60]

Patenting by non-members began to decline only two years after the pool had formed. By 1862, annual patents had fallen to 21 patents per year, below pre-pool levels. Patenting recovered after the Civil War increased demand for sewing machines (to 150 patents in 1873). After this peak, patenting declined again until the pool dissolved in 1877. By 1880, only three years after the pool dissolved, patenting began to rise again, increasing to nearly 300 patents in 1882.

Comparing sewing machine patents with aggregate counts of U.S. patents also indicates that the pool discouraged patenting. An initial increase of sewing machines to 3 percent of all U.S. patents in 1858 had eroded to less than 1 percent by 1866 (Figure 3). Sewing machine patents recovered after the pool dissolved, to 2 percent of all U.S. patents in 1882. Thus, comparisons with total patent counts confirm the results above that the pool discouraged patenting by both members and other firms.

Difference-in-Differences Estimation

To examine the patent data more systematically, we estimate difference-in-differences regressions that compare annual patents by pool members relative to other

[59] Patenting rates in the late 1850s may be an overestimate relative to the early 1850s, when patent solicitors successfully lobbied for the removal of examiners whom they thought to be too strict in assessing novelty. Post ("Liberalizers," p. 52) argues that the share of patent applications that were granted increased as a result of this change; grant rates increased from 32 percent in 1853 to 67 percent in 1859.
[60] See e.g., Shapiro, "Navigating the Patent Thicket"; and Bessen, "Patent Thickets."

firms during the pool with annual patents by pool members relative to other firms before and after the pool. *Pool Members* are Grover and Baker, Singer, and Wheeler and Wilson; *Pool* equals 1 in years when the pool was active for the entire year (1857-1876).[61]

$$(1) \qquad p_{it} = \alpha + \beta_{PM}\, Pool\ Member_i + \beta_{PMP}\, Pool\ Member_i * Pool_t + \beta_L\, Licensee_i + \beta_{Age} \log Firm\ Age_{it} + \delta_t + \gamma_i + \varepsilon_{it}$$

The coefficient β_{PMP} on the interaction *Pool Member * Pool* is our difference-in-differences estimator; it measures the increase in patenting by pool members relative to other firms. Under the assumption that omitted time-varying effects are uncorrelated with pool membership this coefficient can be interpreted as the causal effect of the pool: If β_{PMP} is positive and statistically different from zero, the pool encouraged members to patent more. Similarly, *licensees* may have patented more while the pool was active if they benefitted from reductions in license fees and transaction costs.

We also control for *Firm Age* as a characteristic that may affect patenting regardless of the pool. Specifically, younger firms may patent more because they are more likely to be based on novel technologies. Alternatively, older firms may patent more because they are more established and familiar with the patent system.[62]

[61] As a result some of our untreated years were actually partially treated by the pool, so that we may underestimate the real effect of the pool. We miss two months of pool activity in 1856, because the pool was founded in October 1856, and four months in 1877, because the pool dissolved in May 1877.

[62] For sewing machines models between 1853 and 1882, sales have been found to encourage technological change (Thomson, "Learning by Selling"). In our sample, sales data are available for 30 firms that were licensed by the pool between 1867 and 1876 (20 percent of all firms, yielding a total of 163 observations). In this subsample of the data, the coefficient of correlation between annual sales and annual patents is 0.185. The coefficient is 0.192 assuming a two year grant lag and 0.153 assuming a one year grant lag.

To account for unobservable factors that may influence patenting we include annual and firm fixed effects (δ_t and γ_i). For example, the dismissal of strict examiners in the early 1850s or changes in the demand for sewing machines may help to increase the annual number of patents, independently of the pool. Similarly, certain firms may patent more because they are more creative regardless of age or the existence of a pool.

Regression results confirm that members patented less while the pool was active. Estimates for β_{PMP} indicate that members produced an average of 1.6 fewer patents per year while the pool was active (Table 1, significant at 5 percent). In comparison, across all years, pool members produced between 2.0 and 2.2 more patents per year. Additional regressions that estimate year-specific treatment effects indicate that members generated between 0.8 and 2.3 fewer patents in the last ten years of the pool compared with the pre- and post-pool period.[63]

The data also yield only limited evidence that the pool encouraged licensees to patent more. Licensees produced up to 0.2 additional patents per year than other firms, but this effect is not statistically significant (Table 1, I and III). Interactions between Licensees and Pool are never statistically significant. Another interesting result from the data is that, all else equal, younger sewing machine manufacturers patented more: A 1 percent decrease in age adds about 0.2 patents per year (Table 1, IV, significant at 5 percent).

How did the Civil War Affect Patenting?

[63] Coefficients are negative for all 20 years when the pool was active (1857-76), and they are significant at the 5 percent level for 12 of these years: 1857, 1860, 1863, 1865 to 68, and 1871 to 75.

Alternative specifications control for the Civil War and other factors that may have influenced demand. Specifically, we examine the potential impact of increases in the size of the Union Army, real GDP, and population. Anecdotal evidence suggests that Singer and other pool members benefitted disproportionately from increases in the demand of sewing machines, with Singer selling "tens of thousands machines."[64] To identify these effects, we estimate interaction terms between firms' affiliation to the pool (distinguishing members and licensees) and measures for the intensity of the Civil War. To account that demand effects may operate with a lag, we also include one-year lagged increases in the size of the Union Army.[65] Linear time trends capture changes in patenting over time that may be independent of the pool.[66]

$$(2) \qquad p_{it} = \alpha + \beta_P\, Pool_i + \beta_{PM}\, Pool\ Member_i + \beta_{PMP}\, Pool\ Member_i * Pool_t + \beta_L\, Licensee_i + \beta_{Age}\, \log Firm\ Age_{it} + \beta_{MLF}\, Member\ Fee_t + \beta_{NLF}\, Non\text{-}member\ Fee_t + \beta_{UA}\, \Delta\, Union\ Army_t + \beta_{UAP}\, \Delta\, Union\ Army_t * Pool\ Member_i + \beta_{UAL}\, \Delta\, Union\ Army_t * Licensee_i + \beta_{GDP}\, real\ GDP_t + \beta_{Pop}\, \log Population_t + t + \varepsilon_{it}$$

Regression results from this alternative specification confirm results of regressions with time fixed effects that the pool discouraged its members from patenting. Across all years, members produced about 2 additional patents per year compared with other firms (at 1 percent significance). In comparison, members produced 1.6 fewer patents per year while the pool was actively (at 1 percent significance, Table 2).

