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Competitive Effects of Modern Patent Pools: The Effect of the MPEG-2 Pool on Incumbents? Innovative Performance

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Competitive Effects of Modern Patent Pools:

The Effect of the MPEG-2 Pool on Incumbents' Innovative Performance[1]

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Abstract

Patent pools have been proposed and used as one of the major means to overcome technological holdups. Yet, despite their widespread use and significant economic importance, we know little about their competitive effects. While prevailing theories generally predict that modern pools would boost firms' innovative performance, recent empirical works have raised some serious implications about the intricacies of patent tools at the micro level. In order to reconcile seemingly inconsistent predictions and findings, I first develop a theoretical framework that captures the major mechanisms through which patent pools may affect the innovative performance of firms in their technological proximity. Furthermore, I empirically investigate the effect of the MPEG-2 pool on the innovative performance of technologically proximate incumbents using difference-in-difference methodology. Each mechanism is separately analyzed. The results show that MPEG-2 pool formation had a substantial negative impact on proximate incumbents' innovation rate. The results also suggest that the innovation rate decline can be explained by a strategic shift in firms' R&D direction from further technological inventions to implementing the pool technology in current and new products. Increased litigation risk and increased competition intensity after pool formation are unable to explain the effect.

[1] *I am grateful to Anita McGahan, Ajay Agrawal, Sarah Kaplan, and Anne Fleischer for their great advice and feedback. Also, I would like to thank the seminar participants at the CCC 2012 (Maryland) and Rotman PhD Student Seminar for helpful comments and suggestions.*

1. Introduction

A patent pool is an agreement between two or more parties to license their patents on a particular technology to each other and third parties. Patent pools have been proposed and increasingly used as one of the major means to overcome technological holdups created as a result of overlapping property rights. Yet, despite their increasing prevalence in almost all the advanced fields of technology and their significant economic importance, we know little about their competitive effects; in particular, their effects on the performance and strategies of firms outside the pool. In this study, I address this gap by investigating the competitive effects of the MPEG2 pool as the first instance of modern pools in history.

Studying the competitive effects of patent pools is particularly interesting for two reasons. First, from a theoretical point of view, while both arm's length and fully integrated relationships have been studied extensively in the strategy and economics literatures, hybrid organizations such as patent pools have been much less investigated. Studying patent pools can provide valuable insight into the competitive effects of these arrangements and similar hybrid organizations such as standard setting organizations and R&D consortia. More importantly, the majority of prior studies on patent pools and similar cooperative arrangements have focused either on their total welfare effect (ex: Gilbert, 2004; Lerner, Strojwas, & Tirole, 2007; Lerner & Tirole, 2004; Shapiro, 2001), their design (ex: Layne-Farrar & Lerner, 2011; Chiao, Lerner, & Tirole, 2007; Lerner et al., 2007; Lerner & Tirole, 2004; Simcoe, 2012), or their constituting members or components (Rysman & Simcoe, 2008; Delcamp, 2011). Yet, we know little about their broader competitive impact: How do they affect other firms' performance in the market? And if they have any impact, how do the affected firms respond strategically to the formation of these arrangements?

Second, the exponential increase in patent awards in the past two decades combined with the ambiguity in the scope of patented inventions and the growing global technology races have led to fragmented technology fields with numerous firms claiming overlapping property rights (Heller & Eisenberg, 1998; Ziedonis, 2004; Parchomovsky & Wagner, 2004; Bessen & Hunt, 2007). Several studies have documented how such overlapping rights may lead to detrimental technological holdups in such fragmented areas. Patent pools have been proposed and accordingly used as a means to eliminate these technological holdups (Carlson, 1999; Merges, 1999; Shapiro, 2001). Indeed, since the formation of the first modern pool, MPEG-2 pool, in 1997, patent pools have been constantly increasing in terms of number, economic significance, and the extent of the technological fields in which they are implemented (World Intellectual Property Report, 2011). A recent estimation (Clarkson, 2003) shows that in 2001, the total sales of devices that have been fully or partially based on pooled technologies were above $100 billion. The numbers have been increasing ever since (Figure 1).

Insert Figure 1 about here

Considering the theoretical and practical importance of these institutions, in this paper, I take one step towards better understanding their competitive effects by investigating the effect of the MPEG-2 pool on the innovative performance of technologically proximate incumbents. Formation of the MPEG-2 pool marked the first instance of modern pools in the history of patent pools. Furthermore, following the Department of Justice's recommendation, its structure soon became the template for all the modern pools formed subsequently. This makes the MPEG-2 pool a perfect benchmark for studying the competitive effects of modern pools. Moreover, there is copious anecdotal evidence documenting the considerable impact of this pool on technologically proximate firms in a broad range of industries from software to semiconductors to news and broadcasting services. This further enables me to have an in depth analysis of several potential mechanisms through which modern pools may impact other firms across several industries and markets.

Building on the previous literature, I first develop a theoretical framework to highlight the potential mechanisms through which patent pools may positively or negatively affect the innovative performance of incumbents in close technological proximity. Nevertheless, because of the opposing effects of these mechanisms, it is hard to predict the net impact. Subsequently, in the empirical section of the paper, I first estimate the net effect of the formation of the MPEG-2 pool on the innovative performance of the proximate incumbents using a "difference-in-difference with matching" methodology. Several control groups and robustness tests are used to address the identification challenges in order to establish a causal relationship. Next, using multiple empirical strategies and sources of complementary data, I test each of the potential mechanisms identified in the theoretical framework separately.

The results show that when measured as the writhed patenting rate, the innovation rate of technologically proximate firms drop substantially as a result of the formation of the MPEG-2 pool. The estimation results suggest that the average weighted patenting rate of these firms dropped by more than 35% after the formation of the MPEG-2 pool relative to a matched control sample of firms. However, analyzing the potential driving mechanisms, I find that the decline in the firms' weighted patenting rate can be explained by a change in the direction of firms' R&D investment from further technological inventions to implementing the pool technology in their current and future products. I also find that increased litigation risk and increased competition intensity after pool formation are unable to explain the effect.

At the broad level, the results illustrate how patent pools (and similar organizations) can change their surrounding technology market through changing firms' R&D and product strategies. These changes not only can introduce fundamental structural shifts in a broad range of industries, but can also affect the technological trajectories of pooled technologies in the long term. Furthermore, this study contributes to the growing literature on the effect of institutional innovations on the follow-on innovation (Furman et al., 2005; Furman & Stern, 2011; Murray & Stern, 2007).

2. Competitive Effects of Modern Patent Pools: A Theoretical Framework

When multiple parties hold rights to different pieces of one particular technology, no single party can use that technology unless it acquires licenses from all the other ones. Several theoretical and empirical works suggest that this situation can lead to technological holdup due to high litigation risks, excessive royalty rates, and soaring transaction costs associated with cross-licensing negotiations (Heller & Eisenberg, 1998; Merges, 1994; Shapiro, 2001). One solution to this problem is to put all those patents into a common pool and consolidate all the associated rights into a central entity (pool organizer) for the purpose of joint licensing (Merges, 1999; Shapiro, 2001). Patent pools are thus private arrangements between multiple parties to license their interdependent patents to each other and to third parties usually based on some fixed terms.

Patent pools have a very long history in US history dating back to the formation of the Sewing Machine Combination in 1856. At the same time, however, these arrangements have raised serious antitrust concerns throughout history (Carlson, 1999; Gilbert, 2004). With stronger enforcement of antitrust laws in the early 20th century, traditional pools were increasingly recognized as anticompetitive arrangements and many of them were eventually dismantled by antitrust authorities (Gilbert, 2004). With a few exceptions, almost no major pool arrangements were established since the end of World War II until the introduction of the MPEG-2 pool, the first instance of modern pools, in 1997. Because of the serious concerns regarding the antitrust aspects of traditional pools (pools formed before 1997), most of the literature on modern pools has focused on their total welfare effect and antitrust aspects. The general prediction is that modern pools should be welfare enhancing based on the premise that they solely include essential and complementary patents, unlike their traditional counterparts (Shapiro, 2001; Gilbert, 2004; Lerner & Tirole, 2004).

More recently, however, scholars have started to empirically explore the firm-level performance implications of these arrangements (ex: Lampe & Moser, 2010; Joshi & Nerkar, 2011). The findings have raised some serious implications about the intricacies of patent tools at the micro level. For example, while the mainstream theories on modern pools suggest a positive impact on both members' and nonmembers' innovation rate due to lower costs of access to the pool technology, Lampe and Moser (2010) find a significant decline in the innovation rate of both groups in the sewing machine industry after the formation of the Sewing Machine Combination. While their focus is on a traditional pool, the mechanisms which they propose to explain the effect is hypothetically generalizable to all patent pools. Similarly, studying three modern pools in the optical disk industry, Joshi and Nerkar (2011) find a decline in patenting rate of both licensors (i.e. pool members) and licensees after the formation of each pool. They also propose a number of mechanisms that can potentially explain the controversial findings, yet do not directly test any of them.

