DO PATENT POOLS ENCOURAGE INNOVATION? EVIDENCE FROM EIGHT INDUSTRIES IN THE 1930S

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Patent pools, which allow a group of competing firms to combine their patents, are expected to encourage innovation by limiting litigation risks and lowering transaction costs. There is no contemporary evidence on the effects of patent pools on innovation; nineteenth-century data, however, indicate that pools that operate in the absence of restrictions on anti-competitive practice discourage innovation. This paper examines the effects of eight pools that formed after the Great Depression but before the landmark *Hartford* decision of 1945. Difference-in-difference estimates across these pools indicate a robust negative effect of pool creation on patenting. Estimates for individual pools reveal positive effects for one pool; this effect is due to positive time trends in patenting that preceded the creation of a pool.

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Patent pools, which allow competing firms to combine their patents, have been proposed as a means to facilitate licensing and encourage scientific progress in treatments for HIV, cholera, and malaria.[1] For example, pools may encourage outside firms to innovate by lowering license fees (Lerner and Tirole 2004), and encourage pool members by lowering the expected costs of litigation (Gilbert 2004).[2] As a result, antitrust authorities are supportive of pools that "provide pro-competitive benefits by integrating complementary technologies, reducing transaction costs, clearing blocking positions, and avoiding costly infringement litigation" (Department of Justice 1995).

Evidence on 19th-century innovations, however, indicates that, without restrictions on anti-competitive practices, patent pools may discourage innovation.[3] Fewer inventions were patented while the sewing machine pool was active (1856-1877) relative to pre- and post period, both in absolute terms and relative to overall patenting in the United States (Lampe and Moser 2010). Objectively quantifiable improvements in the performance of the sewing machine, measured as advances in the speed of sewing, also slowed during the pool, and picked up only after it dissolved. A counterfactual comparison with Britain,

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[1] UNITAID's board formally approved an agreement in June 2010 to set up a Medicines Patent Pool Foundation and fund it with $4.4 million in the first year. In May 2010, South Africa's Technology Innovation Agency (TIA), and MIT agreed to join a pool set up by GlaxoSmithKline (GSK) in 2009 to target neglected diseases such as malaria and cholera. More recently, a patent pool was formed in September 2010 between eight companies holding patents on RFID tags.

[2] Pools that combine complementary patents lower license fees for outside firms by preventing "royalty stacking" for multiple patents on the same product, while pools that combine substitute patents may increase license fees (Lerner and Tirole 2004; Shapiro 2001; Merges 1999). Pools may also increase member's incentives to invest in R&D because pool members can sue infringers as a group and lower their expected costs of litigation (Gilbert 2004, Shapiro 2001, p. 134).

[3] Empirical analyses of contemporary pools have focused on the determinants of participation and rules within the pool (Lerner, Strojwas, and Tirole 2007; Layne-Farrar and Lerner 2008).

which did not have a pool, confirms that lower rates of innovation were limited to the United States.

The case of the sewing machine industry suggests that pools, which operate in the absence of regulation, may raise the expected costs of R&D for outside, non-member, firms and discourage innovation among members. Thus the sewing machine pool only licensed to firms that did not directly compete with its own products and earmarked a significant portion of its licensing revenues to sue infringers (Lampe and Moser 2010). This increased the expected cost of litigation for potential entrants, who shifted their research to avoid direct competition.[4] Data on both firm entry and patents reveal that outside firms shifted their research towards a non-competitive, inferior technology while the pool was active, and returned to improving the pool technology after the pool had dissolved (Lampe and Moser 2011).

In this paper, we examine data for eight patent pools that were created after the end of the Great Depression and before the beginning of World War II.[5] Preceding the landmark *Hartford* decision of 1945, these pools operated in a relatively stable regulatory environment. Pools had initially been exempt from antitrust regulation under the Sherman Act of 1890 and in 1902 the United States Supreme Court (*E. Bement & Sons v. National Harrow Company*, 186 U.S. 70. 91, 1902) upheld the National Harrow pool even though it had stipulated a

[4] Lerner (1995) documents a similar move to avoid competition in the biotechnology sector, where firms with less paid-in capital and less prior experience in litigation were less likely to patent in subclasses were competing firms had recently patented.

[5] Recent research documents significant advances in total factor productivity across a broad range of industries in the 1930s (Field 2003 and 2011). Patent data for this period indicate that increases in chemical invention in the 1930s may be due to compulsory licensing, which allowed U.S. firms to produce German-owned inventions after World War I (Moser and Voena 2011).

minimum price for its licensees because the "execution of these contracts did in fact settle a large amount of litigation."[6] Pools became the subject of closer scrutiny in 1912 when the Court dissolved the *Standard Sanitary* pool even though it was less restrictive than *National Harrow* (Gilbert 2004).[7] Pools rose to prominence in 1917 when a congressional committee under Franklin D. Roosevelt encouraged the Wright brothers and their competitor Curtis to pool blocking patents that hindered the production of planes. With a patent pool, industry production increased from 83 planes in 1916 to 11,950 in 1918 (Stubbs 2002).[8] Between the wars, pools were subject to moderate scrutiny. In 1931, for example, the Supreme Court upheld a pool for gasoline cracking processes even though a lower court had found that the pool sought to eliminate competition (*Standard Oil Co. of New Jersey v. United States* 283 U.S. 163 (1931)). In 1945, a period of tight control began after the Supreme Court dissolved the *Hartford Empire* pool for imposing production quotas and product qualities on its licensees (Carlson 1999, *Harford Empire Co. v. U.S.* 323 U.S. 386 (1945); Lerner, Strojwas, and

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[6] Harrows are agricultural tools used to spread crop residue before planting; six companies with competing patents began and counter-sue in the 1880s, before they formed a pool in 1890. By 1902, National Harrow had grown to include 85 patents and 22 firms that covered over 90 percent of the market. National Harrow sued E. Bement & Sons for selling harrows below the minimum prices it had set for licensees; Harrow's defense argued that the pool's licensing provisions violated the Sherman Act (1890).