Similar to regressions with time and firm fixed effects, regressions with controls for specific demand factors yield no significant evidence that licensees patented more

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[64] "tens of thousands of Singer's machines stitched uniforms worn by Union armies in the Civil War." Botti, *Envy*, p. 97

[65] Longer lags are not significant and do not change the main results.

[66] Coefficients are robust to alternative specifications of time trends up to the 4th order polynomial.

while the pool was active or in response to lower license fees. In fact, increases in non-member license fees are positively correlated with increases in the number of licensee patents per year. Thus, because license fees might be endogenous to patenting, we exclude license fees and focus on alternative controls (Table 2, II-V).

Interestingly, the data indicate that the Civil War discouraged innovation in the sewing machine industry, despite its effects on demand. For every 10,000 increase in the number of Union Army soldiers, the average non-member firm produced between 0.004 and 0.006 fewer patents per year (at 1 percent significance, Table 2, II-V). Thus, the data suggest that the disruptions caused by the war outweighed its positive demand effects for outside firms. Consistent with the narrative evidence, however, the Civil War appears to have encouraged patenting by pool members. For every 10,000 increase in Union Army soldiers, pool members produced 0.01 additional patents per year (at 10 percent significance, Table 2).[67]

To account for the large number of zeros in the dependent variable we repeat the analysis as Poisson and negative binomial regressions.[68] All key results are robust to this alternative specification. Across the entire sample, pool members patented more than other firms (producing between 5 and 7 times as many patents per year, at 1 percent significance, Table 3). The coefficient on the interaction *Pool Member*$_i$ * *Pool*$_t$ indicates that the pool reduced the number of member patents by 50 to 57 percent (at 5 percent

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[67] The data suggest that the effect was strongest in the same year, perhaps because the war department demanded uniforms before new soldiers would join the war. Our main results are robust to including absolute numbers of Union Army soldiers rather than changes in the number of soldiers.
[68] In these regressions, patents per year, p_{it}, is assumed to be an exponential function of firm specific characteristics, X_{it}, and a series of controls, γ_{it}: $E[p_{it}|X_{it}]=exp(X_{it}\beta+\gamma_t)$ where i indexes the firm and t indexes the year. Negative binomial and Poisson regressions take into account the fact that the distribution of patents is skewed towards zero; negative binomial regressions also allow the variance of the dependent variable to be larger than its mean. In our data set, the mean number of patents per year is 0.43 and the variance is 1.15. This suggests that a negative binomial model is preferred to a Poisson model.

significance, Table 3). Similar to OLS, Poisson and negative binomial regressions yield no evidence that licensees patented more.[69] The coefficient on *Δ Union Army*$_t$ * *Pool Member*$_i$ is significant at 5 percent confirming OLS results and narrative evidence suggesting that the war encouraged pool members to patent more (Tables 3 and 4).

Did the Pool Encourage Technical Progress?

Two key findings of the patent data suggest that the pool may have encouraged changes in strategic patenting rather than innovation. First, the increase in member patents immediately preceding the pool suggests that prospective members may have patented existing innovations more aggressively to strengthen their bargaining position relative to other members.[70] Second, the spike in patenting for non-member firms immediately after the creation of the pool may represent a strategic response by non-members to a heightened threat of litigation.[71]

To separate changes in strategic patenting from changes in innovation, we examine data on sewing speeds as an objectively quantifiable measure of performance. Data on sewing speeds confirm that the pool slowed rather than encouraged rates of innovation (Figure 5). From 1845 until 1856, the maximum number of stitches that a sewing machine could perform increased from 200 to 2,000 stitches per minute. As soon as the pool had been established, innovation appears to have come to a halt, and sewing speeds stayed roughly constant for the duration of the pool. Improvements in sewing speeds had not yet reached their natural plateau at this time, and continued to advance soon after the pool dissolved in 1877. By 1889 the maximum speed of sewing had

[69] Interactions between *Pool* and *Licensee* are not significant and have been dropped.
[70] Dequiedt and Versaevel, "Patent Pools."
[71] See e.g., Shapiro, "Navigating the Patent Thicket"; and Bessen, "Patent Thickets."

increased to 2,500 stitches per minute.[72] Outside firms produced the fastest machines in 1889 and 1890 (Hurtu & Hautin, an outside firm, with 2,500 stitches-per-minute in 1889 and Willcox and Gibbs, a licensee with 4,000 stitches-per-minute in 1890).[73]

Contemporary accounts indicate improvements in other characteristics of the sewing machine were similarly delayed by the pool: "the machine was still noisy, expensive and inefficient when the Civil War brought a demand by the War Department for a million uniforms."[74]

CONCLUSIONS

This paper has used the example of the 19th century sewing machine industry to examine empirically whether patent pools encourage innovation. Our data broadly confirm theoretical predictions that patent pools lower litigation risks for pool members and that the prospect of a patent pool encourages prospective members to patent more.

