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Author(s): Ryan Lampe and Petra Moser

Source: *The Journal of Economic History*, DECEMBER 2010, Vol. 70, No. 4 (DECEMBER 2010), pp. 898-920

Published by: Cambridge University Press on behalf of the Economic History Association

Stable URL: https://www.jstor.org/stable/40984782

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Do Patent Pools Encourage Innovation? Evidence from the Nineteenth-Century Sewing Machine Industry

RYAN LAMPE AND PETRA MOSER

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. This article 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, an objectively quantifiable measure of innovation, confirm these findings.

Patent pools, where "two or more parties agree to pool their respective technologies and license them as a package,"[1] have attracted interest as a remedy for excessive litigation and patent blocking, when competing patents prevent the commercialization of new technologies.[2] Recent examples include proposals to develop diagnostic tests for breast cancer, improve treatments for HIV and AIDS, and develop cures for neglected diseases, including malaria and cholera.[3] 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.[4] In 2001 the value of U.S. goods produced under pooling agreements exceeded $100 billion.[5] Antitrust authorities in the United States favor pools because they "provide procompetitive benefits

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Ryan Lampe is Assistant Professor, Department of Economics, DePaul University, 1 East Jackson Blvd., Suite 6200, Chicago, IL 60604-2287. E-mail: rlampe@depaul.edu. Petra Moser is Assistant Professor, Department of Economics, Stanford University, Stanford, CA 94305; and NBER. E-mail: pmoser@stanford.edu.

We wish to thank the Wisconsin State Historical Society for granting access to the Singer Archives, and Jim Bessen, Nick Bloom, Tim Bresnahan, Paul David, Eric Hilt, Mark Lemley, Tom Nicholas, Ross Thomson, and seminar participants at the Santa Fe Institute and Stanford for helpful comments. Luke Brennan and Marina Kutyavina provided valuable research assistance.

[1] Gaule, "Towards Patent Pools," p. 3.

[2] E.g., Shapiro, "Navigating."

[3] Verbeure et al., "Patent Pools." See http://www.stopaidssocieties.org.uk/2008/07/patent-pool-plans-progress/.

[4] Merges, "Institutions." These pools combine complementary patents that form a technological standard.

[5] Clarkson, "Objective Identification."

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by integrating complementary technologies, reducing transaction costs, clearing blocking positions, and avoiding costly infringement litigation."[6]

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 members can agree to sue infringers as a group and thereby lower their expected costs of litigation.[7] Pools that combine complementary patents also lower licensing fees for outside firms because they avoid "royalty stacking," which occurs when multiple patents cover the same product.[8] In contrast, pools that combine substitute patents can increase license fees for outside firms.[9] The prospect of a patent pool may also increase the *speed* of innovation in the time immediately preceding the pool: 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 to increase their chance of sharing in the pool's profits.[10]

A lack of contemporary data 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 nonmembers and rent-sharing agreements among pool members.[11] 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.[12]

This article 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.[13] One key advantage of the historical setting is that we can observe an industry from its birth

[6] U.S. Federal Trade Commission and Department of Justice, *Antitrust Guidelines*. "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)).

[7] Choi, "Patent Pools."

[8] Lerner and Tirole, "Efficient Patent Pools"; Choi, "Patent Pools"; Gilbert, "Antitrust"; Shapiro, "Navigating"; Lemley and Shapiro, "Patent Holdup"; and Merges, "Institutions."

[9] Lerner and Tirole, "Efficient Patent Pools"; and Shapiro, "Navigating."

[10] Dequiedt and Versaevel, "Patent Pools." Pools may also increase the speed of innovation by encouraging information sharing across firms. Nuvolari ("Collective Invention"), for example, finds that information sharing accelerated technological progress in the nineteenth-century Cornish steam engine.

[11] Layne-Farrar and Lerner, "Patent Pool Participation"; and Lerner, Strojwas, and Tirole, "Design."

[12] Pools of overlapping patent rights are less likely to form because members cannot be certain that they will receive a large enough share of expected profits (Bessen, "Imperfect Property Rights"). The only recent pool of overlapping patents is the 1992 laser eye surgery pool (Clark et al., "Patent Pools").

[13] 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.

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to technical maturity, including more than 30 years of data to analyze the long-term effects of a pool. 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.[14] The Combination also shared key characteristics of pools that theoretical models predict will encourage innovation: It was intended to end litigation between its members, and it combined complementary patents.

In the first step of the analysis, we use data on litigation and patents to test the predictions of existing theoretical models. Litigation data confirm that the pool lowered litigation risks for its members.[15] They also substantiate the prediction that the prospect of a pool encourages patenting among prospective members.[16]

The data, however, also 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. Nonmembers, which account for the vast majority of patents, appear to have been similarly affected by the creation of the pool; patenting increased immediately after 1856, but declined soon afterwards and remained low until the pool dissolved in 1877. These results are robust to the inclusion of time- and firm-fixed effects, as well as a number of alternative controls for increases in the demand for sewing machines.

A potential problem with using patents as a measure of innovation is that firms use patents strategically, for example to protect themselves from litigation or to negotiate a more advantageous position in a pool.[17] To address this issue, we construct an alternative measure of innovation that objectively quantifies improvements in the performance of sewing machines. Specifically, we use information in company records and trade journals to measure the number of stitches per minute that a sewing machine was able to perform.[18]

Data on sewing speeds confirm the results of the patent data. Innovation slowed soon after the pool had been established and did

[14] *E. Bement & Sons v. National Harrow Co.,* 186 U.S. 70, 91 (1902) was the first major antitrust case. Six firms had combined 85 patents for float spring tooth harrow (which soften top soil for cultivation). National Harrow grew to include 22 firms that covered over 90 percent of the market, and was sued because it required licensees to adhere to a uniform price schedule. The Supreme Court decided that the benefits of the pool—preventing litigation over patent scope and validity—outweighed the costs that price-fixing created for the industry (Gilbert, "Antitrust," pp. 2–3).