[7] The *Standard Sanitary* pool combined three key patents on an enameling process for sanitary ironware such as bath tubs and wash bowls. One of the patentees had proposed the pool in 1909 because the two other patents had infringed on his patent. Standard Sanitary established a fixed royalty and prevented licensees from selling products not approved by the pool. The Court condemned these arrangements because they "transcended what was necessary to protect the use of the patent or the monopoly which the law conferred upon it. They passed to the purpose and accomplished a restraint of trade condemned by the Sherman law" (*Standard Sanitary Manufacturing v. U.S.* 226 U.S. 20 (1912)).

[8] The aircraft pool remained active until the 1970s. In 1972 the Department of Justice argued that the pool's cross-licensing agreement discouraged R&D; in 1975 Justice dissolved the pool (Bittlingmayer 1988).

Tirole 2007).[9] Pools were uncommon after this until the Department of Justice approved the MPEG and DVD standards pools in 1997 and 1999.

This paper examines patent data for eight industries where a pool formed between the end of the Great Depression and the beginning of World War II. They covered innovations in rail joint bars (1931-44), hydraulic oil pumps (1933-52), machine tools (1933-55), Philips screws (1933-49), variable condensers (1934-53), wrinkle finishes (1937-55), dropout cutouts (1938-48), and slip covers (1938-49). For all eight pools, lists of member firms are available in written legal opinions and other primary documents at depositories of the National Archives in Chicago and New York; complete lists of pool patents are available for seven pools excluding hydraulic oil pumps.

Difference-in-difference regressions of U.S. patent grants across all pools suggest that the creation of a patent pool reduced patenting in pool technologies. These regressions compare patent grants in USPTO subclasses with pool patents and technologically-related USPTO subclasses without pool patents ten years before and after the creation of a pool. The most basic estimates imply that subclasses with pool patents produced 14 percent fewer patents after a pool was created. Equivalent estimates that control for the number of pool patents in a given subclass imply that each additional patent that was included in the pool reduced patenting by 8 percent after the creation of a pool.

[9] Two glassware firms formed Hartford Empire in 1924. By 1938, it had grown to include more than 600 patents, which covered the machines that produce 94 percent of glass containers in the United States. Hartford Empire restricted the quantity and types of glassware that members could produce. The Supreme Court argued that invention had been discouraged and suppressed competition (*Harford Empire Co. v. U.S.* 323 U.S. 386 (1945)).

Regressions at the level of individual pools indicate significant negative effects for three industries, no effects for another four, and positive effects for one industry. In the rail bars industry, patenting decreased by 27 percent after the creation of the pool; in variable condensers 21 percent, and in wrinkle finishes 30 percent. In hydraulic pumps, machine tools, and dropout cutouts, there are no statistically significant effects. In Phillips screws, however, patenting increased by 260 percent.

Can these results be explained by changes in the pre-trends of patenting? To examine the timing of effects we estimate a separate pool effect for each year, allowing it to be different from zero ten years before the pool was created, during the pool, and ten years after it dissolved. Comparisons of yearly estimates reveal that the substantial increase in patenting after the creation of the Phillips screw pool can be explained entirely by pre-existing trends. Only the decline in patenting after the creation of the pools for rail joint bars and wrinkle finishes cannot be explained by pre-existing trends. Comparisons of changes in patenting after the pools dissolved reveal no statistically significant effects.

The remainder of this paper is structured as follows. Section I describes the data and summarizes the key characteristics of each patent pool. Section II presents empirical results across all pools. Section III presents results at the level of individual pools.

I. THE DATA

Data on U.S. patents in 8 industries between 1916 and 1938 allow us to explore the effects on innovation of 8 pools, covering a total of 148 patents that U.S. companies formed between 1931 and 1938.[10] These data are likely to over-represent pools that engaged in anti-competitive practices, because such pools were litigated and created a paper trail of court documents that we can trace to identify pool patents.[11] Data on patent pools are drawn from written opinions, defendants' memoranda, and copies of pool agreements, which were preserved in court dockets at regional depositories of the National Archives in Chicago and New York.[12]

Pools cover rail joint bars (1931-1944, bars that hold two ends of the rail in place and prevent lateral and vertical movement), hydraulic oil pumps for oil wells (1933-52), machine tools (1933-55, power-driven metal-cutting or –shaping machines), Philips screws (1933-49), variable condensers (1934-53, devices to select the incoming signal of a particular radio station in a radio set), wrinkle finishes, enamels and paints (1937-55), dropout cutouts (1938-48 devices to

[10] We focused our search on pools of U.S. patents only to ensure that we are capturing the full effects of the pool on invention. Since there is a lag between patent filings and grants, we only consider pools that were active long enough to affect innovation. An additional five pools in the 1930s included foreign companies from Germany, Denmark, Australia, Switzerland and the United Kingdom. They covered water conditioning apparatus (1930), television and radio apparatus (1933), electrical equipment (1934), lecithin (1934) and male hormones (1937). For three pools of domestic firms, we were unable to find court documents or written opinions: the 1932 Rail Springs pool, the 1935 Acrylic Acid for Laminated Glass (Plexigum) pool, and the 1938 Ophthalmic Frames pool, and the 1938 Pour Depressants pool. For the 1938 Induction Heat Treatments pool, we could not find a list of patents that were included in the pool. Another pool for Grinding Hobs (1931) combined two patents owned by the Barber-Colman Company.

[11] Lerner, Tirole and Strojwas (2007) also identify 13 pools formed in the 1930s that were scrutinized during Congressional hearings.

[12] At the San Francisco depository, additional records are available for the 1934 electrical equipment pool, which includes foreign as well as U.S. firms.

protect an electric circuit from shorts and overloads), and furniture slip covers (1938-49).

Three pools resolved litigation over blocking patents: wrinkle finishes, variable condensers, and slip covers. In the case of the pool for wrinkle finishes enamels, Kay & Ess and the Chadeloid Chemical Company formed the New Wrinkle company to settle litigation over 20 overlapping patents.[13] Similarly, the Radio Condenser Company, General Instrument Corporation, and Dejur-Amsco Corporation, resolved litigation by forming the Condenser Development Corporation in 1934.[14] In the case of the pool for slip covers, Sure-Fit and the Comfy Manufacturing Company, cross-licensed two patents in 1938 to end litigation that Sure-Fit had initiated against Comfy earlier that same year.[15]

Six pools combined two firms, variable condensers combined three and machine tools pool combined five. Taken together, the pools covered a total of 148 patents at their creation. Slip covers and Phillips screws combined 2 patents each while variable condensers combined 59 patents at formation (Table 1). We take advantage of such variation in the number of pool patents to measure the effects of pool creation on patents.[16]

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[13] *United States v. New Wrinkle, Inc.*, 342 U.S. 371 (1952). New Wrinkle was a patent holding company which administered, enforced and licensed its patents. Five other pools also established patent holding companies: Associated Patents (machine tools), Phillips Screw Company (Phillips screws), Roko Corporation (hydraulic oil pumps), Condenser Development Corporation (variable condensers), and New Wrinkle (wrinkle finishes).