In contrast to theoretical predictions, however, pool members began to patent less as soon as the pool had been established. For example, difference-in-difference estimates indicate that pool members patented less while the pool was active both relative to the pre-and post-pool period and compared with other manufacturers. Similarly, the share of

[72] Improvements in shuttles and the adoption of cranks in drive mechanisms (replacing springs and cams) are the most likely sources of improvements in sewing speeds (Thomson, *Path*, p. 148). Electrification sets in after the sample period; although Singer introduced a machine with an attached electric motor in 1889, the foot-powered treadle remained the most effective drive mechanism throughout the 19th century (Depew, *One Hundred Years*, p. 534). Basic least square estimations confirm that improvements in speed slowed during the pool years. Specifically, we estimate least squares regressions of stitches-per-minute with a linear time trend and the *Pool* variable as explanatory variable. In such regressions, the coefficient on *Pool* is negative but not statistically significant. As an additional robustness check, we drop observations that record the fastest speed during the pool years (2,000 per minute); these regressions also confirm that improvements in the speed of sewing machines decelerated as long as the pool was active.
[73] In comparison, modern industrial lock-stitch machines sew at speeds of 6,000 stitches per minute. See McGrath and Blachford, "Gale Encyclopedia," p. 3,350.
[74] Crow, *Great American Customer*, p. 205.

sewing machine inventions in the U.S. patent data declined during the pool and recovered only after the pool had been dissolved.

We are also able to improve existing studies of pools by extending the analysis to include outside firms, which account for the majority of innovations in the sewing machine industry. These data suggest that the pool discouraged patenting by outside firms and that it had at best insignificant positive effects on patenting by licensees.

One limitation of using patent data as a measure of innovation is that observed changes in patenting may reflect firms' strategic response, for example to threats of litigation, rather than true changes in innovation. In the case of the sewing machine pools, prospective members such as I. M. Singer & Co. may have been more likely to patent existing innovations in years leading up to the pool to protect themselves from litigation with other prospective members or to improve their bargaining position at the creation of the pool. Similarly, outside firms may have begun to patent more after the pool had been established to protect themselves from litigation with the pool, which made for a substantially more powerful opponent in a court of law.

To separate strategic effects from increases in innovation, we constructed an alternative data set of objectively measurable improvements in the performance of sewing machines (stitches per minute). These data confirm that innovation slowed while the pool was active and only began to accelerate again after the pool dissolved in 1876. Interestingly, significant increases in the demand for sewing machines as a result of the Civil War had only minimal effects on the sewing machine industry as a whole, although they appear to have encouraged patenting by pool members.

Thus, evidence from the sewing machine industry challenges theoretical predictions and regulators' expectations that patent pools encourage innovation. What are the mechanisms by which pools discourage innovation? The experience of the sewing machine suggests two main channels by which pools may discourage innovation, particularly by outside firms: increases in litigation risks and changes in the direction of R&D. Increased litigation risks for outside firms lower expected profits and discourage investments in R&D. Increases in litigation may, however, also encourage outside firms to divert their research efforts away from improving key technologies that are covered by the pool towards substitutes that are still "freely" available.[75]

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TABLE 1 – OLS REGRESSIONS WITH FIRM AND YEAR FIXED EFFECTS
DEPENDENT VARIABLE IS PATENTS PER FIRM AND YEAR (1850-1885)

	(I)	(II)	(III)	(IV)
Pool Member[a]	2.084**	2.016**	2.207**	
	(0.501)	(0.504)	(0.513)	
Pool * Pool Member	-1.659**	-1.689**	-1.621**	-1.513*
	(0.549)	(0.546)	(0.554)	(0.612)
(log) Firm Age	0.093*	0.122*		-0.213*
	(0.046)	(0.057)		(0.097)
Licensee[b]	0.112		0.192	
	(0.115)		(0.126)	
Constant	0.408**	0.383**	0.560**	2.027**
	(0.109)	(0.111)	(0.102)	(0.599)
Observations	1051	1051	1051	1051
Firm Fixed Effects	N	N	N	Y
Year Fixed Effects	Y	Y	Y	Y
R-squared	0.17	0.17	0.16	0.32

Notes: Data from Long and Long (1971), and Johnston and Williamson (2008). Standard errors are clustered at the firm level.
** denotes significant at 1 percent level, * denotes significance at 5 percent level.
a: Pool Member = 1 for Singer, Grover & Baker, and Wheeler & Wilson.
b: Licensee=1 for firms who purchased a license from Howe or the pool.

TABLE 2 – OLS REGRESSIONS WITH CONTROLS FOR CIVIL WAR, GDP, AND POPULATION
DEPENDENT VARIABLE IS PATENTS PER FIRM AND YEAR (1850-1885)

	(I)	(II)	(III)	(IV)	(V)
Pool	-0.189	0.015	0.011	0.032	0.122
	(0.161)	(0.104)	(0.103)	(0.111)	(0.099)
Pool Member[a]	2.072**	2.048**	2.047**	1.977**	1.964**
	(0.496)	(0.504)	(0.504)	(0.503)	(0.500)
Pool * Pool Member	-1.610**	-1.586**	-1.586**	-1.627**	-1.611**
	(0.518)	(0.523)	(0.522)	(0.520)	(0.515)
Log Age	0.082	0.081	0.080	0.112*	0.115*
	(0.045)	(0.045)	(0.045)	(0.055)	(0.055)
Δ Union Army[b]	-0.004	-0.005*	-0.005*	-0.006*	-0.006*
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Δ Union Army Lag	0.001	-0.000	-0.000	-0.001	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Δ Union Army * Member	0.010	0.010	0.010	0.011	0.011
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Δ Union Army (-1) * Member	-0.003	-0.003	-0.003	-0.003	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Real GDP[c]	6.674	9.498*	9.398*	8.772*	8.463*
	(4.418)	(4.141)	(4.119)	(3.917)	(3.906)
Log Population	2.049	7.810	7.966	7.329	
	(5.448)	(4.717)	(4.632)	(4.752)	
Licensee[d]	0.137	0.130	0.123		
	(0.127)	(0.125)	(0.118)		
Δ Union Army * Licensee	-0.000	-0.001			
	(0.002)	(0.002)			
Δ Union Army (-1) * Licensee	-0.001				
	(0.002)				
Member Fee	-0.040				
	(0.023)				
Non-member Fee	0.047				
	(0.025)				
Linear Time Trend	-0.060	-0.222	-0.225	-0.208	-0.027
	(0.147)	(0.119)	(0.117)	(0.120)	(0.018)
Constant	-21.203	-79.243	-80.815	-74.338	-0.339
	(54.867)	(47.635)	(46.787)	(47.993)	(0.238)
Observations	1051	1051	1051	1051	1051
R-squared	0.15	0.15	0.15	0.15	0.15

