Technology Adoption With Staggered Bargaining Over Complementary Patent Licenses*

Erik Hovenkamp† Jorge Lemus‡ John L. Turner§

February 28, 2025

Abstract

In standardized technologies, products require multiple complementary patents, and innovators face challenges in securing preemptive licenses from all standard-essential patent (SEP) holders. Some patentees exploit this by delaying licensing until implementers have licensed other patents, effectively committing to the technology. We propose a framework to analyze how patentees choose whether to join a pool—offering a single ex ante license covering multiple patents—or remain outside and negotiate later. The equilibrium reflects a trade-off between reducing an implementer's "outside exposure" and preserving bargaining leverage. Collective free-riding benefits arise as delaying patentees secure higher bargaining surpluses, which can lead to coordination failure and inefficient adoption. The benefits of delaying licensing hold even when courts use ex ante licenses as comparables for ex post damages. We extend the model to include asymmetric patent valuations, potential patent lurkers, and transaction costs. We show that patentees benefit from low-quality patent holders negotiating earlier, comparable royalties do not deter lurking, and transaction costs can encourage pool formation.

JEL Code: K2, O3

Keywords: Patent pools; FRAND; patents; royalties; standards; technology adoption.

*This is preliminary and incomplete. Please do not cite.

†Cornell University. Email: enh38@cornell.edu

‡University of Illinois at Urbana-Champaign. Email: jalemus@illinois.edu.

§University of Georgia. Email jlturner@uga.edu

1 Introduction

As technology evolves, products become more complex and require the combination of complementary technologies. For example, smartphones incorporate technologies that may be cover by over 250,000 patents.[1] Innovators developing products that integrate multiple technologies often struggle to secure preemptive licensing agreements for every relevant patent their products might infringe.

A prominent example is standardized technology, such as cellular (3G/4G/5G) or Wifi. Notably, Baron et al. (2023) show that standard-essential patent (SEP) owners rarely make unilateral, ex-ante licensing commitments; instead, they typically initiate bilateral licensing an average 2-4 years *after* implementation. On the other hand, implementers rarely approach SEP owners, even though they can identify them through public databases where patents are declared as standard-essential.[2] Implementers may also struggle to identify owners of potentially infringing patents not declared as standard-essential (Contreras, 2016; Mattioli, 2018).[3]

All these factors create significant risk for technology implementers. Patent pools—agreements where multiple patent owners license their patents as a package—offer a potential solution to this problem. Although SEP owners do sometimes coordinate to form patent pools, they often do not include all the standard-essential patents (Baron et al., 2023). Implementers typically must expect to negotiate both with a pool and, in addition, with individual patent holders.[4] Despite the relevance of this question, our understanding of a patent holder's motivation for how to licensing its technology (through a pool or individually) remains limited.

We propose a model of technology adoption and licensing timing to shed light on pool formation and licensing incentives. We study a dynamic game where a technology implementer chooses among alternative technologies and multiple patentees simultaneously choose whether to join a pool. The implementer's choices are an entirely safe (public domain) technology

[1] See https://www.nytimes.com/2012/07/30/technology/apple-samsung-trial-highlights-patent-wars.html

[2] Publicly available databases maintained by Standards Development Organizations (SDOs) list patent holders that have declared their patents as essential to a specific standard.

[3] Currently, over 3 million patents are in force in the United States, each with an average of 16 claims, which are subjective statements. Innovators face infringement risks even if they could evaluate each claim in every patent in force. In practice, innovators lack the resources to perform this risk assessment, and may expose themselves to treble damages, challenging the traditional assumption that they can identify relevant patents (Lemley, 2008).

[4] Examples of pools include MPEG LA (Video Compression), Via Licensing (Audio & Wireless), Avanci (IoT & Automotive), and One-Blue (Blu-ray Disc). See more details in Appendix B. Precise contract terms vary and are not typically disclosed, but in each of these cases a licensee may negotiate a single license that grants use of multiple patents.

and an alternative standardized technology that yields a higher gross payoff but requires securing multiple patent licenses. Crucially, however, the implementer cannot force patentees to bargain over licenses prior to technology adoption. Implementers of often adopt a "wait and see" strategy instead of proactively seeking SEP licenses.[5]

In our baseline setting, the key tension is between endogenous pool formation and technology adoption. Symmetric patentees decide simultaneously whether to join the pool, which offers implementers a single license for multiple patents before technology adoption. The larger the fraction of patents covered by the pool license, the less is the implementer's *outside exposure* to non-pool patentees (who sue for infringement after technology adoption). By joining the pool, a patentee reduces the outside exposure, which helps secure the implementer's adoption of the standardized technology. Importantly, pool patentees bargain with the implementer ex ante, when the implementer has the leverage of credibly threatening to adopt the safe technology. As a result, they earn relatively low royalties.

By staying out of the pool, a patentee may be able to free ride off the commitment effects of a pool license. Intuitively, an implementer will pay for a pool license only if it is profitable to adopt the standardized technology accounting for the outside exposure. Thus, after paying for the pool license, it has less bargaining leverage with the remaining patentees. Thus, if the implementer pays for a pool license and adopts the standardized technology, a non-pool patentee can negotiate a more favorable royalty.

As this is a game of coordination, there are multiple equilibria. Efficient equilibria are characterized by a *minimum sufficient pool size* that guarantees efficient technology choice. This minimum size keeps the outside exposure low enough to make adoption of standardized technology profitable. If fewer patentees than this number join the pool, the implementer adopts the safe technology to avoid the excessive outside exposure. The minimum sufficient pool size is zero when expected court-imposed royalties (the unit cost of outside exposure) are very low and increases with the level of those expected royalties. For sufficiently high expected royalties, no outside exposure is tolerable for the implementer, who adopts the standardized technology only if all patentees join the pool.

Interestingly, the *average* patentee's payoff (in an efficient equilibrium) remains higher than what a patentee would earn if *all* patentees approached ex ante and formed one large pool.

[5]This can avoid establishing evidence of willful infringement while leaving room to accept fair terms later. It also enables immediate use of the technology with delayed royalty payments. Moreover, negotiating with each SEP holder individually is impractical due to high transaction costs. Finally, if competitors also delay licensing, a firm avoids incurring an early cost disadvantage and can speed its product launch while maintaining stronger bargaining power if alternatives arise.

Intuitively, the existence of some outside exposure helps patentees by reducing the bargaining surplus in the pool bargain, lowering the implementer's payoff. Thus, there is also a collective gain from having some patentees delay and free-ride.

Unfortunately, too much outside exposure leads to inefficient adoption, and this can occur in equilibrium. In such a case, the number of patentees that join the pool is below the minimum sufficient size by two or more and the implementer chooses the safe technology. This is an equilibrium because no delaying patentee can unilaterally reduce the outside exposure enough by joining the pool to make it profitable for the implementer to adopt the standardized technology.

We next consider a regime of comparable licenses, where courts use the price of prior licenses to determine royalties in current disputes. The use of comparables is common in determining patent damages in general, but is particularly salient in determining fair, reasonable and non-discriminatory (FRAND) royalties for SEPs.[6] Comparables can also alleviate the implementer's additional risks from opaque pricing of patent licenses, even when patent holders are subject to FRAND terms (Lemley and Myhrvold, 2008; Love and Helmers, 2023).[7] In our model, the use of comparables ensures that all delaying patentees receive the same royalty payments as the patentees that approach ex ante.

This policy affects equilibrium in two main ways. First, it eliminates all inefficient equilibria, thereby guaranteeing efficient technology adoption. Just one ex ante negotiation with one patentee is required to set a comparable rate. This rate must trigger the implementer to adopt the standarized technology (otherwise, every patentee would get zero), after accounting for every future negotiation with patentees that delay licensing. Thus, the rate that emerges in equilibrium must reduce the cost of outside exposure to a level that guarantees the implementer a positive payoff from adopting the standardized technology. As a result, a pool with just one patentee is sufficient to ensure a comparable license rate that yields efficient technology adoption. In other words, the minimum sufficient pool size is one, so every patentee is pivotal and can unilaterally ensure efficient adoption by joining the "pool" and approaching for an early license. Thus, inefficient equilibria do not exist with comparables. Moreover, the use of comparables obviates the need for a FRAND policy, as courts can simply use ex ante license payments to determine ex post license payments. Symmetry and complete information are central for this result.

[6] For example, comparables were used in FRAND determinations in *Microsoft v. Motorola* [2013 WL 2111217], *In RE: Innovatio* [MDL Docket No. 2303 (ND Ill. Sep. 27, 2013)], *Unwired Planet v. Huawei* ([2017] EWHC 711 (Pat), United Kingdom), and many others. See Siebrasse and Cotter (2017).

[7] Lemley and Myhrvold (2008) characterize markets for patent licenses as "blind," while Love and Helmers refer to "... a near vacuum of public pricing information."

Second, patentees continue to benefit collectively from having some patentees delay. This is a bit harder to see, because the presence of comparables removes the discrepancy in royalty payments among patentees. Moreover, if the pool size is at the minimum sufficient level for efficient equilibrium without comparables, using comparables leads to lower average royalties for patentees and higher benefits for implementers. Intuitively, the equilibrium royalty with comparables must lie below the ex post royalty without comparables, because otherwise royalties would be so excessive that the implementer would adopt the safe technology. Thus, because royalties paid to patentees that delay are lower, the equilibrium bargaining surplus in the pool bargain is higher with comparables.

The reason patentees may still gain from comparables is because there is no need for a large pool—just one ex ante bargain will suffice to ensure the implementer adopts the standardized technology. And because the pool bargains ex ante to technology adoption, patentee payoffs are increasing in outside exposure. Intuitively, the bargaining surplus is higher when outside exposure is higher, so the implementer gains when there are more patentees in the pool. Thus, patentees have strict incentives to stay out of the pool as long as one patentee is in the pool. As a result, in equilibrium just one patentee joins the pool. Moreover, since every patentee receives the same royalty, each one is indifferent between being the single patentee in the pool or one of the outsiders.