[15] See e.g., Choi, "Patent Pools"; and Gilbert, "Antitrust."

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

[17] See Cohen, Nelson, and Walsh, "Protecting"; and Hall and Ziedonis, "Patent Paradox."

[18] Measuring effects on innovation is particularly important if inventors' propensity to patent varies systematically across industries and over time (e.g., Moser, "Innovation Without Patents").

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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 potentially negative incentive effects of patent pools on innovation by their members, and incorporate effects of pools on other, nonmember firms which appear to play an important role as drivers of innovation.

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 nonmembers were at a greater risk of being sued while the pool was active; pool members acted as plaintiffs in most of these cases. In turn, lower rates of innovation among its competitors may have reduced incentives for pool members to innovate. Second, the existence of a pool that aggressively defended patents may have shifted innovation by nonmembers 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.[19]

THE EARLY SEWING MACHINE INDUSTRY, 1846–1885

On 10 September 1846, Elias Howe was granted U.S. patent No. 4,750 for "Improvements in the Sewing Machine"—the lock stitch. Although his patent was contested, Howe began to charge a hefty license fee of $25, compared with an average price of $125 per machine in 1856, as soon as the court upheld his patent in 1853.[20]

Despite its high price, Howe's license did not cover all parts that were needed to build a sewing machine, and firms that had patented other parts sued to assert their rights in court. Litigation during the "sewing machine wars" threatened to stop production and sales.[21] 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...The Wheeler & Wilson, and the Grover & Baker

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

[20] Bays, *Encyclopedia*, p. 15.

[21] Cooper, *Sewing Machine.*

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> 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 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

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).[22] With the exception of Howe who did not manufacture any sewing machines, these firms were the dominant producers of sewing machines in 1856.[23] Their pool combined nine complementary patents that were necessary to build a sewing machine. It survived for the duration of all original patents; no additional patents were added after 1856.[24] 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.[25] The pool dissolved on 8 May 1877, when Singer's patent expired.

Consistent with theoretical predictions, the sewing machine pool lowered license fees, especially compared with the high fees that Howe charged prior to the pool.[26] As soon as the pool had formed, it reduced license fees from $25 to $5 per machine for members and $15 for other firms.[27] When Howe's patent was renewed in 1860, the pool further reduced license fees to $1 for members and $7 for other firms; when

[22] There is no historical evidence to suggest that the sewing machine pool was anticipated. The pool was first mentioned in the *New York Herald* on 22 November 1856, nearly a month after it had formed. Contemporary papers, such as the *New York Times, Chicago Tribune*, and *Scientific American* include no prior mentions of the pool. In fact, Grover & Baker was included because its president, Orlando Potter, devised the concept of a patent pool (Cooper, *Sewing Machine*, p. 42).

[23] Cooper, *Sewing Machine*. From 1853 to 1856 Singer produced 5,136 machines, Wheeler & Wilson 4,936, and Grover and Baker 5,787. Thirteen other firms produced fewer than 650 machines each by 1856. There is no evidence of significant imports to the United States, but U.S. firms began to export in the 1860s. For example, U.S. firms had exported nearly $2 million worth of machines in 12 months prior to 30 June 1865 (Depew, *One Hundred Years,* p. 535).

[24] In other words, the pool did not incorporate a *grantback* clause, which requires members' future patents to be offered to the pool without fees (Layne-Farrar and Lerner, "Patent Pool Participation," p. 10).

[25] Wheeler and Wilson's four-motion feed was "so superior but few first-class machines (were) made without it" (Knight, *American Mechanical Dictionary*, p. 2102). It was renewed twice and expired in 1873. The Singer patent, which had been purchased from John Bachelder (Cooper, *Sewing Machine*, p. 23) made possible "the production of a sewing machine in which the cloth to be sewn is supported horizontally, and is fed through the machine perpetually" (*Potter et al. v. Braunsdorf*, 19 F. Cas. 1132 (1869)).

[26] E.g., Shapiro, "Navigating"; and Gilbert, "Antitrust."

[27] Bays, *Encyclopedia*, p. 15.

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Howe's patent expired in 1867, the pool abolished fees for members and lowered fees to \$5 for other firms; in 1870 the pool reduced fees to \$3.[28] Despite these reductions, differences in license fees between members and other firms may have lowered the competiveness of other firms, and thereby discouraged innovation. The pool, however, 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).[29]

In fact, Elias Howe demanded that the pool's patents should be licensed to at least 24 manufacturers at any given point in time.[30] Licensees were free to set their prices independently and the pool placed no other restrictions on their sales.[31]

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 2009 dollars, exceeding the annual sales of most small manufacturers.[32] 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 new data set that combines annual data on patents by pool members, licensees, and other nonmembers with data on improvements in sewing speeds as an objective measure of innovation. Legal records on litigation, as well as alternative measures for changes in the demand for sewing machines, complement these data.

[28] Vaughan, *Patent System*, p. 41. The Florence Sewing Machine Co. paid \$5 per machine in 1869. Florence sued because other firms appeared to pay even less. Its complaint, however, was dismissed (*Florence Sewing Machine Co. v. Singer Manufacturing Co.*, 9 F.Cas. 302 (1870)).

[29] Depew, *One Hundred Years*, p. 530.

[30] Cooper, *Sewing Machine.* Godfrey (*International,* p. 81) suggests that Howe insisted upon at least 24 licensees "fearing that a monopoly might be created."

[31] Hounshell, *American System*, p. 68; and Depew, *One Hundred Years*, p. 530. Although the *Albany Agreement* stipulated that each licensee should not produce more than 1,000 machines per year, licensees habitually exceeded the quota. For example, Ladd & Webster produced 1,788 machines in 1859.

[32] Using the Consumer Price Index, \$10,000 in 1856 was worth \$261,000 in 2009. Other indicators place the value of the litigation fund between \$198,000 and \$35,600,000 (Williamson, "Six Ways").