In order to reconcile the seemingly inconsistent theoretical predictions and empirical findings, in this section, I develop a theoretical framework that highlights the major mechanisms through which modern pools may positively or negatively impact the innovative performance of incumbents in their technological proximity. Such a framework not only illustrates a more nuanced picture of the performance implications of patent pools, but also provides a basis to empirically test the presence and effect of each mechanism separately.

Lower cost of access to the technology and incumbency advantage: Theoretical models of patent pools predict that modern pools can potentially eliminate technological holdups and encourage innovation by lowering the negotiation, searching, and litigation costs associated with using the pool technology (Carlson, 1999; Merges, 1999; Shapiro, 2001; Lerner & Tirole, 2004). According to Antitrust Guidelines for the Licensing of Intellectual Property, patent pools "may provide competitive benefits by integrating complementary technologies, reducing transaction costs, clearing blocking positions, and avoiding costly infringement litigation". To the extent that patent pools successfully achieve this goal, they can open up a window of opportunity for further technological developments based on the pool technology. As an example, the formation of the MPEG-2 pool led to the introduction of a whole range of new technologies such as DVD technology, online video streaming, and digital video broadcasting (DVB). At the same time, the advantage of possessing a related established technological asset suggests that incumbents in technological proximity of the pool would be among the first to capitalize on their financial and technological assets to seize this unblocked opportunity, hence, experiencing a boost in their innovative and financial performance.

Increased Competition: Patent pools can increase the competition intensity for technologically proximate incumbents in two ways. First, to the extent that patent pools improve the financial performance of pool members by reducing their litigation costs and boosting their licensing revenue, pool members would become stronger rivals for other incumbents working on similar or close technologies. Second, lowering the cost of access to the pool technology, patent pools may bring down the barriers to entry into the pool technological area, thus increasing the rivalry by inviting a host of new entrants.

The increased competition can further lead to a decline in incumbents' innovative performance through two different channels. First, increased competition may diminish their profit margin leading to lower R&D investments and thus innovation rates. Second, while the increased number of entrants may increase the total number of technological innovations based on the pool technology, at the same time it may "fish out" the technological opportunity pool, making it more challenging for each single firm to innovate and thrive (Furman et al., 2005). Despite the differences in their underlying logic, both mechanisms predict that increased competition would shrink the incumbents' profit margin and depress their innovative performance.

Increased Litigation Risk: While one of the main intentions behind the formation of patent pools is to bring down the litigation risk for both members and nonmembers, in reality, patent pools may indeed increase the litigation risk for nonmembers. It is well known that firms with larger patent portfolios have higher chance of winning infringement lawsuits in court. In fact, patent proliferation with the intention of enlarging the patent portfolio is one of the main strategies used by firms in fragmented fields such as software and semiconductors to protect their technological inventions (Ziedonis, 2004; Bessen & Hunt, 2007). Once a patent pool is formed, pool members can act as a single party with a much bigger portfolio to enforce their property rights (Lampe and Moser, 2010). As a result, because of the inherent vagueness of the scope of patented inventions (Shapiro, 2001; Parchomovsky & Wagner, 2004), pool members can potentially use their enhanced enforcement power to threat any firm planning to develop a potentially competing technology for the pool technology. Lampe and Moser (2010) in their analysis of the Sewing Machine Combination, find some evidence for an increase in the litigation cases with nonmembers as defendants after the formation of the pool. Furthermore, Simcoe, Graham and Feldman (2009) show that firms, particularly small firms, are more likely to file litigation lawsuits to enforce their rights once they disclose their patents to Standard Setting Organizations (SSO). Considering that many of the current technology standards, including MPEG-2, are in fact developed in these SSOs, their findings suggest that patent pools may indeed discourage other firms from further technological development in technological proximity of the pool due to increased litigation risk. Considering that firms cannot easily change their technological capabilities in the short term, those with established technological assets in proximity of the pool area may thus hold back or redirect their R&D investments to avoid any costly infringement lawsuits. This can not only lead to a decline in their innovation rate, but potentially in their financial performance.

Shift in R&D Investment Direction: The MPEG-2 pool and majority of other modern pools have been formed around some sort of technology standard, in most cases emerged from a standard setting organization. Modern pools can thus be considered as promoters of their respective standards. Several works on standards and general purpose technologies have pointed out how the establishment of a new technological standard can lead to a shift in firms' strategy from further technological exploration towards technological exploitation; implementing the standard in new products and market (David & Greenstein, 1990; Besen & Farrell, 1994; Tassey, 2004; Gambardella & McGahan, 2010). The shift can be further reinforced in the presence of network externalities and growing demand for the new technology in the product market (Katz & Shapiro, 1986). The introduction of the MPEG-2 technology was concurrent with a huge growth in the use of digital media. MPEG-2 standard proved to be a reliable and efficient standard for compressing and transferring digital video and audio. With a sudden decline in the cost of access to this technology due to the formation of the MPEG-2 pool, incumbents with established related technological assets were likely to shift their R&D strategy from further technological exploration to respond to growing demand for products featuring digital media. Such a change in firms' strategy would be rendered in lower technological inventions vis-à-vis a higher rate of new product developments and renovations to implement the pool technology.

As such, while the first mechanism predicts a positive impact on focal incumbents' innovative performance, the other three mechanisms predict a negative impact. As a result, it is hard to predict a positive or negative net effect. However, because of the unique features and side effects of each mechanism, it is possible to test their presence and effect separately.

While increased competition and increased litigation risk predict a clear depressing impact on the incumbents' financial performance, the incumbency advantage predicts a clear positive effect. The effect of the strategic shift to MPEG-2 implementation is less clear. It may have a positive impact if incumbents gain any first mover advantage by such a shift. However, this positive impact can be counteracted with the negative effects associated with redirecting firms' strategic direction and intensified competition in the new market. Furthermore, while increased litigation is expected to have a differential effect on pool licensees and non-licensees since the former face minimal litigation risk, other mechanisms are expected to have similar impact on both groups. Finally considering the importance of the MPEG-2 technology in the industries of interest at the time of the formation of the pool, I expect to see manifestations of any strategic shift towards implementing this technology in the strategic annual reports of the focal incumbents. Table 1 summarizes the main and side effects associated with each mechanism.

Insert Table 1 about here

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3. Institutional Background: MPEG-2 Patent Pool

On June 26th, 1997, the Department of Justice sent an approval letter to MPEG Licensing Agreement (MPEG LA) in connection with their request to pool the patents “essential” to comply with the MPEG-2 standard. MPEG-2 is an international standard developed by Moving Picture Expert Group through the 90s and defined as “the generic coding of moving pictures and associated audio information” (ISO/IEC 13818 MPEG2). The standard contains different coding algorithms to compress and transfer digitalized video and audio signals. The MPEG-2 pool initially contained 27 patents from 9 different entities (8 corporations and Columbia University) The formation of the MPEG-2 pool thus marked the first instance of modern patent pools in history and soon became the template for all pools formed afterwards (Gilbert, 2004).

The approval letter from Department of Justice emphasizes that the portfolio combines only patents that are complementary and essential[2]. According to the MPEG-2 Patent Portfolio License, an essential patent is “any patent claiming an apparatus and/or method necessary for compliance with the MPEG-2 Standard under the laws of the country which issued or published the Patent”. The letter also highlights that there is no technical substitute for any of the portfolio patents. Furthermore, the pool agreement guarantees a non-discriminatory, non-exclusive international license with same terms and conditions to all would-be licensees.

The MPEG-2 pool grew rapidly since its formation. By the end of 1998, the number of patents in the pool went up to 226. By the end of 2011 the pool included more than 1000 patents from 27 different entities and was licensed to 1518 different licensees. More importantly, the DOJ business review for the MPEG-2 pool provided a template for pooling arrangements that would not violate antitrust laws. Soon after the approval of the MPEG-2 pool, DOJ approved a very similar proposal for pooling the patents for Digital Versatile Disc (DVD) technology in 1999.

[2] It is important to note that The Department of Justice did not assess the selected patents directly, but rather evaluated the lawfulness of the arrangement according to the claims of the License Administrator.

Since then, numerous similar pool arrangements, mainly dealing with new technology standards, have been approved. Many others are currently under construction (World Intellectual Property Report, 2011).