Thus, in equilibrium with comparables, the pool size is typically lower. As a result, patentee payoffs may actually be higher with comparables when compared to payoffs without comparables conditional on an efficient equilibrium. The easiest way to see this is to consider the case where expected royalties under litigation are so high that, without comparables, the implementer will adopt the standardized technology only if all patentees join the pool. In that case, the ex ante bargaining surplus is the full incremental value of the standardized technology. But with comparables, a pool of just one patentee is sufficient to ensure adoption, so the ex ante bargaining surplus is, due to the outside exposure, lower than the incremental value of the technology. These collective free-riding benefits are entirely novel in the literature.

We consider multiple extensions. First, we consider the possibility of asymmetric patent valuations. In this extension, different patentees expect courts to impose different royalties in an infringement suit. The outside exposure facing a developer then accounts for the total royalties, and changes based on the composition of the patent pool (not just its size). Without comparables, it remains the case that multiple equilibria may exist. This is mitigated somewhat, however, by the presence of high-quality patent owners. By joining the pool, such an owner can reduce outside exposure by comparatively more than other patentees. Indeed, efficient equilibrium may rely on high-quality patentees joining the pool.

With comparables, by contrast, high-quality patentees do not typically negotiate ex ante. Recall that it is necessary to license just one patent ex ante to secure the implementer's adoption of standardized technology. It remains the case that the average patentee payoff is maximized when outside exposure is maximized. With asymmetric patent values, this occurs when the patentee with the least-valuable patent negotiates ex ante with the implementer.

A second extension analyzes additional incentives to delay emerge if the implementer does not know all relevant patentees initially. In Hovenkamp et al. (2024), we analyze such a framework for a single product implementer and a single (possible) non-producing patentee. Here, we enrich this framework to capture the case of technology with multiple complementary inputs and patents, where pooling and coordination play a central role. A patentee that is unknown to the implementer may prefer to lurk (remain unknown) until after the implementer's technology adoption decision. The need to eliminate outside exposure may prompt patentees to reveal themselves. However, if comparables are used, an unknown patentee is always better off lurking.

Lastly, we study the impact of transaction costs. It is well known that patent pools may economize on transactions costs (Merges, 2001; Heald, 2005; Merges and Mattiolo, 2017), helping to overcome the so-called "anti-commons problem" (Heller and Eisenberg, 1998). In shutting this dimension down, our baseline model highlights an additional way that pools help ensure efficiency—by securing for implementers a set of relatively cheap licenses. We also show why an incomplete pool may be sufficient to accomplish this. Interestingly, large pools enhance efficiency only for the case without comparables.

To further highlight these phenomena, we consider an extension with positive transaction costs. This creates an additional basis for a patentee to join a pool, as joining directly reduces its own total transaction costs. This effect grows with the number of patentees in the pool. Not surprisingly, we find that complete pools are unique in equilibrium for sufficiently high transactions costs. However, if transaction costs are positive but low, patentees may still gain by staying out of the pool. When they do, the equilibrium pool may be quite small and when the pool is small, the average patentee payoff is higher than with a full pool. This effect is particularly pronounced when comparable licenses are used. Indeed, for intermediate levels of transaction costs, the only pools that may form in equilibrium are the very smallest (which maximize patentee payoffs) and very largest (which maximize implementer payoffs and total welfare).

1.1 Related Literature

Patent pools can solve the "patent thicket" or "anticommons" problem, wherein too many fragmented rights can block innovation (Heller and Eisenberg, 1998). Our model features patents for complementary technologies. Lerner and Tirole (2004) show that pools that bundle complementary technologies can be welfare-enhancing.

Deciding whether to join or form a patent pool involves strategic trade-offs. Firms contributing patents to a pool can trigger a broader adoption of the standard but they must share licensing revenue and cede some control over pricing. Patent holders voluntary incentives to join a pool hinge on the pool's rules (e.g., profit sharing). Layne-Farrar and Lerner (2011), Lerner et al. (2007), and Brenner (2009), among others, have studied pool rules and participation incentives. In our model, we assume the pool adopts a proportional sharing rule.

Patent pools can also impact innovation incentives. Choi and Gerlach (2015) show that patent pools may harm innovation by encouraging the filing of weaker patents but may tend to increase the filing rates of patents. Lampe and Moser (2010) show that the formation of a sewing machine patent pool in the 19th century was followed by a decrease in innovation. Lampe and Moser (2016) provide additional evidence that pools reduced subsequent patenting activity. They argue that patent pools formed before 1945 often bundled substitutable patents, thereby dampening technological rivalry. In contrast, more recent studies in high-tech industries suggest patent pools can encourage innovation under the right conditions. Baron and Pohlmann (2015) examine pools in ICT standards and find that the announcement of a new pool is associated with a significant increase in patenting rates for that standard, primarily by companies that anticipate joining the pool.

Pool outsiders in our setting engage in patent hold-up, allowing them to extract a royalty exceeding the patent's value ex ante when alternatives existed (Melamed and Shapiro, 2018). In other words, once manufacturers are locked into using a technology, they are willing to pay much more for a license than they would have early on, before lock-in. Parcu et al. (2025) show that if bargaining power is not too skewed, agreeing on licenses ex-ante (before products launch) is often mutually beneficial and yields royalties closer to the true value of the technology.

More broadly, delay can also be strategic in more pernicious ways, including "submarine patents," where applicants delayed patent issuance to surface only after an industry standard emerged (Righi and Simcoe, 2023), and "patent ambushes," where a participant in a standards committee fails to disclose a relevant patent during the standard's development (Royall et al., 2008), or more generally uncertainty about potential threats (Hovenkamp et al., 2024). On the other side of the coin, implementers can engage in strategic delay too, a behavior often called patent "hold-out" or "reverse hold-up". Hold-out refers to manufacturers using a patented technology without licensing and stalling negotiations or litigation as long as possible, to pressure the patent owner into lower rates or even to invalidate the patents (Llobet and Padilla, 2023). Also, implementers may collectively refuse licenses, betting that the patent owner's threat of injunction is limited, especially under FRAND obligations (Siebrasse, 2019).

The use of comparables has interesting feedback effects on licensing incentives (Sidak, 2016). Because FRAND includes a non-discrimination element, if a patent holder gives one implementer a particularly low rate, other implementers can insist on similar terms. This might make patentees reluctant to drop prices for the first mover ("courting the market") or to settle cheaply with one licensee, since it sets a precedent. Conversely, if a patent holder secures a high royalty in one agreement (perhaps with a smaller player or in a litigation settlement), they will likely present that as a benchmark for all others (Deng et al., 2017).

2 The Model

Consider a single risk-neutral implementer who chooses to adopt one of two technologies, A or B. For simplicity, we assume that technology adoption is irreversible. The market value of A is $(1-\bar{\rho})\pi$, where $\bar{\rho} \in (0,1)$. Technology A is in the public domain, so there is no patent infringement risk by using it. Technology B has a higher market value, π. The parameter $\bar{\rho}$ measures B's incremental value relative to A, $\bar{\rho}\pi$. Technology B is a bundle of T perfect complements, so a implementer must use all of them when adopting B. Each component $t \in \{1, 2, ..., T\}$ is covered by a single patent owned by an independent, non-practicing patent holder. Each patentee prevails in litigation with probability θ, which can be viewed as a measure of patent strength. If the patentee wins in litigation, it gets damages of $r\pi$, where $r \in [0,1]$ is the royalty rate set by the court. It is convenient to work with the *expected* royalties $\rho \equiv \theta r$ that the patentee would obtain in litigation. An alternative to litigation is to settle the lawsuit. In that case, we assume that the license fee is set via Nash bargaining under complete information, where $\beta \in [0,1]$ is the patentee's bargaining ability. Litigation costs are normalized to zero, so the implementer pays the patentee the expected royaly $\rho\pi$. Motivated by the fact that implementers almost never approach patentees for ex-ante licensing, we assume that only patent holders initiate licensing negotiations. All patentees are risk neutral and know about the implementer. Without loss, we henceforth normalize $\pi = 1$.

The timing of the game is the following. First, patentees simultaneously choose to either contribute their patents to form a patent pool or remain as independent patentees. Those patentees that contribute their patents to form a patent pool approach the implementer before the adoption of A or B (i.e., ex-ante bargain) and negotiate patent licenses as a coalition. Pool members split the ex ante bargaining surplus with the implementer, keeping share β for themselves. Upon completing this bargain, the implementer then chooses which technology to adopt based on the patent pool size, considering that the remaining independent patent holders will sue for patent infringement, each one costing in expectation ρ to the implementer.

We solve this game using backward induction.

Proposition 1. *We have:*

1. *Let $\rho \leq \frac{\bar{\rho}}{T}$. Then there is a multiplicity of equilibria. Each patentee is indifferent between forming a pool or not, and the implementer always adopts B.*

2. *Let $\frac{\bar{\rho}}{T-k+1} < \rho < \frac{\bar{\rho}}{T-k}$, for $k \in \{1, ..., T-1\}$.*

   (a) *If $k = 1$, there is a unique pure-strategies equilibrium (up to the patentees' identities). Only one patentee bargains ex-ante (a pool of size one) and the implementer adopts B.*

   (b) *If $k > 1$, then there are multiple pure-strategies equilibria that may be efficient or inefficient. In an efficient equilibrium, k patentees form a pool and the implementer adopts B. In an inefficient equilibrium, strictly fewer than $k-1$ patentees form a pool, and the implementer adopts A.*

3. *Let $\rho \geq \bar{\rho}$. Then there is a multiplicity of equilibria.*

   (a) *There is a unique efficient equilibrium (up to the patentees' identities) where all patentees form a pool and the implementer adopts B.*

   (b) *There are inefficient equilibria in which strictly fewer than $T-1$ patentees form a pool and the implementer adopts A.*

Anticipating the infringement threats, the implementer knows that, unless it reaches a deal before adoption with some patentees, it is liable for $T\rho$ when adopting B. If $T\rho < \bar{\rho}$, adopting B is strictly dominant for the implementer, so every patentee gets ρ.