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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. patent grants for sewing machines per year, distinguishing patents of pool members from patents of other firms.[33] Between 1850 and 1885, 4,563 patents were granted in the USPTO main class 112 ("sewing"). From these data, we exclude patents for ancillary inventions, including "attachments" (subclasses 101 and 122 to 153) and "table and stands" (subclass 217). Our final sample contains 3,508 patents issued between 1850 and 1885.[34] To measure changes in invention in the absence of a pool, we construct a complementary data set of 1,493 British patents between 1850 and 1885.[35]

Firm-level data on individual manufacturers are drawn from collectors' manuals for antique sewing machines. These data indicate that 170 firms entered the industry between 1845 and 1885.[36] Entry and exit dates are available for 135 of these firms, nearly 80 percent. One hundred and twenty-one firms entered between 1853 and 1877. Thirty-five firms were licensees.

In interpreting the data, it is important to keep in mind that they may be subject to survivorship bias. Comparisons with census data suggest that collectors' manuals capture the largest number of firms while the pool was active, 40 percent of all U.S. manufacturers in 1860 (29 of 74 firms), 63 percent (21 of 49 firms) in 1870, and 36 percent (36 of 101 firms) in 1880. Firms that are missing from collectors' manuals are more likely to be outside firms; to the extent that more of their innovations are captured by collectors' manuals in the 1860s but not before or after, the data may overestimate innovation by outside firms during the pool.[37]

[33] Data on application dates are only available after 1873. 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, Juhl, and Johnson, "Time in Purgatory"). In a random sample of 100 sewing machine patents between 1873 and 1875, the average patent was granted 140 days after the application date.

[34] We also compared our data with sewing machine patents in Knight's *Mechanical Dictionary*. Knight includes 337 additional patents, but few of them are for material improvements in sewing machines; 42 percent of Knight's additional patents are for tables and stands, 26 percent are miscellaneous parts such as bobbin winders and tension devices.

[35] British data are constructed by searching *A Cradle of Invention: British Patents from 1617 to 1894* for sewing machine patents.

[36] Cooper, *Sewing Machine.* Most of these manufacturers produced sewing machines for home, rather than industrial use (Godfrey, *International*, p. 125). Patents are matched to firms based on inventor or firm names (e.g., Edward Clark of the Singer Manufacturing Co., or A. B. Wilson of Wheeler and Wilson).

[37] Smaller manufacturers typically produced between 500 and 1000 machines over their lifetime (Bays, *Encyclopedia*). As an alternative test, we compared our data with 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 the Philadelphia directories, a larger number of entries are sewing machine agents.

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Improvements in Sewing Speed

One potential problem with using patents as a measure of innovation is that not all innovations are patented and that inventors may use patents strategically, so that changes in patenting do not accurately reflect changes in innovation.[38] 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, nonmembers may patent more aggressively after the pool has formed to protect themselves from litigation.[39]

To address this issue, we construct an alternative measure of innovation: changes in the number of stitches that a lock-stitch machine can perform within one minute.[40] Data on sewing speeds for 1845 to 1900 are drawn from the *Scientific American*, company records, trade cards, and reports from the records of world's fairs, including the Crystal Palace Exhibition of 1851. For example, a description of work in a clothing factory provides data on sewing speed for Union and Wheeler & Wilson in 1889.

> The linings are made by a Willcox & Gibbs machine, the topping is done by a two needle Union machine which runs at the rate of about 2,220 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 1,000 stitches per minute.[41]

Law Suits and Changes in the Demand for Sewing Machines

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

[38] For example, less than 20 percent of U.S. innovations at the Crystal Palace world fair of 1851 were patented. Equally important, the share of patented innovations varied significantly across industries, ranging from 5 percent in chemicals to 40 percent in manufacturing machinery (Moser "Innovations Without Patents" and "How Do Patent Laws?").

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

[40] Sewing speed is also objectively measurable while alternatives, such as the variety of stitch type are more subjective. *Knight's Mechanical Dictionary* (pp. 2213–14), for example, includes several types of embroidery stitches in its list of 68 distinct stitch types. Improvements in shuttles and the adoption of cranks in drive mechanisms (instead of springs and cams) are the most likely source of improvements in speed (Thomson, *Path*, p. 148), with electric motors only occurring after 1889 (Depew, *One Hundred Years*, p. 534). Estimates of sewing machine and hand productivity are available for 1895 only (U.S. Bureau of Labor, *Hand and Machine Labor*).

[41] Tullidge, *Tullidge's Histories*, p. 368.

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1880 onwards), and the *Supreme Court Reports* and *United States Reports* (decisions of the Supreme Court).[42] Westlaw reports 100 patent disputes regarding sewing machines between 1850 and 1885. We also searched William Robinson's *Law of Patents*, which includes two additional cases.[43]

Litigation data show that the pool as a whole engaged in 19 legal cases, and pool members acting independently engaged in another 23 disputes.[44] Litigation data may, however, underestimate the real risk of litigation because they only capture cases that were decided in court and omit cases that were settled out of court. This bias may be more severe for small outside firms that were reluctant to face the pool and its sizable litigation fund in a drawn-out legal dispute.[45]

Finally, to control for changes in demand, we include data on population growth and real GDP.[46] Across industries, disruptions as a result of the Civil War (1861 to 1865) may have discouraged innovation.[47] For the sewing machine industry, however, the war may have also encouraged innovation, as it increased demand for machine-made uniforms.[48] To measure such changes in demand, we control for increases in the size of the Union Army between January 1861 (16,267 soldiers) and January 1865 (959,460 soldiers).[49]

[42] 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.

[43] Westlaw and Robinson report when a case was decided but not when it was filed. 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 between 1850 and 1851 was decided in 1852 (*Scientific American*, 25 July 1852, 356).