[14] *United States v. General Instrument Corp. et al.* 115 F.Supp. 582 (D.N.J.,1953).

[15] *United States v. Krasnov*, 143 F. Supp. 184 (E.D. Penn., 1956).

[16] Six pools included grantback rules, which required members to offer all new patents to the pool. The predicted effects of grant back rules on innovation are ambiguous: they minimize hold-up problems, but may also reduce the expected private returns for pool members after the creation of the pool (Lerner and Tirole 2004). We plan to examine the effects of grantback rules in future work. In our data, seven pools added new patents while they were active, which are available in written opinions at the National Archives. For Hydraulic Oil Pumps, Machine Tools, and Variable

Seven pools were dissolved by regulators. The 1938 slip covers pool was dissolved independently of regulators in 1949 when one of the two founding members claimed the agreements was "induced by false and fraudulent misrepresentations" but the pool was found guilty of price fixing in 1956 (Table 2). The average pool was active for 16 years; life spans range from 10 years for dropout cutouts to 22 years for machine tools (Table 1).

Six "open" pools licensed voluntarily to non-members; 3 pools, Phillips screws, wrinkle finishes, and dropout cutouts, licensed voluntarily to 28, 200, and 10 firms respectively. Each of these pools was found guilty of price-fixing. For example, the price fixing agreements in a pool formed between two patentees of dropout cutouts in 1938 were held to be illegal ten years later in *United States v. Line Material Co.* 333 U.S. 287 (1948). One firm, Southern States Equipment, held a patent that blocked the patent assigned to Line Material Company. The two firms entered into an agreement whereby Line Material would be the exclusive licensor of Southern's patent and Line Material was free to fix prices for devices that embodied both patents.[17]

Pools for hydraulic oil pumps and machine tools operated like cross-licensing agreements, and did not grant licenses to outside firms; both were dissolved.[18] The hydraulic oil pumps pool had formed in 1933; its legal representative, the Roko Corporation, attempted to limit competition by acquiring

Condensers, we searched Google's website for USPTO patents that were assigned to pool members or the patent holding companies while the pool was active.

[17] *United States v. Line Material Co.* 333 U.S. 287 (1948).

[18] These arrangements resembled cross-licensing agreements in which companies grant each other licenses that resolve blocking patents without licensing to other firms (Shapiro 2001).

every important patent for oil pumps.[19] Similarly, the five members of the 1933 pool for machine tools divided their patents into fields of use and granted members exclusive rights to those fields.

U.S. Patents Grants, 1921-1965

We use changes in the number of U.S. patents across subclasses over time to measure changes in inventive activity across technologies within an industry that were more and less affected by the creation of a pool. Subclass fixed effects control for variation in patent intensity and in the share of innovations that are patented across subclasses. For example, some subclasses may include a disproportionate number of patents because they are especially hot areas of research activity, or inventors may be more likely to patent innovations in a specific subclass, if alternative mechanisms are ineffective (Moser 2011). To address these issues, we include subclass fixed effects so that we can compare changes in patenting in response to the creation of the pool, rather than levels of patenting. Patents are measured at the year of the patent grant (rather than the application).[20]

We take advantage of the two-level structure of the USPTO classification system to distinguish areas of innovation that were affected by the creation of a pool from other areas of innovation. Specifically, we construct the control group for areas that were affected by the pool from other subclasses within the same 3-

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[19] *Kobe, Inc. v. Dempsey Pump Co.*, 198 F.2d 416 (10th Cir. 1952).

[20] The lag between applications and grants has been shown to vary over time and across technologies, depending, among other factors, on the complexity of patent applications and the workload of examiners (Popp, Juhl, and Johnson 2004).

digit USPTO main class. For example, U.S. patent 1,908,080 for Philips screws is assigned to four subclasses (411/403, 411/919, 470/9 and 470/60) in two 3-digit USPTO classes (411 and 470).[21] We include only those subclasses that are listed under the same "mainline" subclass as pool subclasses in each 3-digit USPTO main class.[22] For example, subclass 411/403 is listed under "EXTERNALLY THREADED FASTENER ELEMENT, E.G., BOLT, SCREW, ETC." Thus the control group for the Philips screws pool will include all subclasses under this same heading (in this case subclasses 411/379 - 426).

II. Preliminary Results – Pooled Regressions

A. Changes in patenting before and after the creation of a pool

Difference-in-difference regressions across pools compare changes 10 years before and after the creation of a pool in the number of patents in subclasses that were more strongly affected by the pool (i.e. included a larger number of pool patents) with other subclasses in the same industry that were less affected. Specifically, we estimate

$$(1)\ patents_{ct} = \alpha + \beta_1\, Pool_t * Pool\ Patents_c + \beta_2\, Pool_t + f_c + \varepsilon_{ct}$$

where *pool patents*$_{ct}$ counts the number of patents per subclass and year; $pool_t$ equals 1 for the ten year period after the pool forms and f_c are subclass fixed-

[21] This patent is also assigned to one "digest" subclass: 16/DIG.39. Digests subclasses are for technologies based on "a concept which relates to a class but not to any particular subclass of that class" (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/c_index/explan.htm). We exclude digest subclasses from our regressions.

[22] The USPTO class schedule has a tree structure of "limbs" and "branches." Each mainline forms the main limb with the indented subclasses forming the branches of the limb. See: www.uspto.gov/patents/resources/classification/overview.pdf

effects.[23] The interaction term $pool_t$*$pool\ subclass_c$ measures the change in patenting in pool technologies in the first ten years of the pool relative to the ten years prior to the pool. Regressions are estimated as Poisson.[24]

A specification tests replaces the variable $pool\ patents_c$ with a binary variable for $pool\ subclass_c$, which equals 1 if subclass *c* included a pool patent when the pool formed:

$$(2)\ Patents_{ct} = \alpha + \beta_1\ Pool_t * Pool\ Subclass_c + \beta_2\ Pool_t + f_c + \varepsilon_{ct}$$

Poisson regression results indicate that each pool patent is associated with an 8 percent decline in patenting (significant at 1 percent, column 1, Table 3). The coefficient on *pool* indicates that patenting across all subclasses was 2 percent larger while the pool was active which is consistent with increased patenting over time (significant at 5 percent, column 1, Table 3). Subclasses with pool patents produced 14 percent fewer patents on average while the pool was active compared to the ten years preceding the pool (significant at 1 percent, column 2, Table 3).