Notes: Data from Long and Long (1971), and Johnston and Williamson (2008). Standard errors are clustered at the firm level. ** denotes significant at 1 percent level, * denotes significance at 5 percent level.
a: Pool Member = 1 for Singer, Grover & Baker, and Wheeler & Wilson.
b: Increase in Union Army soldiers in 10,000s.
c: In millions of year 2000 dollars.
d: Licensee=1 for firms who purchased a license from Howe or the pool.

TABLE 3 – NEGATIVE BINOMIAL REGRESSIONS WITH CONTROLS FOR CIVIL WAR, GDP, AND POPULATION
DEPENDENT VARIABLE IS PATENTS PER FIRM AND YEAR (1850-1885)

	(I)	(II)	(III)	(IV)	(V)
Pool	-0.632	-0.261	-0.255	-0.148	0.028
	(0.423)	(0.242)	(0.239)	(0.267)	(0.228)
Pool Member[a]	1.918**	1.886**	1.887**	1.586**	1.551**
	(0.308)	(0.300)	(0.300)	(0.273)	(0.282)
Pool * Pool Member	-0.720*	-0.700**	-0.701**	-0.836**	-0.806**
	(0.279)	(0.268)	(0.268)	(0.282)	(0.299)
Log Age	0.037	0.039	0.039	0.170	0.182
	(0.117)	(0.117)	(0.117)	(0.126)	(0.123)
Δ Union Army[b]	-0.044*	-0.043*	-0.042*	-0.043*	-0.043*
	(0.022)	(0.021)	(0.021)	(0.022)	(0.022)
Δ Union Army (-1)	0.003	0.001	0.003	0.002	-0.000
	(0.011)	(0.010)	(0.012)	(0.012)	(0.012)
Δ Union Army * Member	0.050*	0.047*	0.046*	0.047*	0.047*
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Δ Union Army (-1) * Member	-0.005	-0.004	-0.005	-0.005	-0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Real GDP[c]	11.941	16.353*	16.453*	14.264*	13.555
	(8.169)	(7.733)	(7.755)	(7.168)	(7.289)
Log Population	12.786	21.278*	21.055*	16.136	
	(15.038)	(10.059)	(9.931)	(10.448)	
Licensee[d]	0.465	0.439	0.446		
	(0.304)	(0.300)	(0.294)		
Δ Union Army * Licensee	0.006	0.002			
	(0.009)	(0.005)			
Δ Union Army (-1)* Licensee	-0.005				
	(0.008)				
Member Fee	-0.068				
	(0.054)				
Non-member Fee	0.077				
	(0.060)				
Linear Time Trend	-0.337	-0.575*	-0.570*	-0.446	-0.050
	(0.394)	(0.254)	(0.251)	(0.260)	(0.037)
Constant	-131.394	-217.008*	-214.759*	-164.910	-1.932**
	(151.543)	(101.543)	(100.257)	(105.470)	(0.402)
Observations	1051	1051	1051	1051	1051
R-squared	0.15	0.15	0.15	0.15	0.15

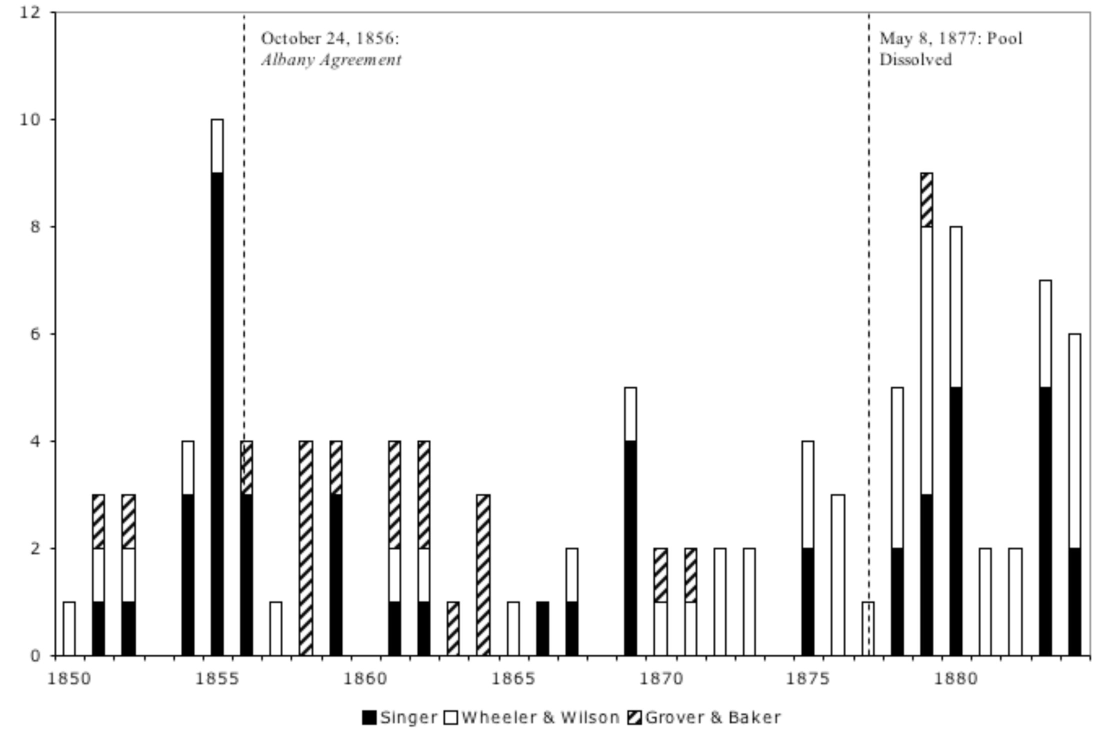
Notes: Data from Long and Long (1971), and Johnston and Williamson (2008). Standard errors are clustered at the firm level. ** denotes significant at 1 percent level, * denotes significance at 5 percent level.
a: Pool Member = 1 for Singer, Grover & Baker, and Wheeler & Wilson.
b: Increase in Union Army soldiers in 10,000s.
c: In millions of year 2000 dollars.
d: Licensee=1 for firms who purchased a license from Howe or the pool.