[44] 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 (1881)), four years after the pool dissolved, when pool members sued for past infringement of Bachelder's patent (USPTO patent 6,439).

[45] Historical case data may also be biased towards general interest decisions, because they are based on contributions of individual reporters (Khan, "Property Rights," p. 94).

[46] *United States Census Bureau, 1850–1890*; and Johnston, "U.S. GDP."

[47] Thomson's ("Continuity") analysis of key innovations in firearms, shoemaking, and petroleum production suggests that the Civil War's impact on innovation was limited. Moreover, all except four of 135 manufacturers in our data were located in the North and may have been less vulnerable to disruptions.

[48] Whitten and Whitten, *Handbook*, pp. 91–92. The war department also placed direct orders for thousands of sewing machines (Crow, *Great American Customer*, p. 205). In its trade cards, Singer proudly claimed: "We clothe the Union Armies" (Jensen, *Stories*, p. 156).

[49] Long and Long, *Civil War.* Both sides reused the uniforms of fallen soldiers. We focus on increases in the number of Union soldiers because most Confederate uniforms were sewn by hand (Drew and Snow, *Eagle's Talons*, p. 113). For example, the daughter of Mrs. Robert M. Patton of Florence, Alabama, remembers "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." (Andrews, *Women*, p. 427).

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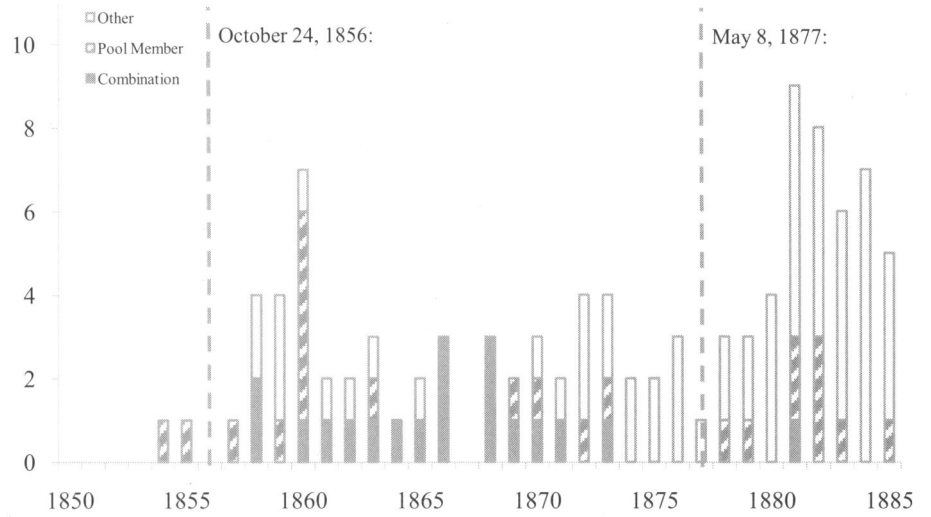

FIGURE 1
LITIGATION: POOL MEMBERS

Notes: Data from *Westlaw Pre-1945 Federal Courts Database*; and Robinson, *Law of Patents*. Pool Members are Wheeler & Wilson, Grover & Baker, and Singer. The Combination refers to the pool.

EMPIRICAL RESULTS

Did the Pool Discourage 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 1856 and 1877, while the pool was active, it was a defendant in only 3 of 55 total legal disputes (Figure 1) 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; both cases were decided in Singer's favor.[54]

[50] See e.g., Choi, "Patent Pools."

[51] See e.g., Cooper, *Sewing Machine*, p. 41.

[52] Two subsequent cases concerned payments by Florence to a judge and jurisdictional concerns. See *Florence v. Singer Manufacturing Co.*, 9 F. Cas. 302 (1870), *Florence v. Singer Manufacturing Co.*, 9 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.*, 110 Mass. 70 (1872).

[53] *Wickersham v. Singer*, 29 F. Cas. 1134 (1859) and *Wilson v. Singer*, 30 F. Cas. 217 (1860).

[54] In *Wilson v. Singer*, 30 F. Cas. 217 (1860), Wilson sought the reissue of a patent that incorporated

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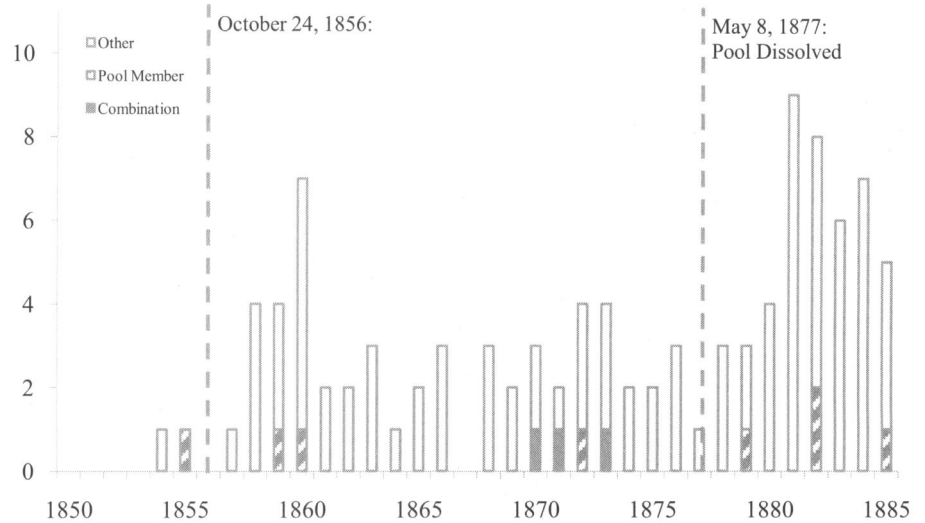

FIGURE 2
LITIGATION: DEFENDANTS IN SEWING MACHINE CASES

Notes: Data from the *Westlaw Pre-1945 Federal Courts Database*; and Robinson, *Law of Patents*. Pool Members are Wheeler & Wilson, Grover & Baker, and Singer. The Combination refers to the pool.