B. Comparing pools that resolved litigation between members

[23] The number of patents in pool subclasses ranges from 1 to 20; the average per pool subclass is 1.6. *Pool* equals 1 in the years after pool formation and includes the year of dissolution.

[24] We prefer Poisson over negative binomial regressions because the Poisson are less sensitive to distributional misspecification (Cameron and Trivedi 1998; Wooldridge 2002). Maximum likelihood estimation of the Poisson model will be consistent for large-sample inference if the variance-mean ratio is any positive constant. Consistency does not depend on equality of the conditional variance and mean. We compute robust standard errors using Tim Simcoe's "xtpqml" command.

Pools that were formed in response to litigation between members may have encouraged innovation if they resolved blocking positions (Gilbert 2004).[25] To test for these differences we compare patenting across pools that resolved litigation (variable condensers, wrinkle finishes, and slip covers) with those that did not.

Regression results indicate that pools that resolved litigation were associated with *larger* declines in innovation. Each pool patent is associated with a 14 percent decline in patenting (significant at 1 percent, column 3, Table 3). The data also indicate that patenting was 25 percent lower in pool subclasses while pools that resolved litigation were active (significant at 1 percent, column 4, Table 3).

C. Comparing open pools with cross-licensing agreements

Pools that license to non-member firms may encourage innovation outside the pool by lowering litigation risks for non-members. Two pools in our sample did not license to outside firms; one pool, the wrinkle finishes pool, licensed to more than 200 firms. To test for differences between pools which licensed to outside firms (open pools) and pools that did not (closed pools), we estimate interactions between *pool*pool subclass* and a dummy variable *open* which equals 1 for pools that licensed to at least one non-member firm.

Poisson regression results indicate that openness to licensing is not significantly correlated with patenting (column 1, Table 4). Interactions with the

[25] Litigation is an imperfect indicator of blocking positions. The dropout cutouts pool was formed to resolve blocking positions (Gilbert 2004). However, the owners never instigated legal proceedings.

number of licensees, *licensees,* as well as the number of pool patents also indicate little correlation with licensing (columns 2-4, Table 4).

III. POOL-LEVEL REGRESSIONS

To account for unobservable differences across industries, we repeat our difference-in-differences test at the level of individual pools. These regressions indicate that three pools are associated with a decrease in patenting: rail joint bars, variable condensers, and wrinkle finishes. Each pool patent in rail joint bars, variable condensers, and wrinkle finishes pool subclasses is associated with a decline in patenting of between 5 and 14 percent (significant at 1 percent, Table 5). Patents per subclass are between 0.21 and 0.30 percent lower in these industries while a pool is active (significant at 5 percent Table 6).

The data also indicate that two pools are associated with increased patenting: Phillips screws, and slip covers. Patents per subclass are between 63 and 260 percent larger (significant at 5 percent, Table 6).[26]

B. Estimating annual coefficients for the pre-, pool, and post-period

One potential problem with the simple-difference-in-differences estimate is that they may be driven by differences in the time trends of patenting that precede the creation of the pool. For example, increased patenting in Phillips screws and decreased patenting in rail joint bars, wrinkle finishes, and variable condensers may reflect pre-existing differences in patenting, rather than a causal effect of the

[26] The maximum number of pool patents per subclass for Phillips screws and slip covers is 1 so results do not change between Tables 5 and 6.

pool. In particular, pools may form around newer technologies that have not yet matured. To identify the existence of pre-existing trends we estimate time-specific changes in patenting β_t:

(3) $Patents_{ct} = \alpha + \beta_t\ Pool\ Patents_c + \delta_t + f_c$

where β_t measures the annual change in patenting between pool subclasses and other subclasses in the same mainline class, δ_t are annual fixed effects and f_c are subclass fixed effects. Standard errors are clustered at the subclass level.

Least squares regressions indicate that the positive effect of the Phillips screw pool can be explained by a pre-existing upward trend which begins to decline during the middle of the pool in 1942 (Figure 1). The data also indicate that lower patenting while the variable condensers pool was active can be explained by a continuation of lower patents per year prior to the formation of the pool (Figure 2).

However, the data indicate that the formation of the rail joint bars and wrinkle finishes pool is associated with a decline in patenting that cannot be explained by pre-existing trends. Annual coefficients peak at 3.4 additional patents in the year the rail joint bars pool formed (1931) and begin to decline afterwards (Figure 3). Similarly, annual coefficients peak at 4.2 additional patents in the year the wrinkle finishes pool formed and began to decline thereafter (Figure 4). Annual effects for the hydraulic oil pumps, machine tools, dropout cutouts, and slip covers pools suggest had little impact of pools on innovation

(Figure 5).

This estimation strategy also allows us to examine changes in patenting that occurred after regulators dissolved the pools. Comparisons of changes in patenting after the pools dissolved, however, reveal no statistically significant effects.

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TABLE 1: PATENT POOLS, 1931-38

Industry	Years	# Members at formation	# Patents at formation	# Patents at dissolution	# Licensees	Resolved litigation about blocking patents
Rail Joint Bars	1931-44	2	31	38	9	No
Hydraulic Oil Pumps	1933-52	2	28	41	0	No
Machine Tools	1933-55	5	3	9	0	No
Phillips Screws	1933-49	2	2	20	28	No
Variable Condensers	1934-53	3	59	72	3	Yes
Wrinkle Finishes	1937-55	2	20	68	>200	Yes
Dropout Cutouts	1938-48	2	3	3	10	No
Slip Covers	1938-49	2	2	2	2	Yes

Notes: Data from license agreements and court opinions are available at the regional depositories of the National Archives in Chicago (machine tools, Phillips screws, wrinkle finishes, and dropout cuts) and New York (variable condensers). Additional information on pool patents, member firms and licensees from *LexisNexis* (rail joint bars, hydraulic oil pumps, and slip covers).