When $T\rho > \bar{\rho}$, however, the patentee will adopt A *unless* it reaches a deal to pay less than ρ for licensing the technologies of some patentees. For this to happen, there is a *minimum sufficient pool size* (MSPS) of size k whenever $\rho > \frac{\bar{\rho}}{T-k+1}$. If the pool is smaller than this, say $j < k$, then the developer faces *outside exposure* to $(T-j)$ patentees that will sue for total damages of $(T-j)\rho > \bar{\rho}$, so that adoption of standardized technology is unprofitable even with a free pool license.

The simplest of these cases occurs where $\rho > \bar{\rho}$, in which case the minimum sufficient pool size is T. In that case, all patentees form a pool and bargain with the implementer. The patentees split the bargaining surplus $\beta\bar{\rho}$, so that each patentee earns a royalty of $\frac{\bar{\rho}}{T}$. The implementer then earns $(1-\beta)\bar{\rho}$. This case serves as a benchmark for the remaining cases, where patentees may be able to earn higher payoffs.

Now consider $\rho \in \left(\frac{\bar{\rho}}{T}, \bar{\rho}\right)$. Fundamentally, the need for an MSPS reflects a potential *royalty stacking* problem. The implementer wants to avoid overpaying, so if too few patentees form a pool, the implementer will adopt A and the outcome will be inefficient.

As an illustration, consider the case of $T = 3$ and $\rho \in \left(\frac{\bar{\rho}}{3}, \frac{\bar{\rho}}{2}\right)$. If all three patentees form a patent pool and bargaining were to break down, then the implementer could credibly threaten to adopt A because it would expect to pay 3ρ in royalties in subsequent litigation. Thus, the bargaining surplus is $\bar{\rho}$, and the patentees would split it with the implementer. Each patentee would earn $\frac{\beta\bar{\rho}}{3}$ and the implementer would then adopt B. Alternatively, But by staying out of the pool, a patentee could earn a higher payoff of ρ. Thus, there is no equilibrium with a full-participation patent pool.

There is also no equilibrium with a two-patentee pool. As before, free-riding incentives ensure this, but the payoffs are slightly different. With a two-patentees pool, the bargaining surplus is $(\bar{\rho}-\rho)$ given that the one patentee that is not in the pool expects to receive ρ in subsequent litigation. The two patentees in the pool, each expect to receive $\frac{\beta(\bar{\rho}-\rho)}{2}$. But again, by staying out of the pool while one other patentee chooses to bargain ex-ante with the implementer, a patentee could earn a higher payoff of ρ. Finally, there can be no equilibrium with all patentees choosing to delay approaching the implementer until after the adoption decision has been made because the implementer would adopt A. Thus, the equilibrium is unique in pure strategies (up to the identity of the patentees).

Now, if the $\rho(T-1) > \bar{\rho}$, there are multiple pure-strategy equilibria. Continue to assume $T = 3$ but now let $\rho \in \left(\frac{\bar{\rho}}{2}, \bar{\rho}\right)$. In an efficient equilibrium, two patentees form a pool while the third patentee stays out of the pool, free-riding and earning a higher payoff. In an inefficient equilibrium, there is no patent pooling, so no patentee chooses to bargain ex-ante. This is an equilibrium because none of the patentees can unilaterally alter the outcome by negotiating ex-ante. Thus, there are inefficient equilibria arising from *miscoordination* by the patentees.

Multiple patentees can also create inefficient equilibria in mixed-strategies. Here, the incentive to free-ride creates a coordination problem that can lead to inefficiency.

Proposition 2. *For $\rho > \bar{\rho}$ there is no symmetric equilibrium in mixed strategies. When $\frac{\bar{\rho}}{T} < \rho < \bar{\rho}$, there always exist inefficient symmetric mixed-strategy equilibria in which patentees join a pool with probability $1 - \delta^* \in (0, 1)$ and the implementer does not always adopt B.*

As an illustration, consider the case of $T = 2$. Our previous results show: (1) for $\rho < \frac{\bar{\rho}}{2}$, adopting B is strictly dominant; (2) for $\rho \in \left(\frac{\bar{\rho}}{2}, \bar{\rho}\right)$, there is an efficient equilibrium in pure strategies in which only one patentee chooses to bargain ex-ante with the implementer, and the implementer adopts B. There is also an *inefficient* symmetric mixed-strategies equilibrium in which patentees join a pool with probability

$$1 - \delta^* = \left(\frac{\beta(\bar{\rho} - \rho)}{\rho(1 - \beta) + \frac{\beta\bar{\rho}}{2}}\right).$$

Note that this drops to zero as $\rho \to \bar{\rho}$. The average patentee payoff from this equilibrium is below the average payoff in the pure-strategy equilibrium, and goes to zero as $\rho \to \bar{\rho}$.

The following Corollary characterizes payoffs for patentees in efficient equilibria.

Corollary 1. *Let $\frac{\bar{\rho}}{T-k+1} < \rho < \frac{\bar{\rho}}{T-k}$ for $k \in \{1, ..., T-1\}$. Then, in the efficient equilibrium where k patentees form a patent pool, those forming the pool get an expected payoff of*

$$V_{Pool} = \beta\left(\frac{\bar{\rho} - (T-k)\rho}{k}\right),$$

and those that are out of the pool get ρ, where $\rho > V_{Pool}$. Moreover, the average payoff among all patentees is

$$\bar{V} = \frac{kV_{Pool} + (T-k)\rho}{T} = \left(\frac{\beta\bar{\rho} + (1-\beta)(T-k)\rho}{T}\right),$$

where $\bar{V} > \left(\frac{\beta\bar{\rho}}{T}\right)$ for any $\beta < 1$.

To see the intuition, suppose the implementer negotiates with patentees that form a pool of size k, in an efficient equilibrium. Given these characteristics, the implementer anticipates paying a royalty in excess of $\frac{\bar{\rho}}{T-k+1}$ to each patentee not in the pool. In the bargain with the pool, the bargaining surplus is then likewise smaller than $\left[\bar{\rho} - (T-k)\left(\frac{\bar{\rho}}{T-k+1}\right)\right] = \frac{\bar{\rho}}{T-k+1}$, which implies that each pool patentee is paid less than $\frac{\beta\bar{\rho}}{(T-k+1)k} \leq \frac{\beta\bar{\rho}}{T}$. Essentially, the implementer will adopt B only if it secures cheap licenses from the pool. As a result, patentees that strategically delay in such an equilibrium gain by free-riding off the patentees in the pool.

More surprisingly, free-riding also pays collectively. The average patentee payoff is higher than the payoff that would accrue if all patentees formed a pool. Or, stated differently, the implementer's total royalty payment is higher and its profit is lower than it would be if all patentees formed a pool. Intuitively, expected payments to patentees outside the pool subtract directly from the bargaining surplus. As discussed above, the bargaining surplus in an efficient equilibrium is smaller than $\frac{\bar{\rho}}{T-k+1}$, which is itself bounded above by $\bar{\rho}$. This means that when some patentees stay out of the pool, this holds the implementer's payoff below $(1-\beta)\bar{\rho}$. Thus, if the patentees were to coordinate among themselves, they would benefit (on average) if some form a pool while others strategically delay licensing.

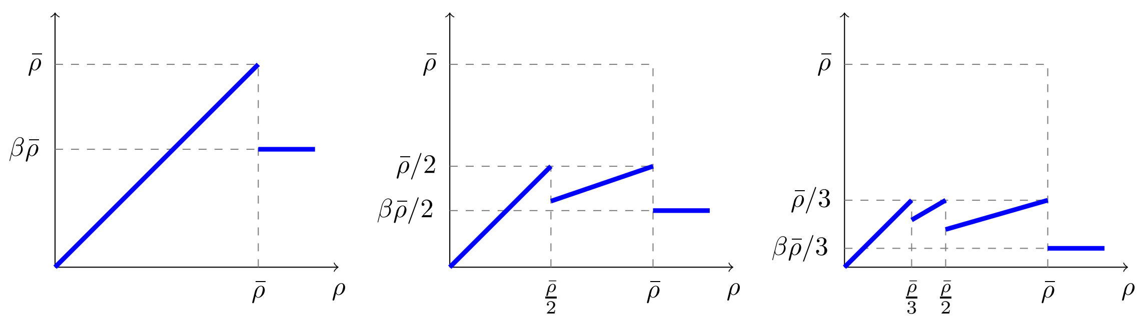

Figure 1: Average patentee payoff in the efficient equilibrium for different number of patents: $T = 1$ (left), $T = 2$ (middle), $T = 3$ (right).

Equilibrium average patentee payoffs for efficient equilibria with $T \in \{2, 3\}$ are highlighted in Figure 1, alongside the $T = 1$ case from Hovenkamp, Lemus and Turner (2024). The regions for $\rho \in \left(\frac{\bar{\rho}}{T}, \bar{\rho}\right)$ yield the novel free-riding incentives and create additional non-monotonicity of payoffs. In this region, the average patentee payoff exceeds the payoff under coalition bargaining. Only for $\rho > \bar{\rho}$ does the coalition payoff obtain.