4. Empirical Strategy

The empirical strategy in this paper takes advantage of several features of the MPEG-2 pool formation process in order to implement a difference-in-difference methodology (DID) and establish the causal impact of the MPEG-2 pool on the innovative performance of the focal incumbents. The goal is to compare the changes in the innovative performance of incumbents in technological proximity of the pool (the treatment sample) after the formation of the pool (treatment) to the changes in the innovative performance of a comparable group of firms (control sample) that ideally were not affected by the formation of the pool. The main underlying idea is that, under appropriate conditions, the outcome trend of the control sample after the pool formation can be used as a proxy for the unobservable counterfactual trend for the treatment sample[3]. Thus, to the extent that the treated and control groups look similar pre-treatment, any differences between their outcome trends post-treatment can be interpreted as the causal effect of the treatment.

Two important assumptions are required for drawing a strong causal inference using the difference-in-difference methodology (Imbens & Wooldridge, 2009). First, the treatment should be exogenous to the treated sample; what Rubin (1990) labels as the “unconfounded assignment”. There are multiple important features of the MPEG-2 pool that lets me treat its formation as an exogenous shock to the incumbents outside the pool. First, the letter from DOJ highlights that an independent patent expert was used to select the 27 essential patents included in the pool. The expert and his assistance reviewed around 8,000 U.S. patent abstracts and studied carefully 800 patents belonging to 100 different assignees. This means that it was not really the choice of nonparticipants to be part of the pool, but rather the professional opinion of the hired expert. Second, the formation process of the pool took place over a short period, and

[3] See Holland’s (1986) and Imbens and Woodbridge (2009) for more detailed description on how to make causal inferences using the difference-in-difference methodology.

hence, it was not really easy for any outside firms to predict it soon enough to respond accordingly by changing their R&D investments or innovation strategies much earlier in advance. Even for those firms which might have some early information on the idea, it was not easy to predict the approval decision considering the history of the negative view of DOJ towards patent pools before 1997, and the absence of any pool formation for half a century. These features assure that the formation of the MPEG-2 pool can be considered as an exogenous shock to the subjects of interest. It is important to note that the exogeneity claim here is only with respect to the firms that had no role in the formation of the pool and could not predict it well in advance. However, by no means, I intend to claim that the formation of a patent pool is a random event. Creating a patent pool is certainly a strategic decision by pool members and other organizations involved in the formation process. However, to the extent that the formation of the MPEG-2 pool was not predictable by the incumbents of interest in this paper, the endogeneity issue is not a concern.

Second, a reliable causal inference requires treatment and control samples to be drawn from similar distributions, what is labeled as the "overlap assumption" (Imbens & Wooldridge, 2009). This assumption implies that the control group should be similar enough to the treatment group in order for me to be able to use its observable behavior as a valid proxy for the treatment groups' unobservable counterfactual. Ignoring this condition may lead to biased results and interpretations. In order to satisfy this condition, I use a matching method to construct a control sample that exhibits similar behavior to the treated group before the formation of the pool.

4. 1. Estimation Equation

I use a straightforward difference-in-difference estimator with firm and year fixed effects to estimate the change in the innovation rate of firms in the treatment sample relative to those in the control. Following previous works in the field, I use firms' citation-weighted patenting rate as the proxy for their innovation rate. Each patent is weighted by the number of times it is cited by subsequent patents in the next four years since its application date (Hall, Jaffe, & Trajtenberg, 2005)[4]. The results are robust to using a five or six year window to count the number of forward citations. Several studies have shown a strong correlation between the value of patents and their forward citation rate (Griliches, 1990; Hall et al., 2005; Harhoff, Narin, Scherer, & Vopel, 1999). This analysis builds on recent similar works using patenting rate to investigate the impact of an

[4] The results are robust to using 4 or 6 year windows to count the number of forward citations.

institutional shock on subsequent innovation rate (Furman, Kyle, Cockburn, & Henderson, 2005; Furman & Stern, 2011; Murray & Stern, 2007). The main estimating equation is:

$$Y_{it} = \beta TreatmentGroup_i * AfterTreatment_t + \alpha . AfterTreatment_t + \theta . X_{it} + \mu_i + \gamma_t + \varepsilon_{it}$$

where Y_{it} stands for the weighted patenting rate of firm i at year t. I further use a log normal transformation to account for the skewness of the data. $TreatmentGroup_i$ is a dummy equal to 1 for firms in the treatment sample and 0 otherwise. $AfterTreatment_t$ is also a dummy equal to 1 for years after 1997, the year in which the MPEG-2 pool was formed, and 0 otherwise.

X_{it} is a set of firm-specific time-varying controls including R&D intensity, capital intensity, and firm size. Since these data is mostly unavailable for private firms in the sample, they are only used in estimations on the subsample of public firms. Following prior studies (Cohen, Levin & Mowery, 1987; Audretsch & Feldman, 1996), R&D intensity is calculated as the logarithm of the amount of R&D spending divided by the total sales in each year. Similarly, capital intensity is calculated as the log transformed ratio of firm's total assets to total sales. Firm size is measured as the logarithm of the firms' total sales per year. All three variables are lagged one year to account for their delayed effect on firm's patenting rate.

μ_i and γ_t stand for firm and year fixed effects respectively. Including firm fixed effects helps controlling for the effects of firms' unobservable idiosyncratic characteristics. Furthermore, year fixed effects control for macroeconomic trends such as periods of technological expansion or depression. ε_{it} is a firm-year error term uncorrelated with constructed dummies, fixed effects and other control variables.

Coefficient α captures the change in the innovation rate of firms in the control group post treatment. Coefficient β captures the differential effect of pool formation on the treated sample relative to the control sample, i.e., the treatment effect. A positive β suggests that the treatment has positively affected the innovation rate of firms in the treatment sample relative to those in the control group and vice versa. For the sake of simplicity and robustness, I use linear regression with robust standard errors. The sensitivity of results to other specifications is tested in the robustness section. All the regressions are estimated for the time period beginning three years before the formation of the pool in 1997 until three years after (1994-2000).

5. Data and Sampling

5. 1. Data Sources

Several sources are used to collect the data for this study. The data on the MPEG-2 pool is collected from the MPEG Licensing Agreement's website[5] and through direct contact with the company. Patent data are extracted from NBER and USPTO patent databases. I manually matched the assignees from NBER patent database with company names in Compustat Database to identify the public firms in the sample and collect their financial data including SIC code, R&D investment, total asset, and sales. Patent litigation data is collected from the Lex Machina database[6], Internet search and other secondary source. Finally, the data on public firms' annual 10-k reports are collected through SEC's EDGAR database.

5.2. Treatment Sample

I use two separate search techniques to identify the group of incumbents in the technological proximity of the pool. In the first step, I identified all the firms owning patents that have cited the patents in the MPEG-2 pool before the formation of the pool, taking advantage of a well-known feature of patents: if patent A cites patent B, it indicates that the idea in patent A is partially built upon the idea developed in patent B. Patent citations thus have been frequently used as a means to measure knowledge flows between firms and the distance between their technological capabilities (Jaffe, Trajtenberg, & Henderson, 1993; Mowery, Oxley, & Silverman, 1998). Using this approach, I am able to identify all the firms that have been directly working on technologies based on the MPEG-2 standard before the pool formation.

In the second step, I identified all the firms owning any patent applied before 1997 with any of the terms "MPEG-1", "MPEG-2", "H.261" and/or "H.263" mentioned in their specifications. According to technology reports and articles, H.261 and its antecedent, H.263, were the main competitors for the MPEG-2 technology about the time when the MPEG-2 pool was assembled. The considerable technical similarities between both technologies assure that any firms familiar with one would also be familiar with the other. The union of both collections resulted in 239

[5] See http://www.mpegla.com/main/default.aspx
[6] See https://www.lexmachina.com.

organizations. I further excluded pool members and organizations other than for-profit firms. The final treatment sample includes 175 firms.

5.3. Control Samples

The validity and reliability of difference-in-differences estimates depend heavily on the extent to which the observable outcomes for the control sample can represent the unobservable counterfactual for the treatment sample. The goal of this study is not to compare the effect of the pool on insiders (members) and outsiders (nonmembers), but rather identifying how modern pools affect those outsiders that are technologically close to the pool area compared to other outsiders that are not ideally affected by the formation of the pool. Thus, the control group is comprised of firms outside the pool that are not affected directly by its formation due to their longer technological distance. In order to acquire robust results, I construct two control samples.

For the first control group, I first extracted all the representative industries in the treatment sample using the SIC codes of the public firms in the sample. Next, I collected all the public firms in those industries excluding the pool members and the firms selected into the treatment sample. I further limited the collected firms to those that had at least one patent before the formation of the pool to assure that the control firms indeed engaged in some sort of technological innovation before the formation of the pool. It resulted in a group of 2166 firms in the first control sample.