TABLE 2: ANTITRUST VIOLATIONS

Industry	Anticompetitive Practices	Remedies	Decision
Rail Joint Bars	Fixed the price of reformed rail joint bars	Pool dissolved. Patents dedicated to public	United States v. Rail Joint Co., 1944 Trade Cas. (C.C.H.) ¶57,287 (N.D. Ill.)
Hydraulic Oil Pumps	Acquired patents related to hydraulic oil pumps and denied licenses to competitors	Damages to competing firm	Kobe, Inc. v. Dempsey Pump Co., 198 F.2d 416 (10th Cir. 1952)
Machine Tools	Divided pool patents into fields of use and granted exclusive rights to fields to pool members. Denied licensed to outside firms	Pool dissolved	United States v. Associated Patents, 134 F. Supp. 74 (E.D. Mich., 1955)
Phillips Screws	Fixed price of Phillips screws and drivers. Prevented licensees from producing competing screws	License agreements terminated. Non-exclusive licenses for "reasonable" royalties	United States v. Phillips Screw Co., 1949 Trade Cas. (C.C.H.) ¶62,394 (N.D. Ill.)
Variable Condensers	Fixed prices for radio tuning devices. Refused to license. Jointly sued infringers	Dissolved. Patents dedicated to the public. Members prevented from acquiring assets of competitors	United States v. Gen. Instrument Corp., 115 F. Supp. 582 (D.N.J., 1953)
Wrinkle Finishes	Fixed price of wrinkle finishes	Pool dissolved	United States v. New Wrinkle, Inc., 1955 Trade Cases (C.C.H.)¶ 68,203 (S.D. Ohio)
Dropout Cutouts	Fixed price and threatened infringement suits against other manufacturers	Price-fixing ruled illegal	United States v. Line Material Co., 333 U. S. 287 (1948)
Slip Covers	Fixed prices. Jointly sued infringers	Agreements dissolved prior to suit	United States v. Krasnov, 143 F. Supp. 184 (E.D. Penn., 1956)

TABLE 3: POISSON REGRESSIONS WITH SUBCLASS FIXED EFFECTS – DEPENDENT VARIABLE IS PATENTS PER SUBCLASS

	All Pools (1)-(2)		Resolved Litigation (3)-(4)		Did Not Resolve Litigation (5)-(6)	
	(1)	(2)	(3)	(4)	(5)	(6)
Pool * Pool Patents	-0.08**		-0.15**		-0.03**	
	(0.03)		(0.03)		(0.01)	
Pool * Pool Subclass		-0.15**		-0.29**		-0.01
		(0.04)		(0.07)		(0.05)
Pool	0.02*	0.02*	0.04**	0.04**	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Pools	8	8	3	3	5	5
Pool Subclasses	213	213	213	213	213	213
Observations	21,544	21,544	10,262	10,262	11,268	11,268

Notes: Poisson regressions with fixed-effects for subclass. The dependent variable is the total number of patent grants ten years before and after a pool formed. The variable *pool* equals 1 for the first ten years after the formation of the pool; it measures the change in patenting after the pool was formed relative to the last ten years before the pool was formed. The variable *pool patents* counts the number of pool patents per subclass included in the pool when it formed. The variable *pool subclass* distinguishes subclasses that include at least one patent that was included in the pool when it formed. Columns (3)-(4) include variable condensers pool (1934), wrinkle finishes pool (1937), and slip covers pool (1938). Columns (5)-(6) include rail joint bars pool (1931), hydraulic oil pumps pool (1933), machine tools pool (1933), Phillips screws pool (1933), and dropout cutouts pool (1938). The control group includes all subclasses within the same three-digit USPTO class that share a common mainline subclass with a pool patent. Robust standard errors. ** significant at 1 percent, * significant at 5 percent.

Table 4: Poisson Regressions with Subclass Fixed Effects – Dependent Variable is Patents per Subclass

	(1)	(2)	(3)	(4)
Pool * Pool Patents	-0.02	-0.07*		
	(0.03)	(0.03)		
Pool * Pool Patents * Open	-0.07			
	(0.04)			
Pool * Pool Patents * Licensees		-0.03^{-2}		
		(0.00)		
Pool * Pool Subclass			-0.02	-0.10
			(0.06)	(0.05)
Pool * Pool Subclass * Open			-0.19*	
			(0.08)	
Pool * Pool Subclass * Licensees				-0.01^{-1}**
				(0.00)
Pool	0.02	-0.04**	0.02	-0.05**
	(0.01)	(0.01)	(0.01)	(0.01)
Pool Subclasses	214	214	214	214
Observations	21,544	21,544	21,544	21,544

Notes: Poisson regressions with fixed-effects for subclass. The dependent variable is the total number of patent grants ten years before and after a pool formed. The variable *pool* equals 1 for the first ten years after the formation of the pool; it measures the change in patenting after the pool was formed relative to the last ten years before the pool was formed. The variable *pool patents* counts the number of pool patents per subclass included in the pool when it formed. The variable *pool subclass* distinguishes subclasses that include at least one patent that was included in the pool when it formed. The variable *open* equals 1 for subclasses in an industry with a pool that licensed to non-member firms. The variable *licensees* counts the number of licensees in an industry with a pool. Columns (2) and (5) include control for *pool*open.* Columns (3) and (6) include control for *pool*licensees.* The control group includes all subclasses within the same three-digit USPTO class that share a common mainline subclass with a pool patent. Robust standard errors. ** significant at 1 percent, * significant at 5 percent.