From the perspective of the implementer, when the technology is made out of multiple components and the equilibrium is efficient, the implementer is be worse off whenever $\rho < \bar{\rho}$, and receives the same payoff for $\rho > \bar{\rho}$. To see this, note that for $\rho \leq \frac{\bar{\rho}}{T}$, the implementer pays $T\rho$ instead of ρ. For $\rho \in \left(\frac{\bar{\rho}}{T}, \bar{\rho}\right)$, the implementer pays $T\bar{V}$, which is larger than ρ for $\rho < \bar{\rho}$.

2.1 Comparable Licenses

In practice, an early license may serve as a *comparable transaction* for a second license. We examine how a comparable license affects royalties and incentives to form a patent pool.

First, if $\rho \leq \frac{\bar{\rho}}{T}$, the implementer does not have a credible threat to use the alternative technology, so every patentee receives ρ and the equilibrium is efficient.

Next, suppose $\rho > \frac{\bar{\rho}}{T}$ and that all patentees—regardless of whether they were part of the pool—continue to reach royalties via Nash bargaining, but under the constraint that all receive the same royalty rate R. Then, in the initial bargain with the pool, each patent holder in the pool must receive R anticipating that all patentees that are not in the pool will subsequently also receive R. This captures that if the bargains with patentees that delay their negotiation broke down, the court would impose the comparable royalty rate R determined in the early bargains. If $k \in \{1, ..., T-1\}$ patentees form a pool, the bargaining surplus from an early agreement is $(\bar{\rho} - (T-k)R)$, which captures that the $T-k$ patentees that are not in the pool will subsequently receive a royalty of R. The patent pool obtains a fraction β of this surplus, which is shared equally among its members. Thus, each one of the pool members receives a payoff of

$$\beta \frac{(\bar{\rho} - (T-k)R)}{k}.$$

We can pin down R by imposing that every patentee will receive the same royalty rate, that is, $R = \beta \frac{(\bar{\rho}-(T-k)R)}{k}$, which implies

$$R^* = \frac{\beta \bar{\rho}}{\beta T + (1-\beta)k}. \tag{1}$$

Importantly, the patentees' payoffs under comparable rates is the same for any $\rho > \frac{\bar{\rho}}{T}$, whereas without comparable rates it is non-monotonic in ρ in the efficient equilibrium (see Figure 1).

Holding k constant, we see three important phenomena. First, the comparable royalty lies between the pool and ex-post royalties from the non-comparable case. With comparables, the implementer cannot get as cheap a license from the pool. The reason is that it is impossible to make the "future" R large enough that the bargaining surplus is as low, because then the "present" R would also be large and the total would then exceed $\bar{\rho}$. Stated differently, to get the bargaining surplus to be as low (as without comparables), "future" R would need to exceed $\frac{\bar{\rho}}{T}$. But if it does, then the present bargaining surplus would be so small that Nash bargaining would dictate that the "present" license would need to be lower than future R. As a result, "future" R must fall and "present" R must rise, so that equilibrium R is between the pool and ex-post royalty payments from the non-comparable case.

Second, comparable licensing improves the implementer's payoff. The intuition is simple. Because equilibrium R with comparables is below the ex post royalty without comparables, the equilibrium bargaining surplus in the pool bargain is higher with comparables. It then follows that the comparable royalty lies below the average royalty from the non-comparable case, as the following Lemma shows.

Lemma 1. *Let* $\rho \in \left(\frac{\bar{\rho}}{T-k+1}, \frac{\bar{\rho}}{T-k+2}\right)$*, so that the minimum sufficient pool is of size* k*. For a pool of size* k*, the equilibrium royalty with comparable licenses is lower than size of the average royalty without comparable licenses. The implementer's payoff is likewise higher with comparables than without them.*

Third, patentee payoffs with $k < T$ continue to exceed the payoffs under the grand pool ($k = T$). Intuitively, with an incomplete pool, some of the ex ante bargaining surplus is lost to future royalties. This reduces the implementer's payoff and raises patentee payoffs.

It is easily seen from (2) that R^* is decreasing in k. Thus, patentee payoffs are highest with a pool of just one patent ($k = 1$). And with comparables, equilibrium obtains with the implementer adopting B and royalties following (2) when $k = 1$, because that single bargain internalizes all future payoffs so that the implementer's payoff is positive. Thus, when the patentees choose whether to join the pool non-cooperatively, *at most one will join the pool.* Their incentives to coordinate around strategic delay remain, because the patentees outside the pool guarantee a higher payoff. But because each patentee earns the same royalty, they all benefit the same way. Thus, strategic delay by some patentees effectively yields a collective free-riding benefit. We have the following result.

Proposition 3. *Consider a comparable license regime where licensing rates are constrained to be equal to earlier rates. If* $\rho \leq \frac{\bar{\rho}}{T}$*, no patentees join the pool and each is paid* ρ *in equilibrium. If* $\rho > \frac{\bar{\rho}}{T}$*, then just one patentee chooses to join the pool and the remaining patentees delay. The equilibrium royalty is*

$$R^* = \frac{\beta\bar{\rho}}{\beta T + (1-\beta)}.$$

Thus, with comparables, the equilibrium royalty is achieved with $k = 1$, whereas without comparables, k may be higher. Thus, by reducing the pool size, the use of comparables may increase the average patentee payoff and decrease the implementer's payoff.

Corollary 2. *If $\rho < \frac{\bar{\rho}}{T}$, then the use of comparable licenses has no effect on the implementer's payoff. If $\rho \in \left(\frac{\bar{\rho}}{T}, \bar{\rho}\right)$, then if the minimum sufficient pool size $k < (1-\beta)T + \beta$ (absent comparables), the implementer's payoff is higher under the use of comparables. If $\rho > \bar{\rho}$, then (conditional on efficient equilibrium without comparables) the use of comparable licenses decreases the implementer's payoff.*

Consider an example with $T = 10$, $\beta = .5$ and $\bar{\rho} = 0.2$. Suppose first that $\rho \in (.02, .022)$, so that the minimum sufficient pool is of size 1. With comparables, each patentee earns a royalty of 0.0181 and the implementer earns 0.818. Without comparables, the average patentee earns at least 0.019 and the implementer earns at most 0.81. For higher ρ the equilibrium payoffs with comparables do not change because a pool of size 1 obtains. But payoffs do change without comparables. For $\rho > .033$, the minimum sufficient pool is at least of size 6. In that case, the average equilibrium royalty may be above or below 0.0181 depending upon ρ (recall the non-monotonicity). Finally, if $\rho > 0.2$, then the implementer's payoff is unambiguously higher *without* comparables. With comparables, the implementer continues to pay each patentee 0.0181 and earns 0.818 in equilibrium. But without comparables, a complete pool forms in the efficient equilibrium. Each patentee is paid a royalty of 0.01 and the implementer's profit is higher, at 0.9. Thus, under comparable royalties, the per-patentee payoff would be about 82% higher. Of course, there is some risk to the implementer without comparables, as there are inefficient equilibria. If one of these were to obtain, then the implementer would adopt A and earns 0.8.

3 Asymmetric Patentees

Suppose there are N patentees, indexed by $j = 1, ..., N$. Each patentee owns a patent portfolio of potentially infringing patents of heterogeneous quality. The implementer expects to pay $\eta_j \rho$ in damages to patentee j if litigation ensues. This generalizes the baseline framework, where $N = T$ and $\eta_j = 1$ for all $j = 1, ..., N$. We normalize $\sum_{j=1}^{N} \eta_j = T$.

Let $J_P \subset \{1, ..., N\}$ be the set of patent holders that pool their patents and negotiate with the implementer before technology adoption. If the implementer decides to adopt B after this negotiation, the expected payment the patent holders that stay out of the pool (henceforth "outsiders") is

$$\rho \sum_{j \notin J_P} \eta_j .$$

We call the term $\sum_{j \notin J_P} \eta_j$ the *outsider exposure.* Fixing ρ, the implementer to adopts B if the outsider exposure is sufficiently low. Specifically, the bargaining surplus from negotiating with the pool must be positive, so B is adopted whenever

$$S(J_P, \rho) \equiv \bar{\rho} - \rho \sum_{j \notin J_P} \eta_j \geq 0.$$

In that case, patent holder $j \in J_P$ in the pool receives a payment of

$$r_{\text{pool}} = \frac{\eta_j}{\sum_{j \in J_P} \eta_j} \beta S(J_P, \rho).$$

Note that payments are proportional to the contribution of patentee j to the pool.

An equilibrium is characterized by the implementer's adoption decision and each patent holder's decision of whether to join the pool. A key measure to characterize the equilibrium is the outsider exposure.

For a given value of ρ, the maximum outsider exposure that guarantees the implementer will adopt B is $\frac{\bar{\rho}}{\rho}$. Figure 2 illustrates this relationship, highlighting two points. The first point, $\frac{\bar{\rho}}{T}$, is the threshold value of ρ such that it is weakly dominant for the implementer to adopt B even if no patentee approaches to negotiate ex ante because $\bar{\rho} - \rho T \geq 0$. In fact, for $\rho \in \left[0, \frac{\bar{\rho}}{T}\right)$the equilibrium in this region is unique: the implementer adopts B and every patentee delays the licensing negotiation.

The second point highlighted in the figure is the minimum exposure with one outsider, that is $\frac{\bar{\rho}}{\eta_{\min}}$, where $\eta_{\min} \equiv \min_{j=1,\ldots,N}\{\eta_j\}$. This is the maximum value of ρ for which the implementer is still willing to adopt B if the patentee with the lowest exposure is outside the pool. For any ρ above this threshold, $\rho > \frac{\bar{\rho}}{\eta_{\min}}$ every patentee must join the pool for the implementer to adopt B. This is the unique efficient equilibrium. However, there are multiple inefficient equilibria: whenever there are two or more patentees are pool outsides. In this case, the outsider exposure is too large, and no unilateral deviation by any of the outsiders makes the implementer willing to to adopt B. Here, coordination failure leads to inefficient adoption.