Columns 1 and 2 in Panel A of Table 2 show the weighted patenting rate for firms in the treatment and first control sample for the three years before the formation of the pool (1994 to 1996). Column 3 reports the t-test stats for the difference in means between the two samples. Firms in the treatment sample have substantially more patents throughout the whole period, suggesting a lack of sufficient overlap between the distributions of firms in the two samples. While firms in the first constructed control sample serve as a good initial point of reference, they cannot be considered as a reliable control sample. Hence, when I compare firms in the treatment sample with firms in this control group, I simply intend to compare the treated firms to “average” firms in similar industries rather than necessarily to a comparable group of firms with similar innovation track prior to the formation of the pool.

Insert Table 2 about here

In order to resolve the overlap issue, in the second stage, I match each firm in the treatment sample with another firm from the control sample constructed in the previous step based on the weighted patenting rate in each of the three years prior to the pool formation and the average growth rate in weighted patenting rate over the three year period. Any treated firm with no matched control is excluded from the matched treatment sample. This reduces the size of treatment and control samples to 67 firms in each group. Panel B in Table 2 shows the weighted patenting rate for the matched treatment and control samples and the difference in their means for each of the three years prior to the formation of the pool. As can be seen, firms in the second control sample look much more similar to those in the matched treatment group in terms of pre-treatment innovation rate. The differences between the mean innovation rates are insignificant for all three years.

One should note that using a matching method in this context produces more conservative results. It is simply impossible to ensure that none of the selected firms in the matched control sample was affected by the pool formation. There might be firms in technological proximity of the pool that never cited any of the MPEG-2 patents and never mentioned any of the searched terms ("MPEG-1", "MPEG-2", "H.261" or "H.263") in their patent specifications prior to the pool formation. With more stringent matching criteria, it becomes more likely to match an unidentified firm that should have been ideally selected into the treatment sample with an identified firm in the treatment sample. This can potentially lead to attenuated results as some of the treated and matched control pairs are in fact both similarly affected by the formation of the pool. However, since this issue works against finding any significant treatment effect, I would be able to establish the robustness of findings as long as I get similar results using both control samples.

6. Results

6.1. Effect of Pool Formation on Technologically Proximate Incumbents

The first set of results show the net effect of the MPEG-2 pool formation on the innovative performance of firms in the treatment sample. Figure 2 depicts the trend in the innovation rate of firms in the treatment sample compared to firms in the broad control sample three years before and after the pool formation. The graph shows an obvious downward trend in the innovation rate of treated firms compared to “average” firms in the broad control sample starting right after the pool formation. Figure 3 shows the same trends for the matched treatment and control samples: a negative impact on the average weighted patenting rate of the treatment sample relative to the matched control sample. To analyze the effect formally, I now turn to the regression results.

Insert Figures 2 and 3 about here

Table 3 reports the difference-in-differences estimation results. The first column shows the results for the regression with the broad control group (all other firms in representative industries), using a linear regression model with robust standard errors. The coefficient of $AfterTreatment_t$ is positive and significant, suggesting an increase in the innovation rate of “average” firms in the representative industries after the formation of the MPEG-2 pool. The coefficient of the interaction term ($TreatmentGroup_i * AfterTreatment_t$) shows a substantial negative effect significant at the 1% level, implying that the formation of the pool has resulted in more than 60% fall in the weighted patenting rate of firms in technologically proximity of the pool compared to “average” firms in the same industries.

Insert Table 3 about here

Column 2 shows the results for estimation with the matched control sample. Similar to the previous case, the coefficient of the interaction term is negative and significant suggesting a 35% drop in the innovation rate of firms in the treatment sample compared to those in the matched control sample. The lower coefficient relative to previous case can be partially due to the more conservative nature of the estimates with the matched control sample as explained earlier.

In model 3, I add two placebo treatments for the two years prior to the formation of the pool to test for any pre-treatment decline in the innovation rate of firms or any divergence in the behavior of the treatment and control groups prior to the formation of the pool. The results show no significant decline in the innovation rate of either groups, nor any pattern of divergence between the two, before the pool was assembled. The main coefficient of interest, β, still suggests a substantial decline in the innovation rate of treated firms post-treatment.

Finally, in model 4, I run the regression on the subsample of public firms controlling for one year lagged R&D intensity, capital intensity, and sales. The main result remains the same although less significant, probably due to the smaller sample size. Overall, the results suggest that the formation of the MPEG-2 pool led to a substantial drop in the weighted patenting rate of firms in its technological proximity compared to other firms in similar industries but more technologically distant from the pool.

6.2. Robustness Tests

I perform several robustness tests to test the validity of main results. First, I test the sensitivity of results to other functional forms. Table 4 reports the regression results for panel Poisson model with robust standard errors. The results are essentially similar in terms of size and significance. The coefficient of interaction suggests a sharper decline in the innovation rate of treatment firms compared to what were estimated in the linear models. Also, the positive and significant $AfterTreatment_t$ suggests a modest increase in the innovation rate of control firms after the pool formation. Results are also robust to Negative Binomial specification. Furthermore, using a 5 year or 6 year window to measure the forward citation rate of patents does not change the results. The results are also robust to more or less stringent matching criteria.

Insert Table 4 about here

Another source of concern is that there might have been firms selected to join the pool by MPEG LA experts but decided not to. While in the absence of any data on these firms, it is hard to predict how they may react to the formation of the pool, to the extent that they redirect their strategy from engaging in any further patenting (to avoid engaging in potential IP infringements with pool members) towards taking advantage of their strategic position in licensing negotiations with pool customers, including them in the treatment sample may lead to overestimating the pool's real effect on the innovation rate of other incumbents. To address this issue, I identified all firms with any track of IP disclosure to the MPEG working group before the formation of the pool. These firms comprise the main candidates for selection into the pool. In an unreported analysis, I removed these firms from the sample and repeated the main regressions. The exclusion has modest effects on the significance of coefficients particularly in regressions with matched samples mainly due to smaller sample sizes, but the results are generally similar for the most part.

Furthermore, to assure that the results are not mainly driven only by those firms that were working on competing technologies (h.261 and h.263), I broke down the treatment sample into two sub-samples: firms with patents mentioning "h.261" or "h.263" in their specifications, and others. I repeated the analysis on each sub-sample separately (unreported here). For both samples, I find similar results to those reported in the previous section. Furthermore, there is no significant difference between the innovation rates of firms in the two sub-samples.

Finally, one may worry that the formation of the MPEG-2 pool and the decline in the innovation rate of treated firms may both be caused by diminishing technological opportunities in the market. In other words, both are strategic responses by two different groups of firms, pool creators and firms in technological proximity of the pool, to receding technological opportunities in the external market. To examine this hypothesis, I collected all patents with the term "MPEG-2" in their abstract. Figure 4 depicts the number of such patents pre- and post-pool formation. Assuming that the number of patents with the term "MPEG-2" in their abstracts is a good proxy for the potential technological opportunity in the market, the steady growth of such patents after the pool formation rejects this alternative explanation. Using alternative measures illustrates a similar story: a growing technological opportunity after the formation of the pool.

Insert Figure 4 about here

6.3. Mechanisms

6.3.1. Increased Litigation Risk

Several studies have previously used the number of litigation cases to identify the level of litigation risk (Agarwal, Ganco & Ziedonis, 2009; Simcoe, Graham & Feldman, 2009).

However, in this case, using the change in the number of litigation cases involving pool patents after the pool formation may result in misleading conclusions. On the one hand, any increase in the number of litigation lawsuits can be interpreted as an increase in the litigiousness of pool members and consequently, an increase in the litigation risk associated with developing technologies based on the pool technology (Agarwal, Ganco, & Ziedonis, 2009; Simcoe, Graham, & Feldman, 2009). On the other hand, any decrease in the number of such lawsuits may indeed be a signal that outsiders have retreated from the pool technological area all together due to the increased perceived litigation risk. In other words, any change in the number of litigation cases (either increase or decrease) can potentially lead to the same conclusion, increase in litigation risk. In fact between 1994 and 2000 there has been only one litigation lawsuit involving one of the MPEG-2 pool patents, filed by France Telecom against Compaq Computer Corporation.