Contrary to the results for member firms, litigation data suggest that the pool increased litigation risks for outside firms. Between 1856 and 1877 the pool initiated 15 legal battles, more than a quarter of all 55 sewing machine cases.[55] Pool members acting independently initiated another nine cases. Only six of the 30 cases that involved the pool or its members were initiated by outside firms (Figure 2).[56]

Did the Pool Encourage Its Members to Patent More?

The most central prediction of the theoretical literature is that patent pools encourage innovation by increasing expected profits for members and reducing licensing costs for other firms. To test this prediction, we examine whether patenting increased in the years leading up to the pool and continued at a higher level while the pool was active. Theoretical analyses have focused on the effects of patent pools on their members; we extend the analysis to include effects on other firms, which accounted for the majority of patents and improvements in performance.

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*, 2 Fisher, 381 (1863)).

[55] Thirteen of these cases concerned Wilson's four motion feeding mechanism (USPTO patent 7,776).

[56] In comparison, outside firms were less likely to sue each other while the pool was active, with a total of 25 cases between 1856 and 1877, compared with 35 cases between 1878 and 1885.

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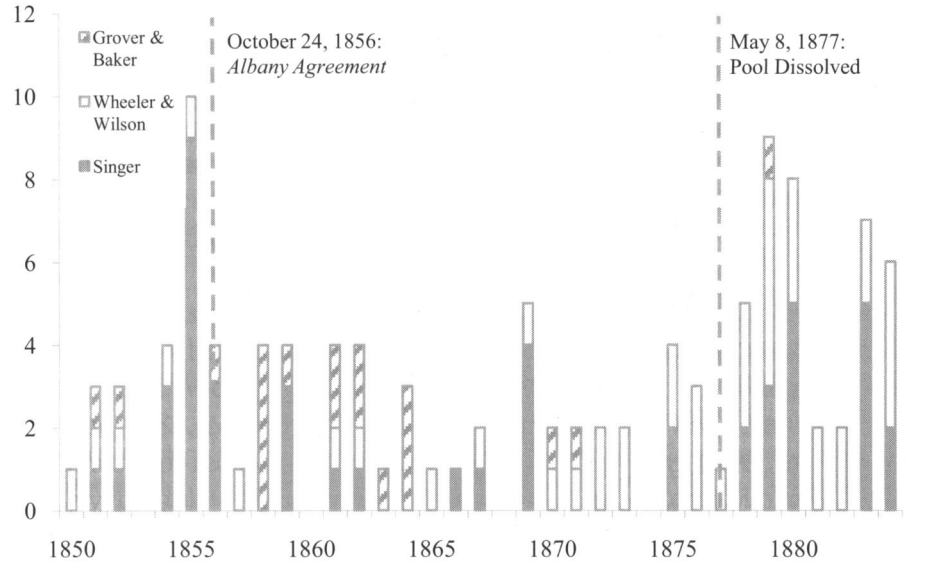

FIGURE 3
SEWING MACHINE PATENTS: POOL MEMBERS

Notes: Data from Knight, *American Mechanical Dictionary*; and Google Patents, www.patents.google.com, include any patent that was either granted to the pool or assigned to the pool at issue.

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 members were granted a total of ten patents, compared with an average of less than three patents per year for 1850 to 1854 (Figure 3). 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. Thus, nine of ten member patents in 1855 were granted to Singer, even though the company contributed no significant inventions to the pool.[57]

Pool members 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

[57] Singer had acquired its patent on the horizontal work surface from John Bachelder (Cooper, *Sewing Machine*, p. 23).

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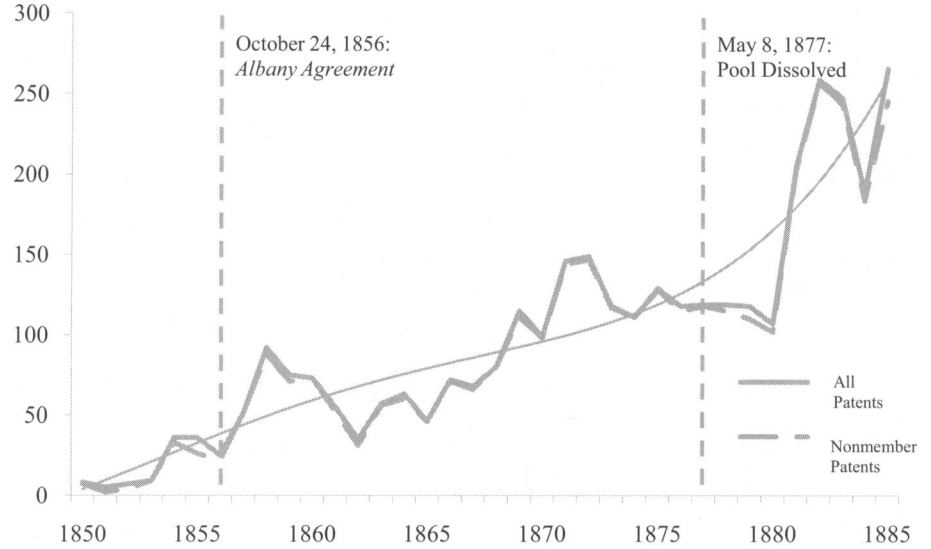

FIGURE 4
U.S. PATENTS FOR SEWING MACHINES

Notes: Series excludes patents granted for attachments, tables, and stands. The thinner line plots a fourth-order polynomial trend.
Sources: Patent grants as reported in the U.S. Patent Office, *Annual Reports*; and Knight, *American Mechanical Dictionary*.

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.[58]

Did the Pool Encourage Outside Firms to Patent More?