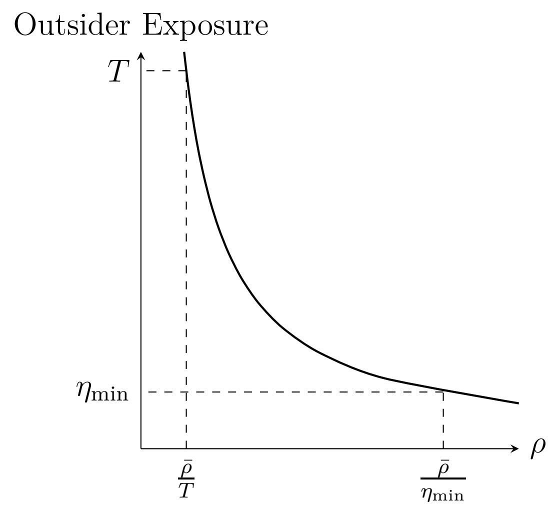

Figure 2: The figure shows the maximum outsider exposure that guarantees the implementer will adopt B for a given value of ρ.

For any $\rho \in \left(\frac{\bar{\rho}}{T}, \frac{\bar{\rho}}{\eta_{\min}}\right)$, there can be multiple equilibria both efficient and inefficient.

There are 2^N different possible subsets of outsiders. Let $\sigma(Z) = \sum_{j \in Z} \eta_j$ be the outsider exposure associated to $Z \subseteq \{1, ..., N\}$. It is easy to see that $Z_2 \subseteq Z_1 \Rightarrow \sigma(Z_2) \leq \sigma(Z_1)$. Moreover, $\sigma(\cdot)$ represents a partial order (complete and transitive) on the subsets of $\{1, ..., N\}$:

$$Z_1 \succeq Z_2 \Leftrightarrow \sigma(Z_1) \geq \sigma(Z_2).$$

For instance, $\sigma(\{j_{\min}\}) = \eta_{\min}$, where $j_{\min}$ is the patent holder with quality $\eta_{\min}$; $\sigma(\{1, ..., N\}) = T$ is the outsider exposure when everyone is an outsider, and $\sigma(\emptyset) = 0$, when everyone joins the pool. It is easy to see that different subsets of patent holders may yield the same outsider exposure. For example, suppose there are three patent holders with $\eta_i = i$, for $i = 1, 2, 3$. Then $\sigma(\{3\}) = \sigma(\{1, 2\}) = 3$.

To further characterize equilibria, we identify specific thresholds for ρ. For each subset of outsiders, $Z \subseteq \{1, ..., N\}$, we define the threshold value $\rho(Z) = \frac{\bar{\rho}}{\sigma(Z)}$, which we can sort as $\rho_1 \equiv \frac{\bar{\rho}}{T} < \rho_2 \leq ... \leq \rho_{2^N - 1} \equiv \frac{\bar{\rho}}{\eta_{\min}} < \rho_{2^N} = \infty$.

Consider a non-empty the interval $I_m = (\rho_m, \rho_{m+1})$, where $m = 1, ..., 2^N - 2$. For any $\rho \in I_m$, the implementer adopts B if the outsider exposure is less than $\frac{\bar{\rho}}{\rho} \in (\sigma(Z_m), \sigma(Z_{m+1}))$, where Z_m is the subset that defines the threshold $\rho_{m+1} = \frac{\bar{\rho}}{\sigma(Z_m)}$ (see Figure 3). We have the following result:

Lemma 2. *If the implementer adopts B regardless of whether patentee k joins the pool, then*

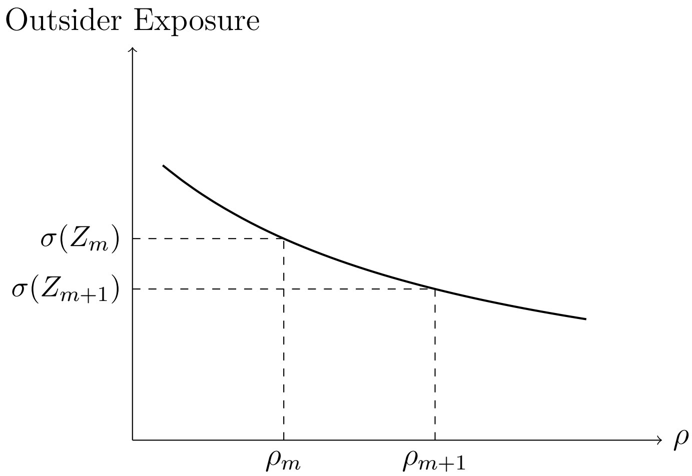

Figure 3: For any $\rho \in (\rho_m, \rho_{m+1})$, the maximum outsider exposure that guarantees the implementer will adopt B is $\frac{\bar{\rho}}{\rho} \in (\sigma(Z_{m+1}), \sigma(Z_m))$.

patentee k is better off being an outsider.

Note that this result hinges on the division of surplus among pool members. This may not be true if not proportional to η_j.

Proposition 4. *For $\rho \in I_m = (\rho_m, \rho_{m+1})$, where $\rho_{m+1} = \frac{\bar{\rho}}{\sigma(Z_m)}$. The implementer adopting B, patentees in $Z \subseteq \{1, ..., N\}$ being outsiders and $\{1, ..., N\} \setminus Z$ forming a pool is an equilibrium if each pool member if pivotal: $\sigma(Z) \leq \sigma(Z_{m+1})$ and for any $j \notin Z$, $\sigma(Z \cup \{j\}) \geq \sigma(Z_m)$.*

It is easy to see that there are many inefficient equilibria:

Proposition 5. *For $\rho \in I_m = (\rho_m, \rho_{m+1})$, where $\rho_{m+1} = \frac{\bar{\rho}}{\sigma(Z_m)}$. The implementer adopting A, patentees in $Z \subseteq \{1, ..., N\}$ being outsiders and $\{1, ..., N\} \setminus Z$ forming a pool is an equilibrium if for any $j \in Z$, $\sigma(Z \setminus \{j\}) \geq \sigma(Z_m)$.*

Example: Suppose there is a "large patentee" with quality η_B, and $N-1$ "small patentee" with quality $\eta_S \leq \frac{T-\eta_B}{N-1} \leq \eta_B$. Heterogeneity does not matter when $\rho \leq \frac{\bar{\rho}}{T}$, the unique the equilibrium is one where the implementer adopts B and no patentee joins a pool.

There are two type of possible subset of pool outsiders: subsets with only small players or subsets that include the large player. The value of $\sigma(Z)$ belongs to

$$\{0, \eta_S, 2\eta_S, \ldots, (N-1)\eta_S\} \cup \{\eta_B, \eta_B + \eta_S, \eta_B + 2\eta_S, \ldots, \eta_B + (N-1)\eta_S\}.$$

To avoid overlap of these numbers, suppose there are no integers $\ell \in \{0, ..., N-1\}$ and $k \in \{0, ..., N-1\}$ such that $\ell\eta_S = \eta_B + k\eta_S$. This implies that $\frac{\eta_B}{\eta_S} = \frac{\eta_B(N-1)}{T-\eta_B} \notin \{1, 2, \ldots, N-1\}$.

In that case, there are $2N$ distinct values of $\sigma(Z)$, leading to $2N$ distinct threshold values of ρ.

To set ideas, let $N = 3$, $\eta_S = 1$ and $\eta_B = 3$, so $T = 5$. There are 8 possible subsets leading to six different values of outsider exposure, $\sigma \in \{0, 1, 2, 3, 4, 5\}$, which partitions the value of σ into the intervals:

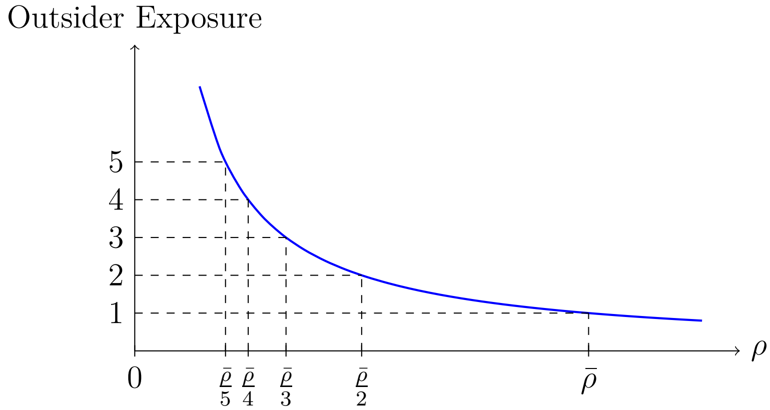

Figure 4: Example with one large patentee and two small ones

- Interval $(0, \frac{\bar{\rho}}{5})$: Equilibrium is efficient and unique. The implementer adopts B and nobody joins the pool; everyone is an outsider because outsider exposure less than $\frac{\bar{\rho}}{\rho} \geq 5$ guarantees that the implementer will adopt B.

- Interval $(\frac{\bar{\rho}}{5}, \frac{\bar{\rho}}{4})$: Equilibrium is efficient. A single patentee joins the pool (either one of the small patentees or the large patentee) and everyone else is an outsider. Outsider exposure less than $\frac{\bar{\rho}}{\rho} \geq 4$ guarantees that the implementer will adopt B.

- Interval $(\frac{\bar{\rho}}{4}, \frac{\bar{\rho}}{3})$: Equilibrium is efficient. A single patentee joins the pool (the large patentee) or the two small ones, or one small and one large. Outsider exposure less than $\frac{\bar{\rho}}{\rho} \geq 3$ guarantees that the implementer will adopt B. The large patentee guarantees the existence of an efficient equilibrium.