Considering the difficulty involved with using litigation data, instead, I use the pool licensing data to test whether litigation risk had any role in explaining the decline in the innovation rate of outsiders. Assuming that acquiring the pool license eliminates potential litigation threats to a great extent, a comparison between innovation rates of licensees versus non-licensees in the treatment sample provides a unique opportunity to measure the effect of the litigation risk. Hence, I first identify all the firms that acquired a license to the pool technology by the end of 1997 (the year in which the pool was formed). Subsequently, I use a difference-in-difference estimation to measure the difference in the innovation rate of licensees versus others in each of the treatment samples separately. It is important to note that in this case, I measure the difference in the patenting rates of two sub-samples of the treatment sample. This is similar to the approach used in Simcoe, Graham, and Feldman (2010) to measure the difference between behaviors of small firms versus large firms after disclosing patents to SSOs. The following estimation equation is used:

(2) $Y_{it} = \beta.Licensee_i * AfterTreatment_t + \alpha.AfterTreatment_t + \mu_i + \gamma_t + \varepsilon_{it}$

where $Licensee_i$ is equal to 1 if the treated firm is a licensee by the end of 1997 and 0 otherwise. Everything else is similar to the main estimation model explained earlier. The results are presented in table 5. Columns 1 and 2 report the results for linear and Poisson models respectively. The interaction term is insignificant in both models, indicating no difference in the patenting rate of licensees and non-licensees after the pool formation. Furthermore, the coefficient of $AfterTreatment_t$ is negative and significant in both estimations, suggesting a similar decline in innovation rate of both groups after the pool formation. The size of the decline in each model is, in fact, very similar to the previously measured decline in the base estimations. The results are also robust to the choice of cutoff year to identify licensees (end of 1998 or 1999).

Insert Table 5 about here

Furthermore, any increase in litigation risk after the formation of the pool should have a depressing impact on the follow-on innovations based on the pool patents. To test the effect of the pool on subsequent innovations, building on the method proposed by Mehta, Rysman, and Simcoe (2010) and Rysman and Simcoe (2008), I compare the forward citation patterns of pool patents to a closely matched sample of patents. Each pool patent is matched with another patent from a similar technological class, same application year, and similar pre-pool citation trend. Their method makes use of the variance in processing time of patents from the same application-year cohort to identify the age effects. Using their method with little modification, I estimate the effect of the pool formation on the yearly citation rates of pool patents relative to their matched counterparts after the pool formation. I use the following difference-in-difference model:

$$C_{it} = \beta Poolpatent_i * AfterTreatment_t + \alpha . AfterTreatment_t + \mu_i + \gamma_t + \alpha_a + \varepsilon_{it}$$

where C_{it} stands for the log transformed number of citations received by patent i in year t (as measured by the application year of the citing patent), μ_i and γ_t are the fixed effects for the application year and citing year respectively, α_a is the set of citing age effects, and ε_{it} is a patent-year error term uncorrelated with the constructed dummies. Coefficient α captures the effect of the pool on the subsequent citation rate of matched control patents and Coefficient of interaction, β, captures the differential effect of the pool on pool patents. I limit the sample of pool patents to those that were initially selected into the pool in 1997 due to potential differences between the initial selection process and the process used later for adding subsequent patents to the pool.

Column 1 in table 6 presents the result for the linear regression with robust standard errors. The coefficient of interaction suggests that the pool formation led to an average 40% increase in the yearly citation rate of pool patents relative to the matched controls. As expected, the formation of the pool had no effect on the yearly citation rate of patents in the control sample. In model 2, I replace the matched control sample with a sample of patents on the competing technologies ("H.261" and "H.263"). The results are essentially the same suggesting that the pool formation not only had no depressing impact on subsequent inventions based on pool patents, but in fact boosted such inventions. The results are robust to other specifications such as Poisson and Negative Binomial. Overall the results demonstrate that increased litigation risk does not play much role in explaining the observed decline in the weighted patenting rate of treated firms.

Insert Table 6 about here

6.3.2 Increased Competition

Patent pools can potentially increase the rivalry for incumbents by presenting a stronger competition from pool members and inviting new entrants into the pool technological area through lowering the barriers to entry. In fact, the increased number of patents with the term "MPEG-2" in their abstract along with the decline in the patenting rate of the firms in the treatment sample already suggests that more firms started to invest into the pool technological area. In order to examine the role of competition as a potential driving mechanism, I analyze the change in the profit margin of firms in the treatment sample post-pool formation. I use the same difference-in-difference estimation model as presented in equation 1, replacing the innovation rate with different measures of financial performance as the dependent variable. I further limit the analysis to the public firms in the sample due to data availability.

Column 1 in Table 7 shows the results for the effect of the pool on the net profit margin of firms in the treatment sample compared to those in the broadly constructed control sample. The coefficient of interaction (β) is insignificant indicating that the formation of the pool had no direct impact on the profit margin of firms in the treatment sample relative to those in the control sample. Columns 2 and 3 report the results for two other measures of financial performance: ROA and Tobin's Q respectively. Columns 4 to 6 report similar estimations for the matched samples. The results are essentially the same. Except for model 3 (with broad control sample and Tobin's Q as the dependent variable) which shows a positive impact, other results indicate no significant change in the financial performance of firms after the pool formation. Overall, the results reject the hypothesis that the decline in innovation rates is due to increased competition intensity in the pool technological area. One should note that the results do not reject the increased competition intensity post-treatment. In fact, anecdotal evidence and observed increase in total technological innovation in the field, suggest the opposite. However, increased competition seems to play an insignificant role in explaining the observed decline in treated firms' innovation rate.

Insert Table 7 about here

6.3.3. Shift in R&D Investment Direction

The last mechanism I examine here is the change in R&D investment direction of firms as a strategic respond to the pool formation. A switch from investing in developing new technologies to implementing the pool technology in current and new products may indeed explain the decline in the patenting rate of firms in spite of their stable financial performance.

However, a direct examination of such shifts in the investment direction of firms requires detailed data on how firms spend their investment money. In the absence of such detailed data, I rely on the information that public firms disclose in their annual 10-k reports to investors. Each report contains activities during the past year and plan for future. These reports typically have comprehensive sections on business and product strategies of firms and their current and future products. Considering that MPEG-2 was an increasingly important technology in industries such as broadcasting, software, and semiconductors at the time, mentioning any activities towards implementing it in current or future products could potentially give firms a positive edge in investors' evaluations. This lets me to identify any investment towards implementing the MPEG-2 technology in the annual reports of collected firms.

In particular, first, I collect the annual reports of all public firms in the treatment and control samples between 1994 and 2001 in the top 6 representative industries[7]. I further exclude the firms that had no annual reports disclosed before 1997 or after 1998 to assure coverage before and after the formation of the pool. Subsequently, I identify the first report in which each firm mentions a product compatible with the MPEG-2 technology or a plan to implement it in current or new products. Doing so, I am able to identify all the firms that have reported their attempt towards implementing the MPEG-2 technology between 1994 and 2001. This resulted in identifying 14 firms in the pool of treated firms and 26 firms in the associated constructed control sample.

In order to test this mechanism, I use a two step approach. In this first step, I verify whether mentioning any strategic intention towards implementing the MPEG-2 technology has any association with lower patenting rate subsequently. I expect the firms that have mentioned any effort towards implementing MPEG-2 technology to experience a decline in their innovation rate relative to other firms. In the second step, I test whether firms in technological proximity of the pool are more likely to mention MPEG-2 implementation in their annual reports compared to other firms in the control samples.

For the first step, I use the following estimation equation:

(3) $$Y_{it} = \beta . MPEG2\_mentioned_i * AfterTreatment_t + \alpha . AfterTreatment_t + \mu_i + \gamma_t + \varepsilon_{it}$$

where $MPEG2\_mentioned_i$ is equal to 1 for firms mentioning MPEG-2 implementation in at least one of their annual reports between 1997 and 2000 and 0 otherwise. Everything else is similar to the main estimating equation. Column 1 of table 8 reports the estimation results for the full sample of eligible firms. The negative and significant β indicates that firms mentioning MPEG-2

[7] Selected industries include Radio and TV Broadcasting, Telephone Communications, Cable and Other Pay Television Services, Communication Services, Services-Packaged Software, and Semiconductors.

implementation indeed experienced a decline in their weighted patenting rate after the pool was formed. In order to assure that the results are not solely driven by firms in the treatment sample, I repeat the estimation focusing only on firms in the control sample. The new estimations are reported in the second column of table 8. The interaction coefficient is still negative, significant and of the same magnitude. Taken together, the results verify that any attempt towards implementing MPEG-2 technology is indeed associated with lower patenting rate post-pool formation.