In contrast to patents by members, patents by outside firms spiked just *after* the pool had been established. The annual number of patents in Figure 4 jumped from 25 in 1856 to almost 100 patents in 1858.[59] If outside firms failed to enter the pool because they were slower (rather than less productive), this increase is consistent with the idea of a patent race leading

[58] The number of high-quality patents (as measured by citations) also increased after 1877: 267 of 3,508 sewing machine patents between 1850 and 1885 (7.6 percent of the patents in our sample) were still cited by U.S. patents granted between 1975 and 2002 (in the NBER data set; see Hall, Jaffe, and Trajtenberg, "Patent Citations"). Twelve of these patents (1.7 per year) were granted before 1857, 100 patents (5.0 per year) were granted between 1857 and 1876, and 155 patents (17.2 per year) were granted after 1876.

[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.

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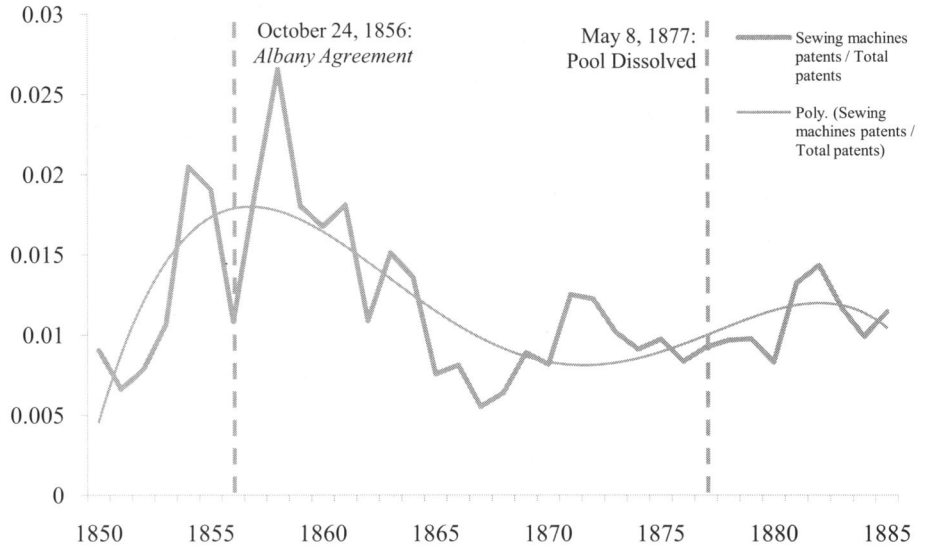

FIGURE 5
SHARE OF SEWING MACHINE PATENTS AMONG ALL U.S. PATENTS

Notes: Patent grants as reported in the U.S. Patent Office, *Annual Reports*. The thinner line plots a fourth-order polynomial trend. Series excludes patents granted for attachments, tables, and stands.

up to the pool.[60] It may, however, also reflect a strategic response to an increase in litigation risks for outside firms after the pool had formed.[61]

Patenting by outside firms began to decline only two years after the pool had formed. By 1862 the number of patents had fallen to 35 patents per year. The number increased to 149 in 1872 after the Civil War increased demand for sewing machines. After this peak, the number of patents per year declined again until the pool dissolved in 1877. By 1880, only three years after the pool dissolved, the number of patents per year began to rise again, increasing past 250 patents in 1882.

Changes in sewing machine patents as a share of all U.S. patents also indicate that the pool discouraged patenting. An initial increase to 2.7 percent of patents in 1858 eroded to 0.5 percent by 1867 in Figure 5. After the pool dissolved, the share of sewing machine patents recovered, reaching nearly 1.5 percent of all U.S. patents in 1882.

An additional test compares changes in sewing machine patents in the United States with Britain, where the sewing machine industry

[60] See e.g., Dequiedt and Versaevel, "Patent Pools."
[61] See e.g., Shapiro, "Navigating"; and Bessen, "Patent Thickets."

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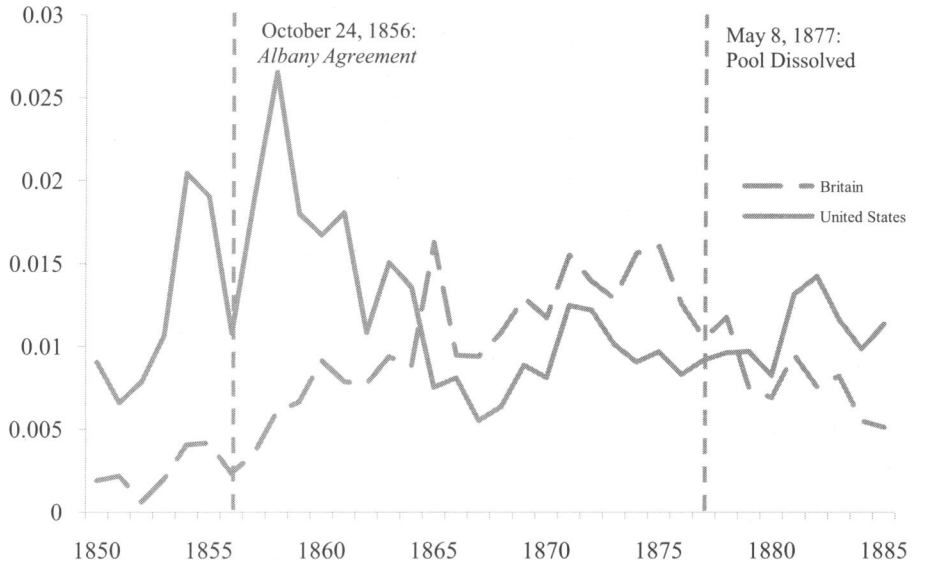

FIGURE 6
SHARE OF SEWING MACHINE PATENTS IN ALL PATENTS:
UNITED STATES VERSUS BRITAIN

Sources: U.S. patents granted in USPTO main class 112 ("sewing") and British patents from *A Cradle of Inventions: British Patents from 1617 to 1894*. Excludes patents for attachments, tables, and stands.

evolved without a patent pool. This comparison suggests that the decline in innovation during the pool was limited to the United States. British patents followed a more continuous growth path. As a share of all British patents, sewing machine patents continued to increase until the early 1870s and declined after 1874 (Figure 6). In contrast to the U.S. case, the share of sewing machine patents did not increase in Britain after the pool dissolved in 1877.