- Interval $(\frac{\bar{\rho}}{3}, \frac{\bar{\rho}}{2})$: Equilibrium is efficient and unique. Outsider exposure less than $\frac{\bar{\rho}}{\rho} \geq 2$ guarantees that the implementer will adopt B. This can be achieved by the large patentee joining the pool.

- Interval $(\frac{\bar{\rho}}{2}, \bar{\rho})$: Outsider exposure less than $\frac{\bar{\rho}}{\rho} \geq 1$ guarantees that the implementer will adopt B. This requires the large patentee a a single small patentee to join the pool. If nobody joins the pool, equilibrium is inefficient. If nobody joins the pool, outsider exposure is 5 and no single patentee can reduce the outsider exposure by more than 3. There also exists efficient equilibria where the large patentee and one small patentee join the pool.

- Interval $(\bar{\rho}, \infty)$: Every patentee must join the pool. Again equilibria can be efficient or inefficient.

Relative to the case of homogeneous small patentees ($N = 5$ and $\eta = 1$), heterogeneity increases the cases for which equilibria is efficient.

3.1 Comparable Royalties and Heterogeneity

As before, if $\rho \leq \frac{\bar{\rho}}{T}$, the implementer does not have a credible threat to use the alternative technology, patentee j receives $\rho\eta_j$ and the equilibrium is efficient.

For $\rho > \frac{\bar{\rho}}{T}$, suppose that the set J_P are the patentees in the pool. In the initial bargain with the pool, each patent holder $j \in J_P$ must receive $R\eta_j$ anticipating that all patentees that are not in the pool will subsequently also receive $R\sum_{j\notin J_P}\eta_j$. This captures that if the bargains with patentees that delay their negotiation broke down, the court would impose the comparable royalty rate R determined in the early bargains, adjusting for patent quality. Thus, the bargaining surplus from an early agreement is $\bar{\rho} - R\sum_{j\notin J_P}\eta_j$. The patent pool obtains a fraction β of this surplus, which is shared proportionally among its members. Thus, pool members j receives a payoff of

$$\beta\frac{\eta_j}{\sum_{j\in J_P}\eta_j}\left(\bar{\rho} - R\sum_{j\notin J_P}\eta_j\right).$$

We can pin down R by imposing that patentee j will receive the same royalty rate than subsequent litigants, that is, $R\eta_j$. This yields

$$R\eta_j = \beta\frac{\eta_j}{\sum_{j\in J_P}\eta_j}\left(\bar{\rho} - R\sum_{j\notin J_P}\eta_j\right)$$

which implies

$$R^* = \frac{\beta\bar{\rho}}{\sum_{j\in J_P}\eta_j + \beta\sum_{j\notin J_P}\eta_j}.$$

Since $\beta < 1$, it is easy to see that $R^* > \beta\frac{\bar{\rho}}{T}$. Also, since $\beta < 1$, the highest value of R^* is achieved making $\sum_{j\notin J_P}\eta_j$ as large as possible. This occurs when everyone except the patentee with the *lowest* quality is a pool outsider.

That is, patentees with higher-quality patents would be expected to delay negotiations in a regime with comparable royalties.

4 Residual Uncertainty

Suppose now there is some residual uncertainty for the implementer. Adopting B exposes the implementer to potential infringement of M additional patents owned by a single additional patentee, which we refer as the "potential" patentee.

Crucially, there is uncertainty about whether the potential patentee even exists. It does exist with probability $\lambda \in (0, 1)$.

The timing is the following. The potential patentee chooses between revealing itself, resolving the uncertainty about its existent for the implementer and the other pantees, or lurking and demanding royalties from the implementer after B has been adopted. If the potential patentee revels itself, then the patentees and the implementer play a game of complete information, analogous to the one described in the previous section.

Alternatively, if the potential patentee does not reveal itself, or does not exist, the implementer only is certain about T patentees. All players (the implementer and the T patent holders) form a symmetric belief that the potential patentee exists but it is lurking. This belief is given by Bayes rule

$$\hat{\lambda} = \frac{\lambda \ell}{\lambda \ell + 1 - \lambda},$$

where ℓ is the strategy of the potential patentee, which corresponds to its probability of lurking. Here, when the negotiations with the pool take place, the bargaining surplus must take into account the possibility of the lurking patent holder.

Simple case. Consider the simple case $T = 1$ and $M = 1$. That is, there is a single known patent holder, and one potential lurker. Figure 5 depicts the game. Initially, nature moves and creates an unknown patent threat for the implementer with probability λ. If that patent exists, the patentee chooses with probability ℓ to lurk until after the adoption decision, and with probability $1 - \ell$ reveals itself before technology adoption and pool formation.

There are two relevant scenarios for the implementer: (1) It observes a single (known) patentee, in which case form a belief $\hat{\lambda}$ that there is a lurking patentee (left branch in Figure 5); (2)

It observes two patentees, in which case all uncertainty about potential threats is resolved (right branch in Figure 5). In general, there can be multiple equilibria in the bargaining game in each one of these branches. The incentive to lurk depends on what equilibrium is selected.

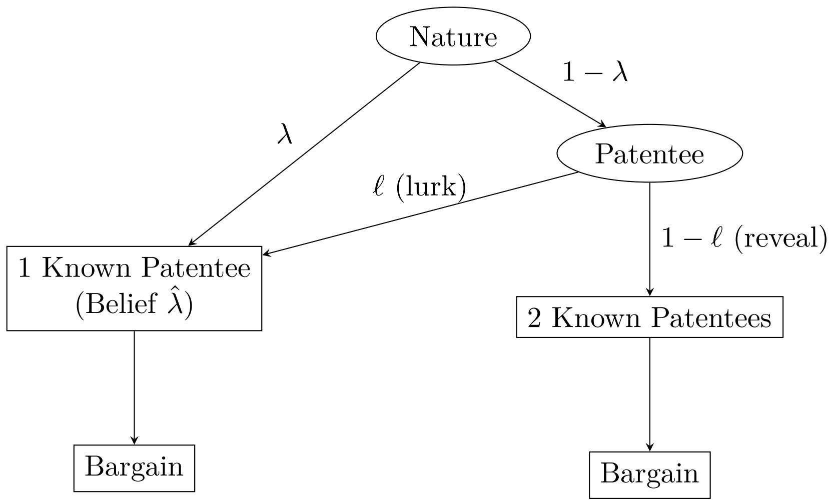

Figure 5: Description of the game.

Consider the bargaining game in the right branch. Here, we have two patentees and the (pure-strategy) equilibria features no pool formation if $\rho < \bar{\rho}/2$, and both patentees receive ρ. If $\rho \in (\bar{\rho}/2, \bar{\rho})$, only one patentee joins the pool. If that is the ex-ante known patentee, then the potential lurker receives ρ. If $\rho > \bar{\rho}$, the equilibrium is a full-coalition pool and each member receives $\beta\bar{\rho}/2$. In every region, equilibria is efficient: the implementer adopts B.

Consider the bargaining game in the left branch. Here, the implementer only the knows one patentee and forms a belief $\hat{\lambda}$ that there is a lurking patentee. The outcome of the bargaining game hinges on that belief. If $\rho < \bar{\rho}/(1+\hat{\lambda})$, the implementer adopt B and no patentee bargains ex-ante. If $\rho \in (\bar{\rho}/(1+\hat{\lambda}), \bar{\rho}/\hat{\lambda})$, the known patentee approaches the implementer; otherwise, the implementer adopts A. If $\rho > \bar{\rho}/\hat{\lambda}$, both patentees have to pool their patents otherwise the implementer will not adopt B.

Note that, in contrast to the case of no lurking patentees, the known patentee approaches more often because of the risk introduced by the potential lurker.

It is clear that if $\rho < \bar{\rho}/2$, there is indifference between lurking or reveling because even if the ex-ante unknown patentee reveals itself, it will not pool its patents.

If $\rho \in (\bar{\rho}/2, \bar{\rho})$ lurking may be profitable, depending on equilibrium selection. If the ex-ante known patentee is the one that bargains ex-ante, then lurking or revealing gives the same payoff, ρ. Otherwise, lurking is strictly profitable because $\rho > \beta(\bar{\rho} - \rho)$.

If $\rho \in (\bar{\rho}, \bar{\rho}/\lambda)$ lurking is strictly profitable, and the implementer adopt B.

If $\rho > \bar{\rho}/\lambda$, there is no pure-strategy equilibria. To see why, note that in this region both patentees must pool their patents for the implementer to adopt B. If $\ell = 1$ (lurking), the implementer adopts A, so it is profitable to deviate to $\ell = 0$ (reveal) to receive $\beta\bar{\rho}/2$ instead of 0. Now if $\ell = 0$, when the implementer only observes the known patent holder it assumes that there is no lurker (otherwise, it would have approached). Therefore, $\hat{\lambda} = 0$. But in this case, a single patentee is enough for the implementer to adopt B, so deviating to lurking is strictly profitable.

Equilibrium here must be in mixed strategies: the ex-ante unknown patentee (if exists) lurks with probability ℓ^* such that the implementer is indifferent between adoption A or B. That is,

$$1 - \bar{\rho} = 1 - (1 - \beta)(\bar{\rho} - \hat{\lambda}\rho) - \hat{\lambda}\rho \Rightarrow \ell^* = \frac{\rho(1 - \lambda)}{\lambda(\rho - \bar{\rho})}.$$

4.1 Comparable Royalty

A comparable royalty nullify the incentive to lurk. If $\rho \leq \frac{\bar{\rho}}{T}$, the implementer does not have a credible threat to use the alternative technology, so every patentee receives ρ and the equilibrium is efficient.