Insert Table 8 about here

In the next step, I compare the rate at which firms in technological proximity of the pool shifted their R&D investments towards implementing the MPEG-2 technology relative to their counterparts in the constructed control sample using the following difference-in-difference estimation model:

(4) $Y_{it} = \beta TreatmentGroup_i * AfterTreatment_t + \alpha . AfterTreatment_t + \theta . X_{it} + \mu_i + \gamma_t + \varepsilon_{it}$

where Y_{it} is equal to 1 if firm i has already mentioned MPEG-2 implementation in any of its annual reports in years t or before. All the other variables are similar to what was explained in the base estimation model. Hence, coefficient α captures the effect of the pool formation on the probability of firms in the control sample mentioning MPEG-2 implementation in their annual reports. Coefficient of interaction, β, measures the difference in the response rates of treatment and control samples. If firms in technological proximity of the pool were in fact more likely to shift their investments towards implementing the MPEG-2 technology, I expect β to be positive and significant. I only focus on the broad control sample since all the five firms in the matched treatment and control samples that have mentioned MPEG-2 implementation in their 10-K reports solely belong to the treatment sample.

The regression results are depicted in table 9. The positive and significant coefficient of $AfterTreatment_t$ suggests that there is indeed an increased tendency towards implementing the MPEG-2 technology after the formation of the pool. Furthermore, the positive and significant coefficient of the interaction term indicates that firms in the treatment sample had a higher rate of investment redirection towards implementing the MPEG-2 technology relative to control firms in the time period of analysis. The size of coefficient suggest that treated firms were 16% more likely to mention MPEG-2 implementation in their annual reports in the four years following the formation of the pool relative to their counterparts in the control samples.

Insert Table 9 about here

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7. Conclusion

Despite their growing and widespread use in advanced fields of technology and their significant economic importance, little research has investigated the competitive effects of modern pools. More importantly, we know little about how firms that are affected by these organizations strategically respond to their formation. In this paper, I investigate the effect of the formation of MPEG-2 pool on the innovation rate of incumbents in technological proximity of the pool. Furthermore, I examine three different mechanisms through which the pool formation may have influenced the innovative performance of these firms.

Table 10 summarizes the findings. The results suggest that the formation of the MPEG-2 pool had a substantial negative impact on proximate incumbents' innovation rate measured by their weighted patenting rate. The results are consistent with those reported by Lampe and Moser (2010) and Joshi and Nerkar (2011). Furthermore, I find that the decline in firms' innovation rate is mainly due to their strategic shift from further technological exploration to implementing the pool technology in their current and new products. Moreover, I find that increased litigation risk and increased competition cannot explain the observed decline.

This study does have its own limitations. First, this paper focuses only on one patent pool, the MPEG-2 pool. Although, the fact that the MPEG-2 pool has been the template for almost all the other modern pools enhances the external validity of current findings, further theoretical and empirical research on other modern pools are required in order to make more generalizable conclusions. In addition, it is important to note that this study does not evaluate the total welfare effect of modern patent pools or the MPEG-2 pool in particular. The overall welfare effect of modern pools certainly depends on numerous factors. Identifying all of these factors and understanding the mechanisms through which they influence other firms and the economy as a whole is out of the scope of this study. Nevertheless, this work takes one step towards this goal.

Overall, the findings provide a better understanding of how patent pools affect the competition arena through changing the investment incentives of firms outside the pool across several industries and markets. The results also illustrate how patent pools can shape the trajectories of pool technologies and their competitors. More broadly, the results of this paper call for more attention to studying how hybrid collaborative organizations such as Standard Setting Organizations and R&D consortia may affect outside organizations.

Insert Table 10 about here

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Figure 1: Number of patent pools per decade (Source: World Intellectual Property Report 2011, WPO Economics & Statistics Series)

Each bar shows the number of patent pools formed in each decade of the 20th century. As can be seen, the number peaked in 1930s and declined subsequently due to the rise and enformcement of antitrust laws. No major pool was formed since the end of World War II until the formation of the MPEG-2 pool, the first instance of modern pools, in 1997. The number of modern pools has been increasing since then.

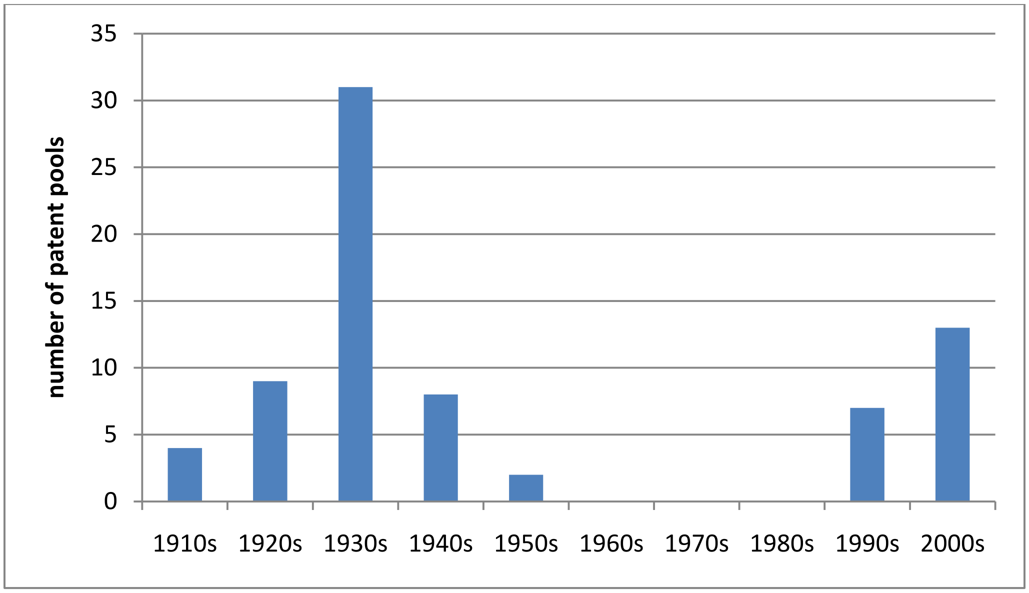

Figure 2: The effect of the formation of the MPEG-2 pool in 1997 on weighted patenting rate of incumbents in technological proximity of the pool (treated firms) compared to other firms in similar industries (control firms). Weighted patenting rate of control firms is plotted on the right axis.

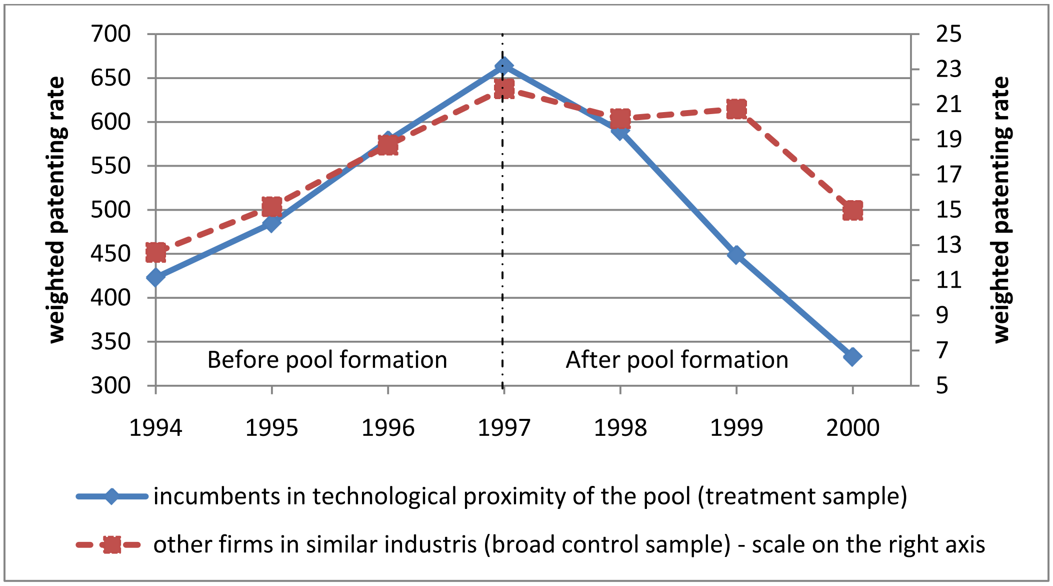

Figure 3: The effect of the formation of the MPEG-2 pool in 1997 on weighted patenting rate of proximate incumbents in the matched treatment sample compared to firms in the matched control sample.