TABLE 4 – POISSON REGRESSIONS WITH CONTROLS FOR CIVIL WAR, GDP, AND POPULATION
DEPENDENT VARIABLE IS PATENTS PER YEAR (1850-1885)

	(I)	(II)	(III)	(IV)	(V)
Pool	-0.591	-0.218	-0.214	-0.153	0.010
	(0.360)	(0.222)	(0.218)	(0.234)	(0.199)
Member[a]	1.854**	1.816**	1.817**	1.533**	1.517**
	(0.308)	(0.308)	(0.308)	(0.287)	(0.277)
Pool * Member	-0.776**	-0.747**	-0.749**	-0.845**	-0.831**
	(0.265)	(0.269)	(0.269)	(0.270)	(0.267)
Log Age	0.104	0.111	0.111	0.229	0.240
	(0.114)	(0.113)	(0.114)	(0.131)	(0.126)
Δ Union Army[b]	-0.045	-0.044	-0.044	-0.045	-0.045
	(0.025)	(0.025)	(0.023)	(0.024)	(0.024)
Δ Union Army (-1)	0.004	0.002	0.002	0.001	-0.001
	(0.009)	(0.009)	(0.011)	(0.011)	(0.011)
Δ Union Army * Member	0.052*	0.050*	0.049*	0.051*	0.051*
	(0.024)	(0.023)	(0.022)	(0.023)	(0.023)
Δ Union Army (-1) * Member	-0.005	-0.005	-0.005	-0.005	-0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Real GDP[c]	11.581	15.772*	15.811*	14.542*	13.488
	(7.724)	(7.132)	(7.166)	(6.851)	(6.981)
Log Population	8.541	16.994	16.855	14.625	
	(12.577)	(9.503)	(9.331)	(9.803)	
Licensee[d]	0.410	0.383	0.386		
	(0.321)	(0.317)	(0.314)		
Δ Army * Licensee	0.005	0.001			
	(0.008)	(0.005)			
Δ Army (-1) * Licensee	-0.004				
	(0.008)				
Member Fee	-0.070				
	(0.048)				
Non-member Fee	0.081				
	(0.050)				
Linear Time Trend	-0.231	-0.468	-0.465	-0.411	-0.049
	(0.338)	(0.244)	(0.239)	(0.249)	(0.037)
Constant	-88.629	-173.812	-172.404	-149.730	-2.032**
	(126.738)	(95.883)	(94.140)	(98.934)	(0.344)
Observations	1051	1051	1051	1051	1051
R-squared	0.15	0.15	0.15	0.15	0.15

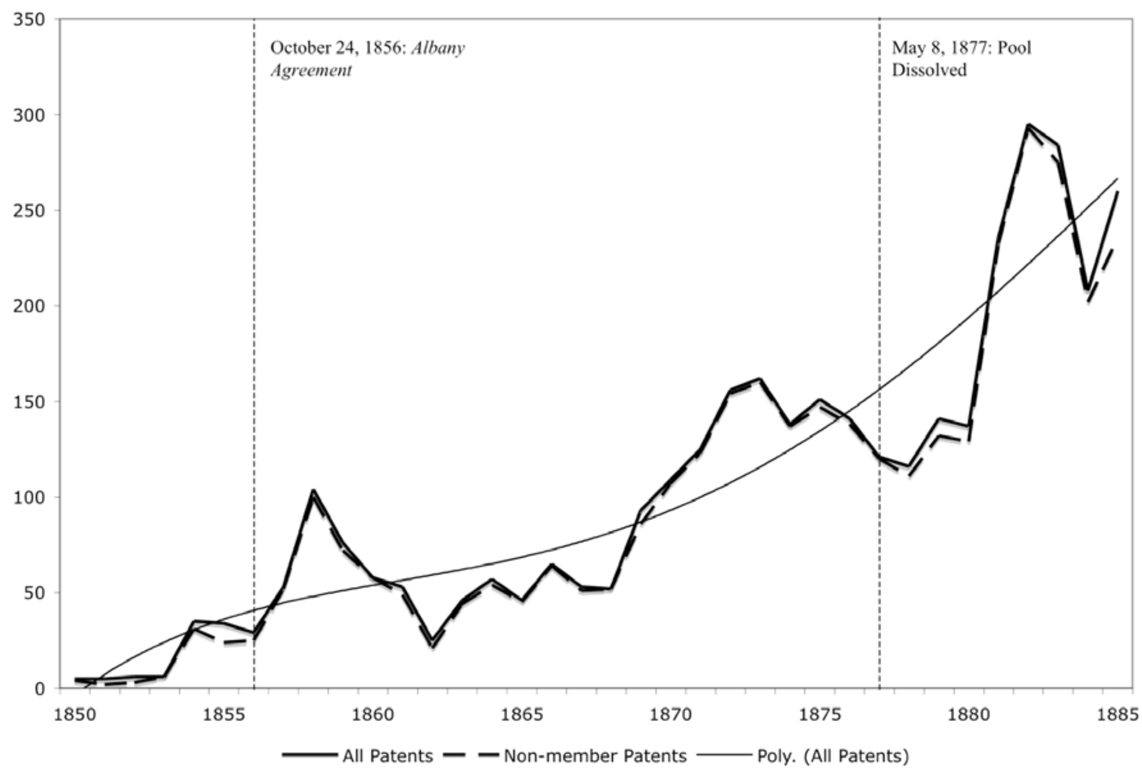
Notes: Data from Long and Long (1971), and Johnston and Williamson (2008). Standard errors are clustered at the firm level. ** denotes significant at 1 percent level, * denotes significance at 5 percent level.
a: Pool Member = 1 for Singer, Grover & Baker, and Wheeler & Wilson.
b: Increase in Union Army soldiers in 10,000s.
c: In millions of year 2000 dollars.
d: Licensee=1 for firms who purchased a license from Howe or the pool.