TABLE 5: POISSON REGRESSIONS – INTENSITY, CONTROLLING FOR THE NUMBER OF POOL PATENTS – DEPENDENT VARIABLE IS PATENTS PER SUBCLASS

	Rail Joint Bars	Hydraulic Oil Pumps	Machine Tools	Phillips Screws	Variable Condensers	Wrinkle Finishes	Dropout Cutouts	Slip Covers
Pool * Pool Patents	-0.05**	-0.03	0.21	1.30**	-0.15**	-0.14**	-0.12	0.49*
	(0.00)	(0.03)	(0.19)	(0.24)	(0.03)	(0.03)	(0.20)	(0.24)
Pool	0.19**	0.01	0.04	-0.63**	-0.15**	0.23**	-0.05	-0.66**
	(0.02)	(0.01)	(0.04)	(0.06)	(0.02)	(0.02)	(0.03)	(0.24)
Year Formed	1931	1933	1933	1933	1934	1937	1938	1938
Patents at Formation	35	28	3	2	59	25	3	2
Pool Subclasses	20	75	7	5	52	45	8	2
Observations	2,284	6,368	918	720	4,136	6,092	972	34

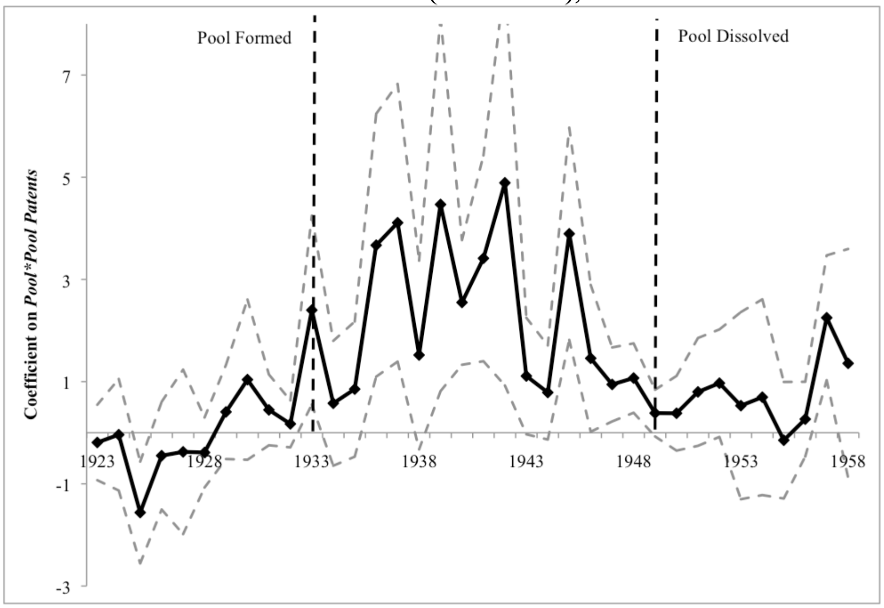
Notes: Poisson regressions with fixed-effects for subclass. The dependent variable is the total number of patent grants either ten years before or ten years after a pool formed. The variable *Pool* equals 1 for the first ten years after the formation of the pool; it measures the change in patenting after the pool was formed relative to the last ten years before the pool was formed. The variable *pool patents* counts the number of pool patents per subclass included in the pool when it formed. The control group includes all subclasses within the same three-digit USPTO class that share a common mainline subclass with a pool patent. Robust standard errors. ** significant at 1 percent, * significant at 5 percent.

TABLE 6: POISSON REGRESSIONS WITH SUBCLASS FIXED EFFECTS– DEPENDENT VARIABLE IS PATENTS PER SUBCLASS

	Rail Joint Bars	Hydraulic Oil Pumps	Machine Tools	Phillips Screws	Variable Condensers	Wrinkle Finishes	Dropout Cutouts	Slip Covers
Pool * Pool Subclass	-0.32*	-0.05	0.21	1.30**	-0.23*	-0.35**	-0.12	0.49*
	(0.14)	(0.06)	(0.19)	(0.24)	(0.11)	(0.07)	(0.20)	(0.24)
Pool	0.19**	0.01	0.04	-0.63**	-0.16**	0.23**	-0.05	-0.66**
	(0.02)	(0.01)	(0.04)	(0.06)	(0.02)	(0.02)	(0.03)	(0.24)
Year Formed	1931	1933	1933	1933	1934	1937	1938	1938
Patents at Formation	31	28	3	2	59	20	3	2
Pool Subclasses	20	75	7	5	52	45	8	2
Observations (Patents)	2,284	6,368	918	720	4,136	6,092	972	34

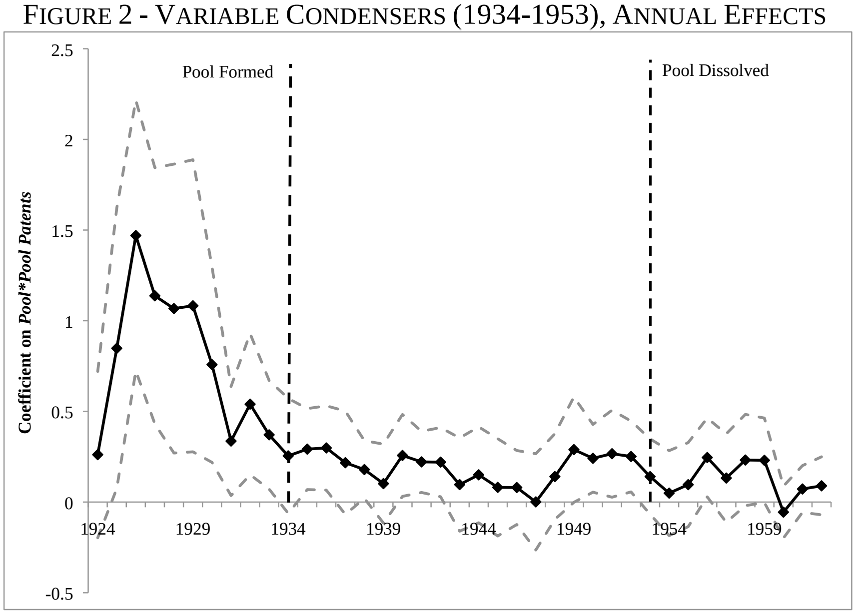
Notes: Poisson regressions with fixed-effects for subclass. The dependent variable is the total number of patent grants either ten years before or ten years after a pool formed. The variable *Pool* equals 1 for the first ten years after the formation of the pool; it measures the change in patenting after the pool was formed relative to the last ten years before the pool was formed. The variable *pool subclass* distinguishes subclasses that include at least one patent that was included in the pool when it formed. The control group includes all subclasses within the same three-digit USPTO class that share a common mainline subclass with a pool patent. Robust standard errors. ** significant at 1 percent, * significant at 5 percent.