Next, suppose $\rho > \frac{\bar{\rho}}{T}$. Suppose that k known patent holders pool their patents and bargain ex ante. The expected bargaining surplus from an early agreement is $(\bar{\rho} - (T - k + \hat{\lambda})R)$, which captures that the $T - k$ patentees that are not in the pool will subsequently receive a royalty of R and wuth probability $\hat{\lambda}$ the lurking patentee also receives R. The patent pool obtains a fraction β of this surplus, which is shared equally among its members. Thus, each one of the pool members receives a payoff of

$$\beta\frac{(\bar{\rho} - (T - k + \hat{\lambda})R)}{k}.$$

We can pin down R by imposing that every patentee will receive the same royalty rate, that is, $R = \beta\frac{(\bar{\rho} - (T-k+\hat{\lambda})R)}{k}$, which implies

$$R^* = \frac{\beta\bar{\rho}}{\beta T + (1 - \beta)k + \hat{\lambda}}. \tag{2}$$

Lurking is always beneficial because makes $\hat{\lambda}$ as small as possible, which increases the royalty R. Hence, even with a potential lurking patentee, a comparable royalty does not void lurking incentives.

5 Transaction Costs

Define a *transaction* as an execution of one standalone agreement between the implementer and a set of patentees. When the implementer takes a pool license, that requires one transaction. An ex post license with a delaying patentee similarly requires one transaction. Thus, if $T = 10$ and $k = 5$, the implementer conducts six transactions.

Each transaction imposes a *transaction cost* of c on each side of the transaction, for a total cost of $2c$ per transaction. Thus, if $T = 10$ and $k = 5$, the implementer pays transaction costs totaling $6c$, each patentee in the pool pays transaction costs of $\frac{c}{5}$, and each of the five delaying patentees pays transaction costs of c.

Consider pool formation and the implementer's adoption decision. First consider the case $\rho \leq \frac{\bar{\rho}}{T} - c$, in which case the implementer adopts B regardless of whether it secures a pool license. With positive transactions costs, we will see that the ex ante bargain is not trivial and pool formation affects payoffs. Suppose that k patentees join the pool, so that there are $T - k$ delaying patentees. Then if bargaining breaks down, the implementer expects to earn $_D = 1 - T(\rho + c)$ while each of the k pool patentees expect to earn $\rho - c$, for a total joint profit (implementer + k pool patentees) of $_0 = 1 - (T - k)\rho - (T + k)c$. If a bargain is reached for a total royalty payment of R_{Tot}, then the implementer expects to earn $_D = 1 - R_{Tot} - c - (T - k)(\rho + c)$, the k pool patentees jointly earn $R_{Tot} - c$, for a total joint profit (implementer + k pool patentees) of $_{Barg} = 1 - 2c - (T - k)\rho - (T - k)c$. The bargaining surplus is then $_{Barg} - _0 = 2c(k - 1)$. It is then easy to solve to find

$$R_{Tot} = k\rho + (2\beta - 1)(k - 1)c.$$

In the simple case where that each patentee earns (inclusive of transactions costs)

$$_P = \frac{R_{Tot} - c}{k} = \rho + c\left(\frac{(2\beta - 1)(k - 1) - 1}{k}\right).$$

Any patentee that delays licensing instead earns $\rho - c$. It is easy to show that the patentee's payoff from joining the pool is strictly higher unless $k = 1$, in which case the payoffs are equal.

Thus, we have two equilibria. In the good equilibrium, all patentees join the pool and earn gross payoff ρ. They split a single transaction cost and the implementer pays just one transaction cost. In the bad equilibrium, no patentees join the pool and earn the same gross payoff ρ, but each pays the transaction cost and the implementer pays Tc in transaction costs. Notice that if just one patentee chooses to join the pool, it becomes a strict best response for each other patentee to join the pool. We say that $k = 1$ is a *tipping point*, because for any equal or larger k, all patentees strictly prefer to join the pool and thus there is no equilibrium with k strictly between 0 and T.

Now consider the case $\rho > \frac{\bar{\rho}}{T} - c$, in which case the implementer adopts A if bargaining breaks down and the joint profit is ${}_0 = 1 - \bar{\rho}$. With k patentees joining the pool, total joint profit (implementer + k pool patentees) is ${}_{Barg} = 1 - 2c - (T - k)\rho - (T - k)c$, as was the case earlier. Then the bargaining surplus is $\bar{\rho} - 2c - (T - k)(\rho + c)$. It is then easy to show that the minimum sufficient pool size, to guarantee the bargaining surplus is positive, is k if

$$\rho \in \left(\frac{\bar{\rho} - (T - k + 1)c}{T - k - 1}, \frac{\bar{\rho} - (T - k + 2)c}{T - k} \right).$$

5.1 Comparables

With comparables and $\rho > \frac{\bar{\rho}}{T} - c$, it is simple to work out equilibrium. If bargaining breaks down, the implementer adopts A. Thus, with k pool patentees, the bargaining surplus is $\bar{\rho} - 2c - (T - k)(\rho + c)$. Thus, $R_{Tot} - c = \beta\left(\bar{\rho} - 2c - (T - k)(\rho + c)\right)$. This can be solved to find the individual royalty

$$R = \frac{\beta\bar{\rho} - (2\beta - 1)c - \beta(T - k)(\rho + c)}{k}.$$

Then setting $\rho = R$ and solving, we find

$$R_{Comp}(k) = \frac{\beta\bar{\rho} - (2\beta - 1)c - \beta(T - k)c}{\beta T + (1 - \beta)k}.$$

The patentee's payoff if it joins the pool as the k^{th} member is $R_{Comp}(k) - \frac{c}{k}$. If it stays out of the pool, it earns $R_{Comp}(k - 1) - c$. Because $\rho > \frac{\bar{\rho}}{T} - c$, the implementer will always choose A if the pool is empty. Thus, a given patentee will always join the pool if no other patentees are joining the pool. The interesting question is whether and when the pool is larger than size 1. For low c, $R_{Comp}(k)$ is decreasing in k. Thus, if c is sufficiently low, $R_{Comp}(1) - c > R_{Comp}(2) - \frac{c}{2}$. Then no second patentee joins the pool if just one other patentee is in the pool.

However, there might be another equilibrium with a full pool. With k other pool members, the payoff to staying out of the pool, $R_{Comp}(k) - c$, falls with k faster than the payoff from joining the pool, $R_{Comp}(k+1) - \frac{c}{k+1}$. Intuitively, the latter payoff falls slower both because R_{Comp} is decreasing and convex in k and also because the additional pool members reduce the patentee's share of the transaction cost when it is in the pool. Thus, for k higher than 1, the cutoff c such that the pool payoff is higher, is itself lower. And if it is optimal to join as the k^{th} member, it is also optimal to join as the T^{th} member.

Thus there are two critical values of c. For $c < \underline{c}$, the only pool that forms is the trivial $k = 1$ pool. For $c \in (\underline{c}, \bar{c})$, there are two equilibria—one with $k = 1$ and the other with $k = T$. The latter pool is welfare-efficient because transaction costs are minimized, while the former yields a higher payoff for patentees. For $c > \bar{c}$ there is just one equilibrium with $k = T$.

Consider an example with $T = 10$, $\beta = .5$ and $\bar{\rho} = 0.2$. Then if $c < .0005$, the only pool that forms is the trivial $k = 1$ pool. For $c \in (.0005, .0024)$, there are two equilibria—one with $k = 1$ and the other with $k = T$. For $c = .001$, the tipping point is $k = 5$ and this falls with c. For $c > .0024$, the tipping point reaches $k = 1$ so there is just one equilibrium with $k = T$.

Numerically, the two cutoffs $\underline{c}$ and $\bar{c}$ are 0.25% and 1.20% of the incremental value of the standardized technology $\bar{\rho}$. Thus, selection on the small-pool equilibrium can yield a sizable difference (10 percentage points plus) in total transactions costs.

6 Conclusion

We develop a dynamic model to analyze the interplay between technology adoption and licensing timing in environments where products rely on multiple standard-essential patents (SEPs). Our analysis shows that implementers face a trade-off: adopting a standardized technology is profitable only when a sufficiently large pool of patentees negotiate early, thereby reducing the implementer's exposure to costly bilateral negotiations. In contrast, if too few patentees join, the implementer opts for a safe, non-standardized technology. Moreover, our results show that when courts employ comparables to set royalty rates, even a pool as small as a single patentee can trigger efficient adoption while still preserving collective free-riding benefits for delaying patentees. Extensions of our model incorporating asymmetric patent valuations, potential patent lurkers, and transaction costs further underscore the complex strategic incentives that shape pool formation and licensing behavior. Overall, our findings offer insights into how policy and market structure can promote efficient SEP licensing in standardized industries.

7 References

Baron, Justus and Tim Pohlmann (2015) "The effect of patent pools on patenting and innovation-evidence from contemporary technology standards," *Unpublished Manuscript*.

Baron, Justus, Tim Pohlmann, Pere Arque-Castells, Amandine Leonard, and Eric Sergheraert (2023) "Empirical Assessment of Potential Challenges in SEP Licenses,"Technical report, European Commission.

Brenner, Steffen (2009) "Optimal formation rules for patent pools," *Economic Theory*, Vol. 40, pp. 373–388.

Choi, Jay Pil and Heiko Gerlach (2015) "Patent pools, litigation, and innovation," *The RAND Journal of Economics*, Vol. 46, pp. 499–523.

Contreras, Jorge L (2016) "When a stranger calls: Standards outsiders and unencumbered patents," *Journal of Competition Law & Economics*, Vol. 12, pp. 507–540.

Deng, Fei, Gregory K Leonard, and Mario A Lopez (2017) "Comparative Analysis of Court-Determined FRAND Royalty Rates," *Antitrust*, Vol. 32, p. 47.