FIGURE 1 – SEWING MACHINE PATENTS: POOL MEMBERS



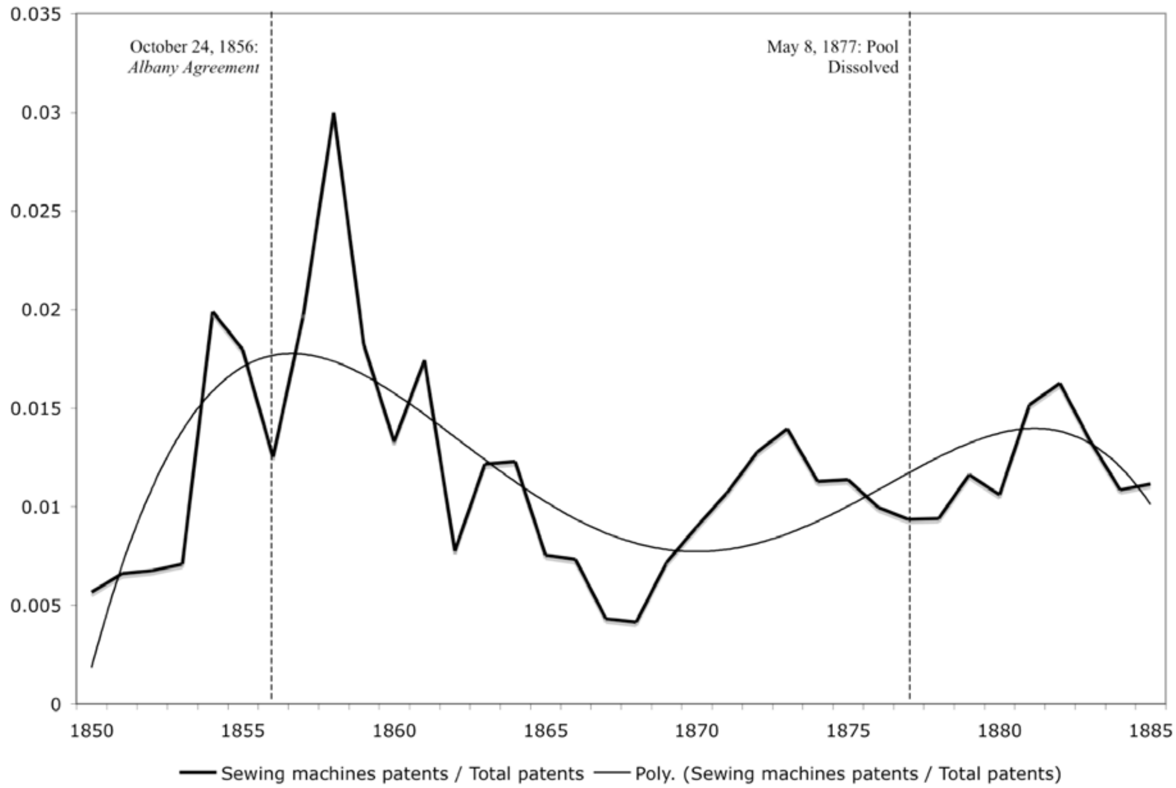
Notes: Data from Knight (1876) and www.patents.google.com include any patent that was either granted or assigned to a pool member when it was granted.

FIGURE 2 – U.S. PATENTS FOR SEWING MACHINES



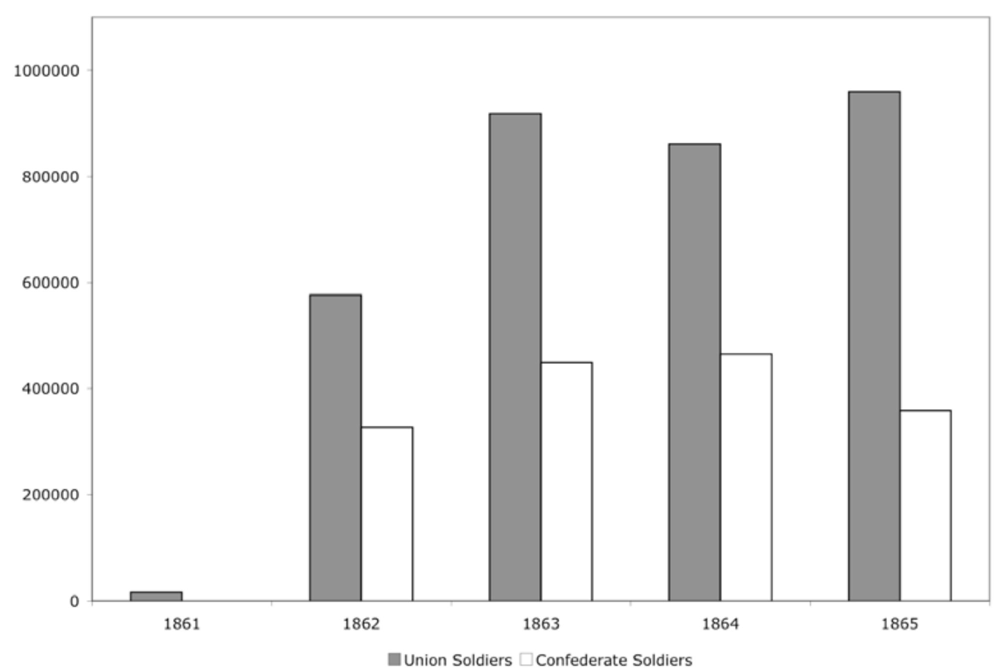
Notes: Patent grants as reported in the *Annual Reports of the United States Patent Office* and Knight (1876). The solid line plots a fourth-order polynomial trend.