FIGURE 1 - PHILLIPS SCREWS (1933-1949), ANNUAL EFFECTS



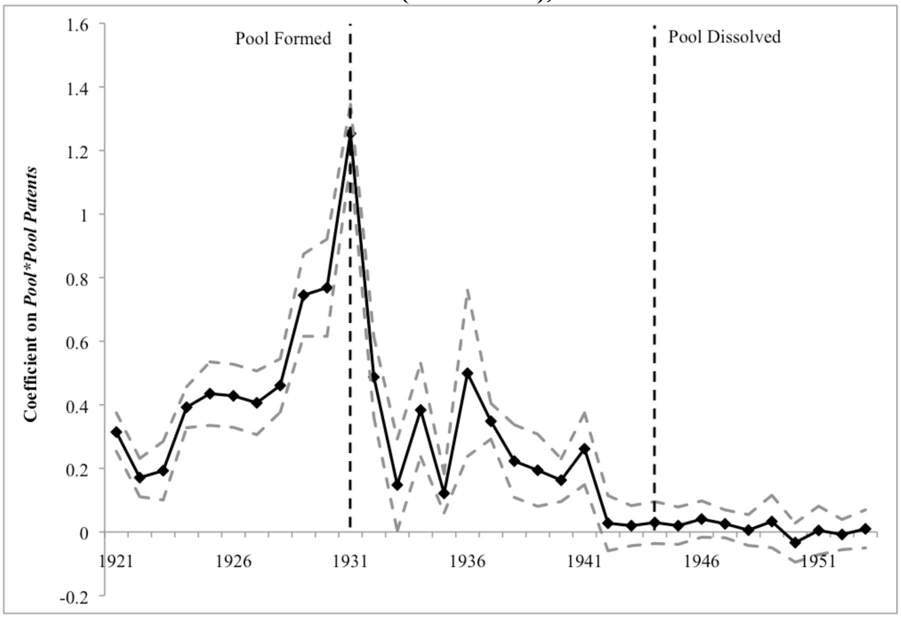
Notes: Estimates of β_t in the OLS regression $Patents_{ct} = \alpha + \beta_t\, Pool\ Patents_c + \delta_t + f_c$, where the dependent variable counts patents in subclass c and year t; δ_t are year fixed-effects and f_c are subclass fixed-effects. *Pool Patents* measures the number of patents in subclass *c* that were included in the pool when it formed. The Phillips Screws pool formed in 1933 when Henry Phillips and the American Screw Company agreed to pool their patents on screws and screw drivers. *Phillips Screws* licensed to 28 firms; it was found guilty of price fixing in 1949 and non-exclusive licenses were ordered on a reasonable royalty basis. Data from court dockets of *United States v. Phillips Screw Co.*, 1949 Trade Cas. (C.C.H.) ¶62,394 (N.D. Ill.) available at the National Archives.

FIGURE 2 - VARIABLE CONDENSERS (1934-1953), ANNUAL EFFECTS



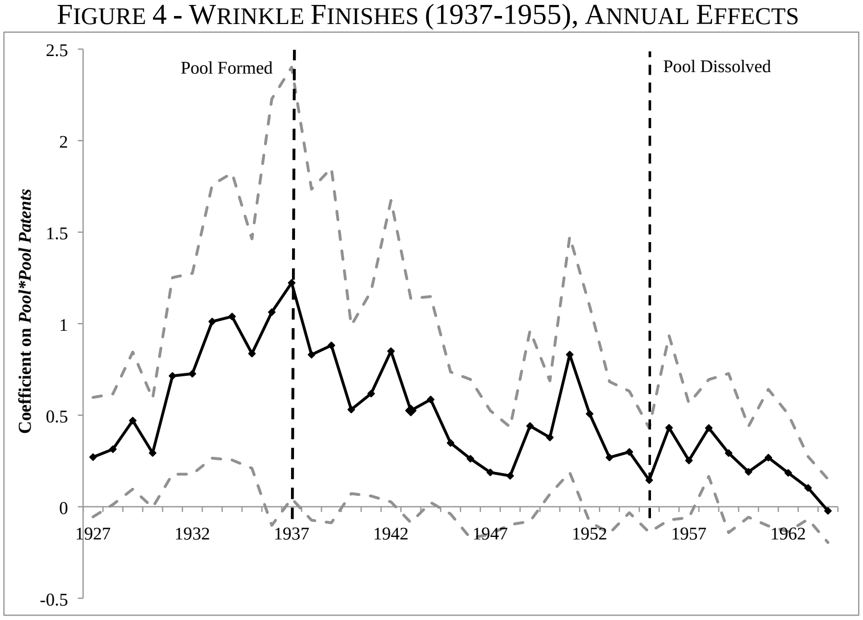
Notes: Estimates of β_t in the OLS regression $Patents_{ct} = \alpha + \beta_t\, Pool\ Patents_c + \delta_t + f_c$, where the dependent variable counts patents in subclass c and year t; δ_t are year fixed-effects and f_c are subclass fixed-effects. *Pool Patents* measures the number of patents in subclass *c* that were included in the pool when it formed. The Variable Condensers pool formed in 1934 when the Radio Condenser Company, General Instrument Corporation, and Dejur-Amsco Corporation agreed to resolve cross-litigation and pool their patents on variable condensers used to receive radio signals. *Variable Condensers* did not license to outside firms licensed to 3 firms; it was found guilty of price fixing and refusing to license in 1953, and its patents were dedicated to the public. Data from court dockets of *United States v. Gen. Instrument Corp.*, 115 F. Supp. 582 (D.N.J., 1953) available at the National Archives.

FIGURE 3 - RAIL JOINT BARS (1931-1944), ANNUAL COEFFICIENTS



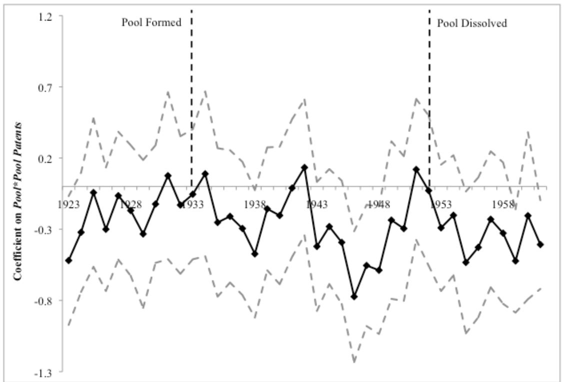
Notes: Estimates of β_t in the OLS regression $Patents_{ct} = \alpha + \beta_t \, Pool\ Patents_c + \delta_t + f_c$, where the dependent variable counts patents in subclass c and year t; δ_t are year fixed-effects and f_c are subclass fixed-effects. *Pool Patents* measures the number of patents in subclass *c* that were included in the pool when it formed. The Rail Joint bars pool formed in 1931 when the McKenna Process Company and the Rail Joint Company combined their patents on a process to shape rail joint bars used to prevent movement in rails. *Rail Joint Bars* licensed to nine firms; it was found guilty of price fixing in 1944 and its patents were dedicated to the public. Data from court decision of *United States v. Rail Joint Co.,* 1944 Trade Cas. (C.C.H.) ¶57,287 (N.D. Ill).