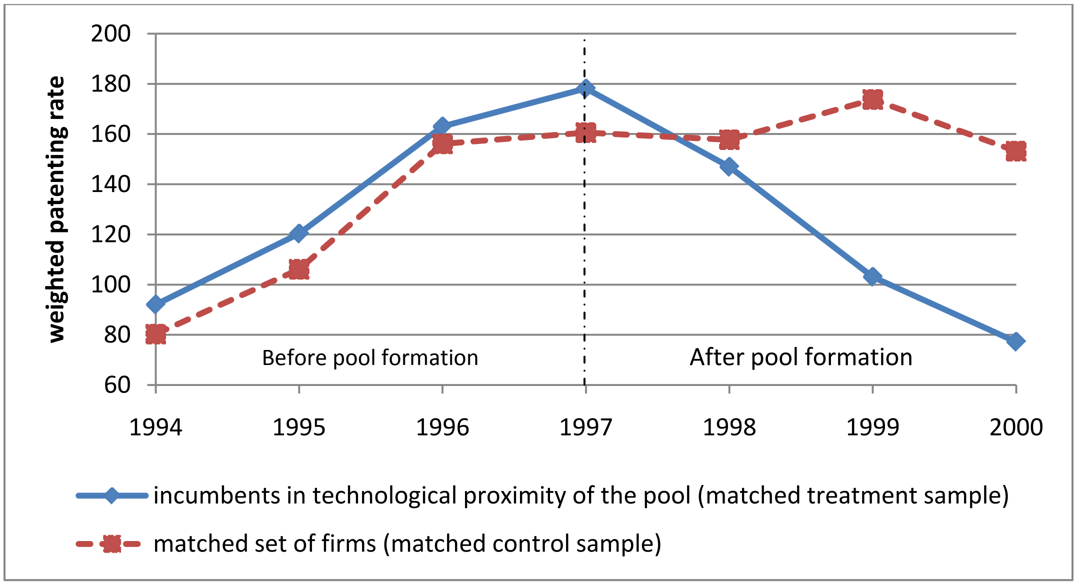

Figure 4: Number of patents with the term "MPEG-2" in their abstract per year before and after the formation of the MPEG-2 pool in 1997.

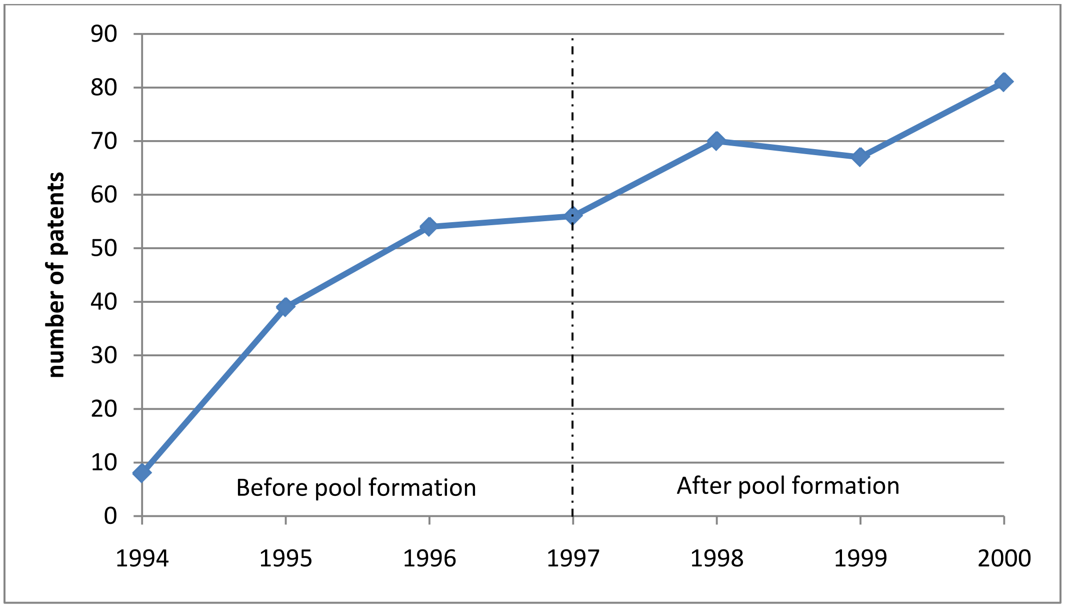

Table 1: Theoretical Framework

Mechanism	Predicted main effect	Distinguishing side-effects
Lower cost of access to the pool technology and incumbency advantage	Positive effect on proximate incumbents' innovation rate	Positive effect on proximate incumbents' financial performance
Increased competition	Negative effect on proximate incumbents' innovation rate	Negative effect on proximate incumbents' financial performance
Increased litigation risk	Negative effect on proximate incumbents' innovation rate	Negative effect on proximate incumbents' financial performance; Different effect on licensees vs. non-licensees; Negative effect on follow-on inventions based on pool patents
Shift in R&D investment direction	Negative effect on proximate incumbents' innovation rate	Indications of investment in MPEG-2 implementation in firms' annual reports to investors

Table 2: Average weighted patenting rate of firms in each pair of treatment and control samples for each of the three years prior to the formation of the MPEG-2 pool in 1997

	Treatment	**Control**	**Difference**
Panel A: treatment sample vs. broad control sample			
Weighted patenting rate one year prior to the formation of the pool (year=1996)	578.886 [175]	18.682 [2166]	560.204** (0.000)
Weighted patenting rate two years prior to the formation of the pool (year=1995)	484.703 [172]	15.180 [2101]	469.523** (0.000)
Weighted patenting rate three years prior to the formation of the pool (year=1994)	422.9438 [160]	12.580 [1976]	410.363** (0.000)
Panel B: matched treatment sample vs. matched control samples			
Weighted patenting rate one year prior to the formation of the pool (year=1996)	163.030 [67]	156.075 [67]	6.955 (0.890)
Weighted patenting rate two years prior to the formation of the pool (year=1995)	120.328 [67]	106.106 [67]	14.222 (0.704)
Weighted patenting rate three years prior to the formation of the pool (year=1994)	92.016 [62]	80.277 [65]	11.739 (0.684)

Note: In brackets in each cell is the number of observations. Column 3 also reports the p-value for testing the null hypothesis that the average weighted patenting rates are equal across treatment and control samples.

** $p<0.01$, * $p<0.05$, + $p<0.1$

Table 3: The effect of the formation of the MPEG-2 pool in 1997 on weighted patenting rate of firms in technological proximity of the firm using linear regression models

	(1)	(2)	(3)	(4)
Dependent variable: ln(weighted patenting rate)	broad control sample	matched sample	matched sample, w/ pre-treatment placebos	matched sample, public firms
Treatment * After Pool Formation (1997)	-0.951** (0.415)	-0.428* (0.198)	-0.488* (0.205)	-0.589+ (0.343)
After Pool Formation (1997)	0.160** (0.036)	-0.128 (0.199)	-0.073 (0.154)	-0.037 (0.270)
Treatment * After 1996			0.126 (0.262)	0.435 (0.421)
After 1996			-0.301 (0.209)	-0.513+ (0.298)
Treatment * After 1995			-0.068 (0.261)	-0.069 (0.381)
After 1995			0.488* (0.199)	0.694* (0.294)
Constant	0.995** (0.022)	3.353** (0.105)	3.353** (0.105)	3.858** (0.882)
Control for lagged R&D intensity, lagged capital intensity, and lagged sales	No	No	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	15817	903	903	302
Number of firms	2778	134	134	46

Note: All estimates are from panel ordinary-least-squares (OLS) models with firm fixed effects. Dependent variable is the ln(weighted patenting rate) for all models. Treatment (0/1) = 1 if firm is in technological proximity of the pool, 0 otherwise. Columns 3 and 4 include two placebo treatments to control for pre-pool formation trends. Robust standard errors are shown in parentheses. ** p<0.01, * p<0.05, + p<0.1

Table 4: The effect of the formation of the MPEG-2 pool in 1997 on weighted patenting rate of firms in technological proximity of the pool using Poisson model with robust standard errors

	(1)	**(2)**	**(3)**	**(4)**
Dependent variable: weighted patenting rate	broad control sample	matched sample	matched sample, pre-treatment placebos	matched sample, public firms
Treatment * After Pool Formation (1997)	[0.677]** -0.390 (0.096)	[0.650]* -0.430 (0.170)	[0.642]** -0.443 (0.153)	[0.543]** -0.610 (0.169)
After Pool Formation	[1.241]* 0.216 (0.088)	[1.446]* 0.369 (0.176)	[1.108]+ 0.102 (0.057)	[1.176]* 0.162 (0.082)
Treatment * After 1996			[1.062] 0.060 (0.111)	[1.241] 0.215 (0.148)
After 1996			[1.029] 0.028 (0.084)	[0.993] -0.007 (0.135)
Treatment * After 1995			[0.928] -0.074 (0.149)	[0.884] -0.123 (0.199)
After 1995			[1.471]** 0.386 (0.109)	[1.650]** 0.501 (0.183)
Control for lagged R&D intensity, lagged capital intensity, and lagged sales	No	No	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	11383	903	903	302
Number of firms	1921	134	134	46