FIGURE 3 - SHARE OF SEWING MACHINE PATENTS AMONG ALL U.S. PATENTS



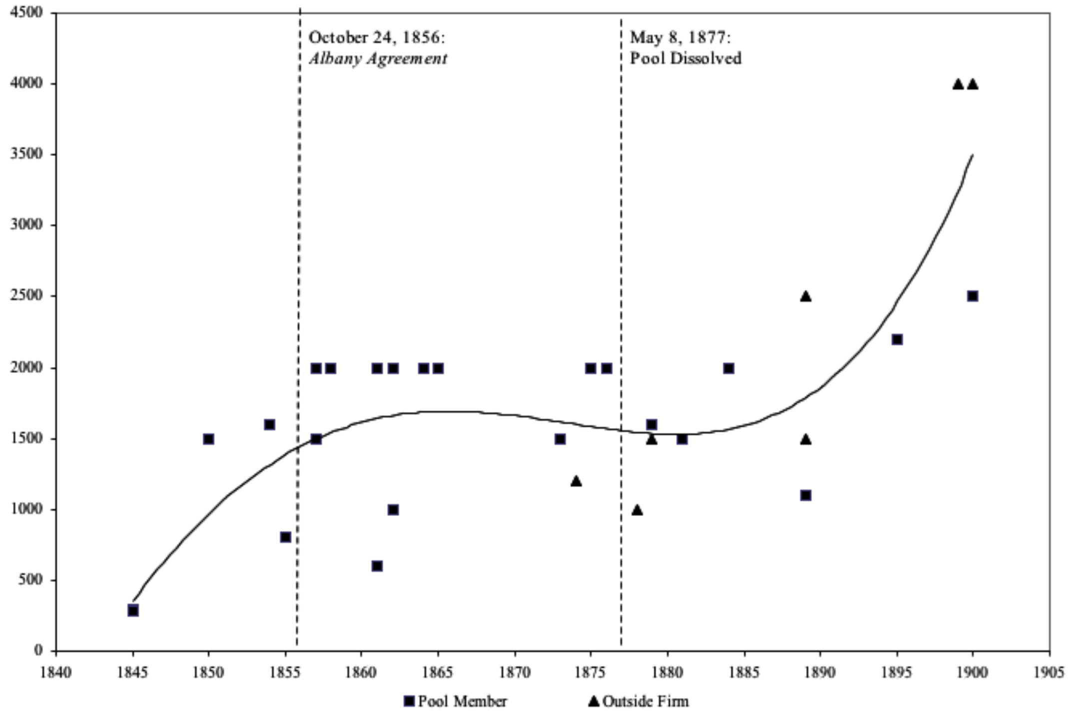
Notes: Patent grants as reported in the *Annual Reports of the United States Patent Office*. The solid line plots a fourth-order polynomial trend. Series excludes patents granted for tables and stands.

FIGURE 4 – THE CIVIL WAR: UNION AND CONFEDERATE ARMY SOLDIERS



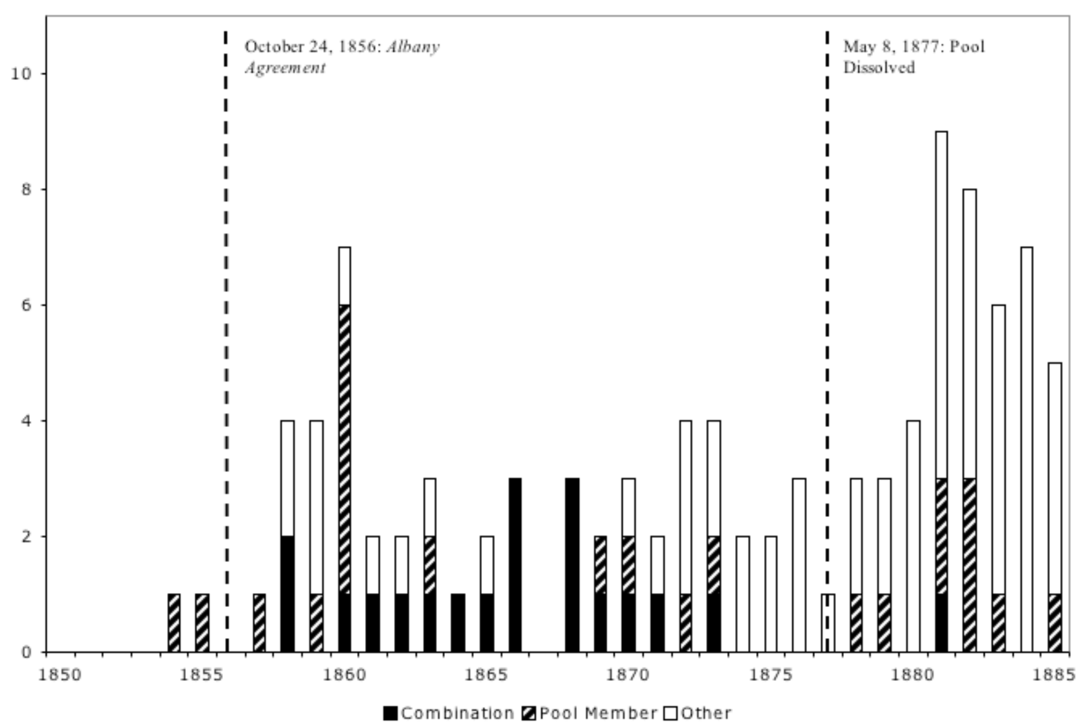
Notes: Total number of soldiers, including deserters wearing their uniform (Long and Long, 1971).