FIGURE 4 - WRINKLE FINISHES (1937-1955), ANNUAL EFFECTS

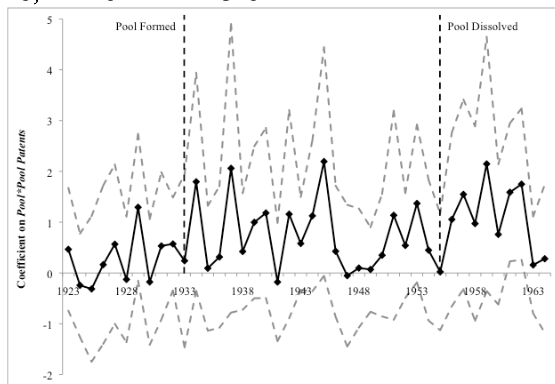


Notes: Estimates of β_t in the OLS regression $Patents_{ct} = \alpha + \beta_t \, Pool\ Patents_c + \delta_t + f_c$, where the dependent variable counts patents in subclass c and year t; δ_t are year fixed-effects and f_c are subclass fixed-effects. *Pool Patents* measures the number of patents in subclass *c* that were included in the pool when it formed. The Wrinkle Finishes pool formed in 1937 when the Kay & Ess Company and Chadeloid Chemical Company agreed to resolve litigation by pooling their patents on wrinkle finishes. *Wrinkle Finishes* licensed to more than 200 firms; it was found guilty of price fixing in 1952. Data from court dockets of *United States v. New Wrinkle, Inc.,* 1955 Trade Cases (C.C.H.)¶ 68,203 (S.D. Ohio).

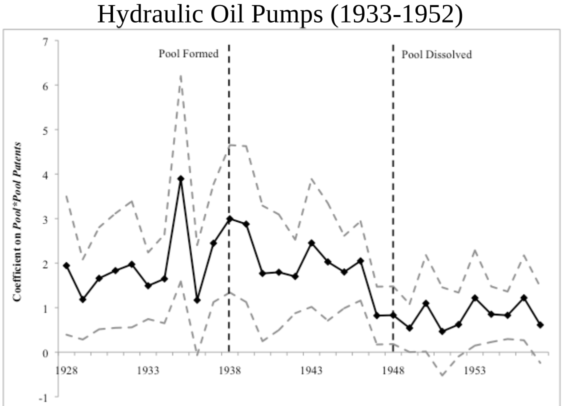
FIGURE 5 - FOUR POOLS, ANNUAL EFFECTS



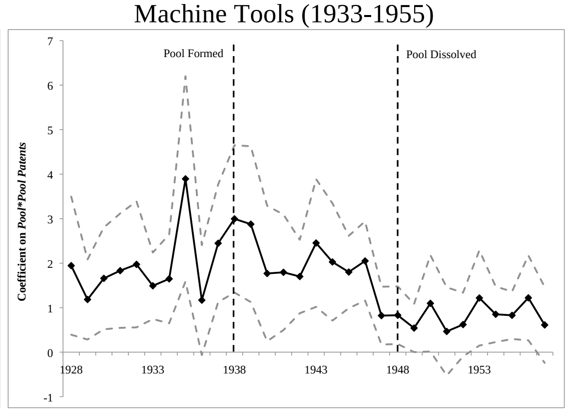
Hydraulic Oil Pumps (1933-1952)



Machine Tools (1933-1955)



Dropout Cutouts (1938-1948)



Slip Covers (1938-1949)

Notes: Estimates of β_t in the OLS regression $Patents_{ct} = \alpha + \beta_t\, Pool\ Patents_c + \delta_t + f_c$, where the dependent variable counts patents in subclass c and year t; δ_t are year fixed-effects and f_c are subclass fixed-effects. *Pool Patents* measures the number of patents in subclass *c* that were included in the pool when it formed. The Hydraulic Oil Pumps pool formed in 1933 when the Rodless Pump Company and Old Kobe pooled their patents on hydraulic oil pumps. *Hydraulic Oil Pumps* did not license; it was found guilty of monopolization and denying licenses to competitors in 1952. Data from opinion of *Kobe, Inc. v. Dempsey Pump Co.,* 198 F.2d 416 (10th Cir. 1952). The Machine Tools pool was formed in 1933 when the Lodge and Shipley Machine Tool Company, the Brown & Sharpe Manufacturing Company, the Lucas Machine Tool Company, the Carlton Machine Tool Company Lundberg and Charles B. DeVlieg agreed to pool patents on machine tools used to cut or shape metal. *Machine Tools* did not license; it was found guilty of dividing patents into fields of use and granting exclusive rights to fields to pool members in 1955. Data from court documents of *United States v. Associated Patents,* 134 F. Supp. 74 (E.D. Mich., 1955) available at the National Archives. The Dropout Cutouts pool was formed in 1938 when Line Material Company and Southern States Equipment Corporation pooled their patents on dropout cutouts used to protect electrical circuits from overloading. *Dropout Cutouts* licensed to 10 firms; it was found guilty of price fixing in 1948. Data from court documents of *United States v. Line Material Co.,* 333 U. S. 287 (1948) available at the National Archives. The Slip Covers pool was formed in 1938 when Sure-Fit and the Comfy Manufacturing Company pooled their patents on ready-made furniture slip covers to resolve a patent infringement suit. *Slip Covers* licensed to two firms; it was found guilty of price fixing in 1956, though the pool has dissolved independently in 1949. Data from court opinion of *United States v. Krasnov*, 143 F. Supp. 184 (E.D. Penn., 1956).