Difference-in-Differences Estimation

To examine the patent data more systematically, we estimate changes in the average number of patents per year by pool members relative to other firms after the pool was established and after it dissolved.

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

where p_{it} measures the number of patents granted to firm i in year t. The coefficient β_{PMP} for the interaction *Pool Member* * *Pool* is the difference-in-differences estimator; it measures the increase in annual patents by pool

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members relative to patents by other non-licensee firms while the pool was active compared with years before and after the pool.[62] The coefficient β_{LP} for the interaction *Licensee* * *Pool* measures the increase in annual patents by licensees relative to other nonmember firms. 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 new technologies. Alternatively, older firms may patent more because they are more familiar with the patent system or because they tend to be larger and produce more, increasing the likelihood of learning-by-doing and purposeful as well as accidental innovation.[63]

To account for unobservable factors that may influence patenting, we include year and firm fixed effects (δ_t and γ_i). Year fixed effects measure factors such as the dismissal of strict examiners in the early 1850s or changes in the demand for sewing machines that would have helped to increase the annual number of patents by all firms, independently of the pool.[64] Firm fixed effects control for differences in the long-run inventiveness of firms or in their propensity to patent. Separate regressions without firm fixed effects distinguish *Pool Members* and *Licensees* from other firms. The dummy variable *Pool Member* equals 1 for the firms Grover & Baker, Singer, and Wheeler & Wilson; the dummy variable *Licensee* equals 1 for any firm that bought a license from Howe or the pool.

Regression results confirm that members patented less while the pool was active. Statistically significant estimates for β_{PMP} in Table 1 indicate that pool members produced between 1.3 and 1.7 fewer patents per year while the pool was active. Across all years, members produced 2.2 more patents per year.[65] Additional regressions that estimate year-specific coefficients indicate that members generated between 0.7 and 2.3 fewer patents in the last ten years of the pool compared with the pre- and post-pool period.[66] Effects on licensees are not statistically significant.

[62] This approach may lead us to underestimate the effects of the pool because we miss two months of pool activity in 1856 (the pool formed in October), and four months in 1877 (the pool dissolved in May).

[63] For sewing machines sales between 1853 and 1882, increases in the volume of sales were associated with technological change (Thomson, "Learning by Selling"). In our sample, the coefficient of correlation between annual sales and annual patents is 0.185 (or 0.153 assuming a one-year lag), based on U.S. sales for 30 licensees between 1867 and 1876 and 163 year-firm observations.

[64] Post, "'Liberalizers'."

[65] Summing β_{PMP} and β_{PM} indicates that pool members produced 0.4 more patents than other firms while the pool was active compared with 2.2 additional patents in other years in Table 1, specification I.

[66] Coefficients are negative for all 20 years when the pool was active (1857–1876), and they are significant at the 5 percent level for 12 of these years: 1857, 1860, 1863, 1865 to 1868, 1870 to 1872, 1874, and 1875.

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TABLE 1
DEPENDENT VARIABLE IS PATENTS PER FIRM AND YEAR
(1850–1885)

	OLS	OLS	OLS	Negative Binomial
	(I)	(II)	(III)	(IV)
Pool			–0.036	–0.484
			(0.175)	(0.478)
Pool member[a]	2.187**		2.155**	2.017**
	(0.525)		(0.508)	(0.357)
Pool * Pool member	–1.748**	–1.260*	–1.674**	–0.733*
	(0.564)	(0.612)	(0.526)	(0.352)
Log age	0.060	–0.426**	0.056	0.001
	(0.046)	(0.121)	(0.046)	(0.126)
Licensee[b]	0.267		0.252	0.535
	(0.249)		(0.247)	(0.421)
Pool * Licensee	–0.197	0.233	–0.150	–0.027
	(0.208)	(0.242)	(0.200)	(0.384)
Δ Union Army[c]			–0.005	–0.045*
			(0.003)	(0.022)
Δ Union Army (–1)			–0.000	0.003
			(0.002)	(0.010)
Δ Union Army * Member			0.010	0.049*
			(0.006)	(0.021)
Δ Union Army (–1) * Member			–0.003	–0.005
			(0.003)	(0.005)
Real GDP[d]			7.767	15.781*
			(4.117)	(7.748)
Log population			3.408	18.638
			(5.469)	(15.656)
Δ Union Army * Licensee			–0.000	0.005
			(0.002)	(0.009)
Δ Union Army (–1) * Licensee			–0.000	–0.004
			(0.002)	(0.008)
Member fee			–0.033	–0.054
			(0.019)	(0.045)
Nonmember fee			0.041	0.057
			(0.023)	(0.050)
Linear time trend			–0.097	–0.501
			(0.147)	(0.409)
Constant	0.400**	1.535**	–36.825	–190.657
	(0.105)	(0.349)	(54.413)	(157.226)
Observations	1050	1050	1050	1050
Firm fixed effects	N	Y	N	N
Year fixed effects	Y	Y	N	N
R-squared / Log-likelihood	0.17	0.33	0.15	–848.927

** denotes significance at the 1 percent level.
* denotes significance at the 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.
[c] Increase in Union Army soldiers in 10,000s. Δ Union Army (–1) measures the one-year lag.
[d] In millions of year 2000 dollars.
Note: Standard errors are clustered at the firm level.
Sources: Data from Long and Long, *Civil War*; and Johnston and Williamson, "U.S. GDP."

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The data estimated effect of firm age is also relatively small. Firms that were 10 percent younger produced 0.04 additional patents per year (Table 1, specification II).