FIGURE 5 - STITCHES PER MINUTE



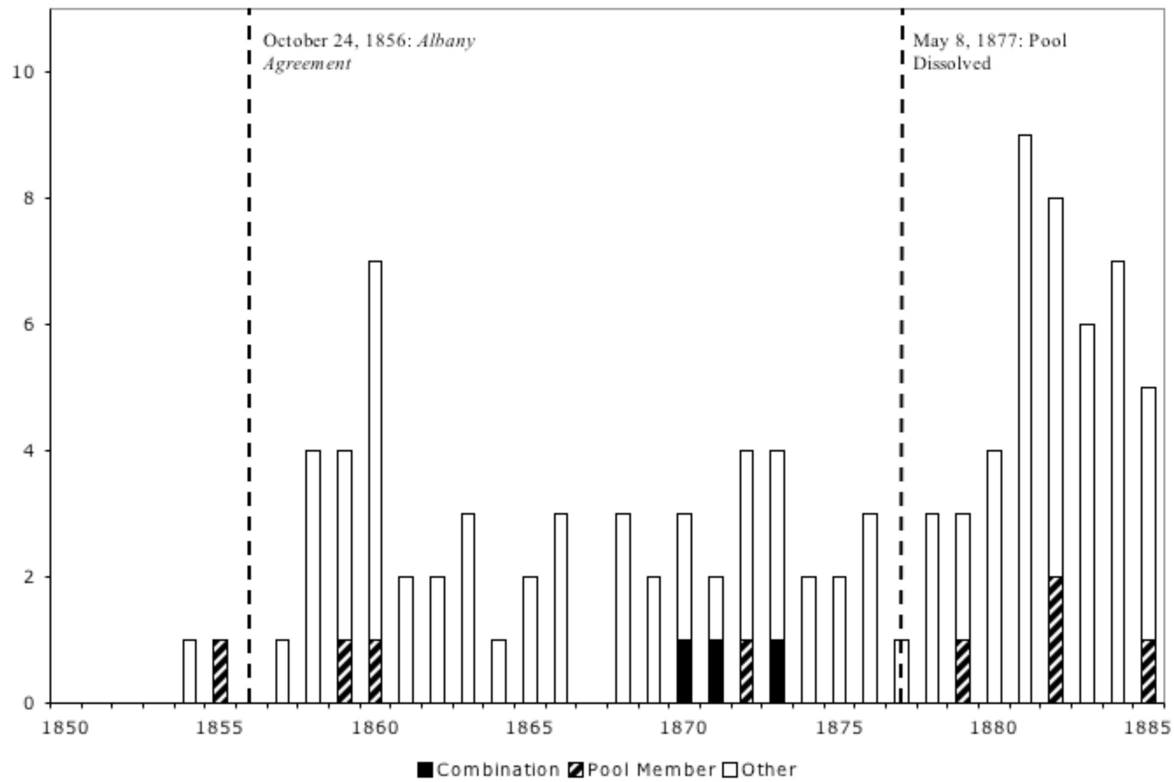
Notes: Data from the *Scientific American* (1846-1869), exhibition catalogues, such as the "United States Commissioners Report to the Universal Exposition in Paris," "The Report of the Twenty-seventh Exhibition of American Manufactures, Held in the City of Philadelphia," ads in contemporary trade publications, including "The Textile American;" and historical industry analysis, such as *Uniting the Tailors: Trade Unionism amongst the Tailoring Workers of London and Leeds, 1870-1939*. A complete list of references for each observation is available upon request. The solid line plots a fourth-order polynomial trend.

FIGURE 6 – LITIGATION: POOL MEMBERS



Notes: Data from *Westlaw Pre-1945 Federal Courts Database* and Robinson (1890).

FIGURE 7 – LITIGATION: DEFENDANTS IN SEWING-MACHINE CASES



Notes: Data from the *Westlaw* Pre-1945 Federal Courts Database and Robinson (1890).

APPENDIX A – POOL PATENTS

Number	Issue Date	Inventor	Innovation
4,750	Sept. 10, 1846	E. Howe, Jr.	Eye-pointed needle and lock-stitch.
6,099	Feb. 6, 1849	C. Morey & J. Johnson (re-issued to Singer and Clark)	Barbed needle.
6,439	May 8, 1849	J. Bachelder (owned by Singer)	Continuous feeding device, horizontal table.
7,659	Sept. 24, 1850	J. Bachelder (owned by Singer)	Vibrating loop chain-stitch.
7,776	Nov. 12, 1850	A. B. Wilson	Lock-stitch using vibratory shuttle.
8,294	Aug. 12, 1851	I. M. Singer	Feed-wheel, thread controller.
12,116	Dec. 19, 1854	A. B. Wilson	Four-motion feed.
12,233	Jan. 16, 1855	Conant	Rotary cloth-feeder, two needle chain-stitch.
16,030	Nov. 4, 1856	I. M. Singer	Rotary lock-stitch improvements.

Notes: Data from the Singer Papers, Box 225, Knight (1876), and Depew (1968).