Note: All estimates are from panel Poisson models with robust standard errors and firm fixed effects. Incident-rate ratios reported in square brackets. Estimated coefficients are reported in second line. Estimations are done using xtpqml in Stata (Simcoe, 2007). Dependent variable is the “weighted patenting rate” for all models. Treatment (0/1) = 1 if firm is in technological proximity of the pool, 0 otherwise. Columns 3 and 4 include two placebo treatments to control for pre-pool formation trends. Robust standard errors are shown in parentheses. ** p<0.01, * p<0.05, + p<0.1

Table 5: The effect of the formation of the MPEG-2 pool in 1997 on weighted patenting rate of licensees versus non-licensees (Treatment is equal to 1 if the firm has acquired a license from the pool, 0 otherwise)

	(1)	**(2)**
	Linear regression DV: ln(weighted patenting rate)	Poisson regression DV: weighted patenting rate
Licensee * After Pool Formation (1997)	0.169 (0.359)	[1.093] 0.089 (0.096)
After Pool Formation (1997)	-0.622** (0.184)	[0 .422]** -0.862 (0.071)
Constant	3.874** (0.114)	
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	1101	1052
Number of firms	191	171

Note: Estimates in column 1are from panel ordinary-least-squares (OLS) models with firm fixed effects. Estimates in model 2 are from panel Poisson models with robust standard errors and firm fixed effects. In column 2, incident-rate ratios are reported in square brackets. Estimated coefficients are reported in second line. Poisson estimations are done using xtpqml in Stata (Simcoe, 2007). Dependent variable is ln(weighted patenting rate) for model 1 and "weighted patenting rate" for model 2. Licensee (0/1) = 1 if firm has acquired a pool license by the end of 1997, 0 otherwise. Robust standard errors are shown in parentheses. ** $p<0.01$, * $p<0.05$, + $p<0.1$

Table 6: The effect of the formation of the MPEG-2 pool on subsequent inventions based on initial pool patents

	(1)	(2)
Dependent variable: ln(citation rate)	Pool patents vs. matched patents	Pool patents vs. patents on competing technologies
Pool Patent * After Pool Formation (1997)	0.345+ (0.173)	0.420** (0.117)
After Pool Formation (1997)	0.022 (0.156)	-0.300* (0.118)
Constant	0.345* (0.158)	0.164 (0.164)
Patent fixed effects	Yes	Yes
Age since grant dummies	Yes	Yes
Application year dummies	Yes	Yes
Citing year dummies	Yes	Yes
Observations	232	2631
Number of patents	34	476

Note: All estimates are from panel ordinary-least-squares (OLS) models with patent fixed effects. Dependent variable is the ln(citation rate) for both models. Pool patent (0/1) = 1 if patent was initially included in the MPEG-2 pool, 0 otherwise. Model 1 compares the forward citation rate of pool patents with that of a set of matched patents. Model 2 compares the forward citation pattern of pool patents with that of patents on main MPEG-2 competitors (H.261 and H.263). Robust standard errors are shown in parentheses. ** p<0.01, * p<0.05, + p<0.1

Table 7: The effect of the formation of the MPEG-2 pool on the financial performance of treated firms

	(1)	(2)	(3)	(4)	(5)	(6)
	Treatment and broad control sample			Matched treatment and control samples		
	DV: net profit margin	DV: ROA	DV: ln(Tonin's Q)	DV: net profit margin	DV: ROA	DV: ln(Tonin's Q)
Treatment * After Pool Formation	36.699 (101.122)	7.870 (8.060)	0.198** (0.052)	45.029 (37.080)	-5.681 (5.962)	-0.118 (0.134)
After Pool Formation (1997)	-36.600 (89.881)	-8.317 (5.125)	0.124** (0.021)	-142.386 (97.454)	3.428 (5.479)	0.129 (0.139)
Constant	419.970 (902.540)	-52.300 (62.801)	1.930** (.114)	-1195.191+ (708.617)	40.061** (13.557)	0.227 (0. 518)
Control for lagged R&D intensity, lagged capital intensity, and lagged sales	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10039	10053	9798	296	296	293
Number of firms	2070	2074	2049	46	46	46

Note: All estimates are from panel ordinary-least-squares (OLS) models with firm fixed effects. Treatment (0/1) = 1 if firm is in technological proximity of the pool, 0 otherwise. Each model has a set of control dummies for 1 year lagged R&D intensity, capital intensity and sales. Robust standard errors are shown in parentheses. ** p<0.01, * p<0.05, + p<0.1

Table 8: The effect of MPEG-2 implementation on weighted patenting rate of firms after the formation of the MPEG-2 pool (Treatment is equal to 1 if the firm mentioned MPEG-2 implementation in at least one of its annual 10-k reports, 0 otherwise).

	(1)	(2)	(3)	(4)
	Pooled sample of firms in both treatment and broad control samples		Only firms in the broad control sample	
	Linear regression DV: ln(weighted patenting rate)	Poisson regression DV: weighted patenting rate	Linear regression DV: ln(weighted patenting rate)	Poisson regression DV: weighted patenting rate
MPEG-2 implementation * After Pool Formation (1997)	-0.323+ (0.194)	[0 .698]** -0.359 (0.140)	-0.390+ (0.230)	[0 .537]** -0.621 (0 .155)
After Pool Formation (1997)	0.527** (0.099)	[0 .878] -0.130 (0 .145)	0.090 (0.099)	[0.956] -0.044 (0 .188)
Constant	1.031** (0.059)		0.920 (0.063)	
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	2463	2007	2003	1563
Number of firms	325	263	299	232

Note: Estimates in columns 1 and 3 are from panel ordinary-least-squares (OLS) models with firm fixed effects. Estimates in models 2 and 4 are from panel Poisson models with robust standard errors and firm fixed effects. In columns 2 and 4, incident-rate ratios are reported in square brackets. Estimated coefficients are reported in second line. Poisson estimations are done using xtpqml in Stata (Simcoe, 2007). Dependent variable is ln(weighted patenting rate) for models 1 and 3 and “weighted patenting rate” for models 2 and 4. MPEG-2 implementation (0/1) = 1 if firm has mentioned MPEG-2 implementation in its annual 10-K reports to investors, 0 otherwise. Robust standard errors are shown in parentheses. ** $p<0.01$, * $p<0.05$, + $p<0.1$

Table 9: The effect of the MPEG-2 pool on the tendency of firms towards mentioning MPEG-2 implementation in annual 10-k reports after the pool formation

	(1)
DV: mentioning MPEG-2 implementation in annual 10-K report (0/1)	broad control samples
Treatment * After Pool Formation	0 .164** (0.059)
After Pool Formation	0.090** (0.017)
Constant	-0.002 (0.011)
Firm fixed effects	Yes
Year fixed effects	Yes
Observations	2984
Number of firms	325

Note: Estimates are from panel ordinary-least-squares (OLS) models with firm fixed effects. Dependent variable is a dummy variable equal to 1 if a firm has mentioned MPEG-2 implementation in its annual 10-K reports after the formation of the MPEG-2 pool, 0 otherwise. Treatment (0/1) = 1 if firm is in technological proximity of the pool, 0 otherwise. Robust standard errors are shown in parentheses.
** p<0.01, * p<0.05, + p<0.1

Table 10: Overview of results

Mechanism	**Predicted main effect**	**Distinguishing side-effects**	**Empirical findings**
Lower cost of access to the pool technology and incumbency advantage	Positive effect on proximate incumbents' innovation rate	Positive effect on proximate incumbents' financial performance	<u>Not supported</u> Evidence against: 1. No evidence for a positive effect on proximate incumbents' innovation rate (main effect) 2.No evidence for a positive effect on proximate incumbents' financial performance
Increased competition	Negative effect on proximate incumbents' innovation rate	Negative effect on proximate incumbents' financial performance	<u>Not supported</u> Evidence against: 1.No evidence for a negative effect on proximate incumbents' financial performance
Increased litigation risk	Negative effect on proximate incumbents' innovation rate	Negative effect on proximate incumbents' financial performance; Different effect on licensees vs. non-licensees; Negative effect on follow-on inventions based on pool patents	<u>Not supported</u> Evidence against: 1.No evidence for a negative effect on proximate incumbents' financial performance 2.Similar effect on licensees vs. non-licensees; 3.Positive impact on follow-on inventions based on pool patents
Shift in R&D investment direction	Negative effect on proximate incumbents' innovation rate	Indications of investment in MPEG-2 implementation in firms' annual reports to investors	<u>Supported</u> Evidence for: 1.Firms that mentioned MPEEG-2 implementation experienced a decline in their innovation rate after the formation of the MPEG-2 pool; 2.Proximate incumbents are more likely to mention MPEG-2 implementation in their annual 10-K reports.