Alternative specifications, without year and firm fixed effects, control for changes in the demand for sewing machines, which varied over time but not by firm. For example, anecdotal evidence suggests that Singer and other pool members benefitted disproportionately from increases in the demand for sewing machines, with Singer selling "tens of thousands machines."[67] To identify these effects, we estimate interaction terms between pool membership and measures for the intensity of the Civil War.[68] Linear time trends capture changes in patenting over time that may be independent of the pool.[69]

Regression results from this alternative specification confirm that the pool lowered annual patents for its members. Across all years, members produced 2.2 additional patents per year compared with other firms (Table 1, specification III). In comparison, members produced 1.7 fewer patents per year while the pool was active. There are no statistically significant effects for licensees.

The results also indicate that the Civil War had relatively limited effects on sewing machine patents. For every 10,000 person increase in the size of the Union Army, the average member firm produced 0.01 additional patents per year, while nonmember firm produced 0.005 fewer patents per year (see Table 1, specification III).[70]

To account for the large number of zeros in the dependent variable, we repeat the analysis as a negative binomial regression. All key results are robust to this alternative specification. The coefficient on the interaction *Pool Member* * *Pool* indicates that the pool reduced the number of member patents by 52 percent. Like OLS, negative binomial regressions yield no evidence that the pool encouraged licensees to patent more.[71]

Did the Pool Encourage Innovation (Rather Than Patenting)?

Two key findings of the patent data suggest that the pool may have encouraged changes in strategic patenting rather than innovation. First,

[67] Botti, *Envy*, p. 97; and Jensen, *Stories*, p. 156.

[68] One-year lags are reported. Longer lags are not significant and do not change the main results.

[69] Coefficients are robust to alternative specifications of time trends up to the fourth-order polynomial.

[70] These results confirm the findings of Thomson ("Continuity"), which suggest that the war's effect on innovation was limited.

[71] The coefficient on *Union Army * Pool Member*$_i$ is significant at 5 percent. Poisson regressions and alternative specifications that restrict the number of explanatory variables yield nearly identical results.

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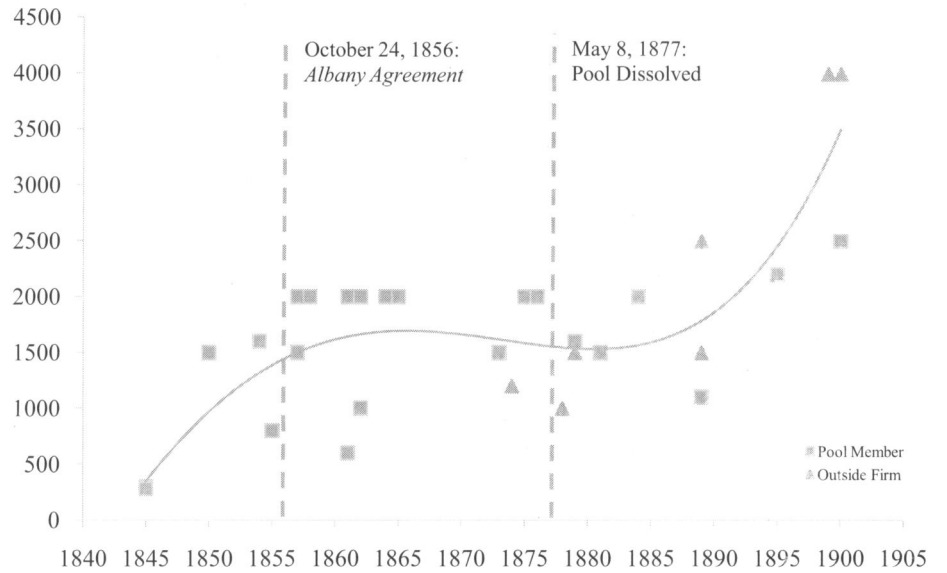

FIGURE 7
STITCHES PER MINUTE

Notes: A complete list of references for each observation is available upon request. The solid line plots a fourth-order polynomial trend.
Sources: 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 Kershen, *Uniting the Tailors*.

the increase in the number of 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, so that the increase in patents may reflect an increase in the share of patents per innovation, rather than a true increase in innovation.[72] Second, the spike in patenting for nonmember firms immediately after the creation of the pool may represent a strategic response by nonmembers to a heightened threat of litigation.[73]

To separate changes in strategic patenting decisions from changes in innovation, we examine data on sewing speeds as an objectively quantifiable measure of performance. Data on sewing speeds in Figure 7 confirm that the pool slowed rather than encouraged rates of innovation. From 1845 until 1856 the maximum number of stitches that a lock-stitch sewing machine could perform increased from 200 to

[72] Dequiedt and Versaevel, "Patent Pools."
[73] See e.g., Shapiro, "Navigating"; and Bessen, "Patent Thickets."

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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 began to advance again soon after the pool dissolved in 1877. By 1889 the maximum speed of sewing had increased to 2,500 stitches per minute.[74] Outside firms produced the fastest machines in 1889 and 1900 (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 1900).[75]

CONCLUSIONS

Evidence from the sewing machine industry challenges theoretical predictions and regulators' expectations that patent pools encourage innovation. In contrast to theoretical predictions, 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 relative to the pre-and post-pool period. Similarly, sewing machine speeds barely changed while the pool was active and then rose after the pool had been dissolved.

Our article also extends the analysis of patent pools to include the effects of pools on outside firms, which account for the majority of innovations. Nineteenth-century data suggest that the sewing machine pool discouraged invention by outside firms and that it had at best statistically insignificant effects on licensees.

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: 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. These changes in the rate and direction of innovation among outside firms may weaken incentives to innovate for the members of a patent pool.[76]

[74] 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 t, the *Pool* variable, and an interaction term *Pool*t*, as explanatory variables. In such regressions, the coefficient on *Pool*t* 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.

[75] 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.

[76] See Lampe and Moser, "Patent Pools."

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