Heald, Paul (2005) "A Transaction Cost Theory of Patent Law," *Ohio State Law Journal*, Vol. 66, pp. 473–509.

Heller, Michael A and Rebecca S Eisenberg (1998) "Can patents deter innovation? The anticommons in biomedical research," *Science*, Vol. 280, pp. 698–701.

Hovenkamp, Erik, Jorge Lemus, and John L. Turner (2024) "Product Development with Lurking Patentees," *RAND Journal of Economics*, Forthcoming.

Lampe, Ryan and Petra Moser (2010) "Do patent pools encourage innovation? Evidence from the nineteenth-century sewing machine industry," *The Journal of Economic History*, Vol. 70, pp. 898–920.

——— (2016) "Patent pools, competition, and innovation—evidence from 20 US industries under the new deal," *The Journal of Law, Economics, and Organization*, Vol. 32, pp. 1–36.

Layne-Farrar, Anne and Josh Lerner (2011) "To join or not to join: Examining patent pool participation and rent sharing rules," *International Journal of Industrial Organization*, Vol. 29, pp. 294–303.

Lemley, Mark (2008) "Ignoring patents," *Michigan State Law Review*, Vol. 19.

Lemley, Mark A and Nathan Myhrvold (2008) "How to make a patent market," *Hofstra Law Review*, Vol. 36, p. 257.

Lerner, Josh, Marcin Strojwas, and Jean Tirole (2007) "The design of patent pools: The determinants of licensing rules," *The RAND Journal of Economics*, Vol. 38, pp. 610–625.

Lerner, Josh and Jean Tirole (2004) “Efficient patent pools,” *American Economic Review*, Vol. 94, pp. 691–711.

Llobet, Gerard and Jorge Padilla (2023) “A theory of socially inefficient patent holdout,” *Journal of Economics & Management Strategy*, Vol. 32, pp. 424–449.

Love, Brian J and Christian Helmers (2023) “Patent hold-out and licensing frictions: Evidence from litigation of standard essential patents,” *International Journal of Industrial Organization*, Vol. 89, p. 102978.

Mattioli, Michael (2018) “Patent Pool Outsiders,” *Berkeley Technology Law Journal*, Vol. 33, pp. 233–296.

Melamed, A Douglas and Carl Shapiro (2018) “How antitrust law can make FRAND commitments more effective,” *The Yale Law Journal*, pp. 2110–2141.

Merges, Robert (2001) “Institutions for Intellectual Property Transactions: The Case of Patent Pools,” in Rochelle Dreyfuss et al. eds. *Expanding the Boundaries Of Intellectual Property: Innovation Policy for the Knowledge Society*, Oxford, UK: Oxford University Press.

Merges, Robert and Michael Mattiolo (2017) “Measuring the Costs and Benefits of Patent Pools,” *Ohio State Law Journal*, Vol. 78, pp. 281–347.

Parcu, Pier Luigi, Maria Alessandra Rossi, and David Silei (2025) “FRAND Licensing of Standard-Essential Patents: Comparing Realistic Ex-Ante and Ex-Post Contracts,” *The BE Journal of Economic Analysis & Policy*.

Righi, Cesare and Timothy Simcoe (2023) “Patenting inventions or inventing patents? Continuation practice at the USPTO,” *The Rand Journal of Economics*, Vol. 54, pp. 416–442.

Royall, M Sean, Amanda Tessar, and Adam Di Vincenzo (2008) “Deterring patent ambush in standard setting: Lessons from Rambus and Qualcomm,” *Antitrust*, Vol. 23, p. 34.

Sidak, J Gregory (2016) “Apportionment, FRAND Royalites, and Comparable Licenses after Ericsson v. D-Link,” *U. Ill. L. Rev.*, p. 1809.

Siebrasse, Norman V (2019) “Holdup, Holdout, and Royalty Stacking; A Review of the Literature,” *Patent Remedies and Complex Products: Toward a Global Consensus*, Vol. 437.

Siebrasse, Norman V and Thomas F Cotter (2017) “The Value of the Standard.”

A Proofs

Proof of Proposition 1

Proof of Proposition 2

Proof of Lemma 1

Proof. As stated above, the equilibrium royalty with comparables and a pool of size k is $R^* = \frac{\beta\bar{\rho}}{\beta T+(1-\beta)k}$, while the average royalty with a pool of size k and no comparables is $\bar{V} = \left(\frac{\beta\bar{\rho}+(1-\beta)(T-k)\rho}{T}\right)$. Given $\rho > \frac{\bar{\rho}}{T-k+1}$, it follows that $\bar{V} > \left(\frac{\beta\bar{\rho}+(1-\beta)\left(\frac{(T-k)}{T-k+1}\right)\bar{\rho}}{T}\right)$. It thus suffices to show

$$\frac{\beta\bar{\rho}}{\beta T+(1-\beta)k} < \left(\frac{\beta\bar{\rho}+(1-\beta)\left(\frac{T-k}{T-k+1}\right)\bar{\rho}}{T}\right).$$

After some algebra and cancellation of proportional terms, this can be rearranged to yield

$$\beta\left(\frac{(T-k)(k-1)}{T-k+1}\right)+(1-\beta)\left(\frac{k(T-k)}{T-k+1}\right) > 0.$$

□

Proof of Proposition 3

Proof of 2

Proof. If $\rho < \frac{\bar{\rho}}{T}$, then previous results show that all patentees are paid ρ with or without comparables.

Suppose next that $\rho \in \left(\frac{\bar{\rho}}{T}, \bar{\rho}\right)$. From Proposition 3, the equilibrium royalty with comparables is $R^* = \frac{\beta\bar{\rho}}{\beta T+(1-\beta)}$, while from Corollary 1 the average royalty with a minimum sufficient pool of size k (and no comparables) is $\bar{V} = \left(\frac{\beta\bar{\rho}+(1-\beta)(T-k)\rho}{T}\right)$. Given $\rho > \frac{\bar{\rho}}{T-k+1}$, it follows that $\bar{V} > \left(\frac{\beta\bar{\rho}+(1-\beta)\left(\frac{(T-k)}{T-k+1}\right)\bar{\rho}}{T}\right)$. It thus suffices to show

$$\frac{\beta\bar{\rho}}{\beta T+(1-\beta)} < \left(\frac{\beta\bar{\rho}+(1-\beta)\left(\frac{T-k}{T-k+1}\right)\bar{\rho}}{T}\right).$$

After some algebra and cancellation of proportional terms, this can be rearranged to yield

$$k < (1-\beta)T + \beta.$$

The implementer then earns ${}_D(Comp) = -T\left(\frac{\beta\bar{\rho}}{\beta T+(1-\beta)}\right)$.

Finally, if $\rho > \bar{\rho}$, then the equilibrium with comparables is unchanged but from Proposition 1 the efficient equilibrium yields a complete pool. In that case, each patentee earns $\frac{\beta\bar{\rho}}{T}$ and the implementer earns ${}_D(NoComp) = -\beta\bar{\rho}$. It is easily shown that ${}_D(NoComp) \geq_D (Comp)$ for any $\beta \in [0,1]$, and the inequality is strict for $\beta \in (0,1)$. □

Proof of Lemma 2

Proof. Suppose that $J_P = Z_m \setminus \{k\}$ is the set that forms a pool such that B is adopted regardless of whether k joins or not. Thus, if k does not join the pool, the surplus is

$$S \equiv \bar{\rho} - \rho \sum_{j \notin J_P} \eta_j \geq 0,$$

and if k joins the pool, the surplus is

$$\bar{\rho} - \rho \sum_{j \notin J_P, j \neq k} \eta_j \geq 0 \Leftrightarrow S + \rho\eta_k \geq 0$$

Then, this patentee prefers to stay out of the pool if

$$\eta_k \rho \geq \frac{\beta\eta_k}{\sum_{j\in J_P}\eta_j + \eta_k}\left(\bar{\rho} - \rho \sum_{j \notin J_P, j\neq k}\eta_j\right),$$

which is the same as

$$\rho \geq \frac{\beta\bar{\rho}}{\sum_{j\in J_P}\eta_j + \eta_k + \beta\sum_{j\notin J_P, j\neq k}\eta_j}. \tag{3}$$

Note that $\beta \leq 1$ implies that

$$\frac{\beta\bar{\rho}}{\sum_{j\in J_P}\eta_j + \eta_k + \beta\sum_{j\notin J_P, j\neq k}\eta_j} \leq \frac{\bar{\rho}}{\sum_{j\in J_P}\eta_j + \eta_k + \sum_{j\notin J_P, j\neq k}\eta_j} = \frac{\bar{\rho}}{T},$$

so for any $\rho \geq \frac{\bar{\rho}}{T}$ inequality (3) holds. □

Proof of Proposition 4

Proof. First, for the implementer to adopt B, we need $\sigma(Z) \leq \frac{\bar{\rho}}{\rho}$. By construction of the thresholds, this is the same as $\sigma(Z) \leq \sigma(Z_{m+1})$. Next, if there exist $j \notin Z$ such that $\sigma(Z \cup \{j\}) \leq \sigma(Z_m)$, from Lemma 2 patentee j would be better off being an outsider, so j joining the pool would not occur in equilibrium. $\square$

Proof of Proposition 5

Proof. If for any $j \in Z$, $\sigma(Z \setminus \{j\}) \geq \sigma(Z_m)$, there is no unilateral deviation that motivates the implementer to adopt B. $\square$

B Examples: Pool Formation, Licensing, and Holdouts

B.1 MPEG LA (Video Codecs)

MPEG LA was company that licensed patent pools covering essential patents required for use of the MPEG-2, MPEG-4, IEEE 1394, VC-1, ATSC, MVC, MPEG-2 Systems, AVC/H.264 and HEVC standards.[8]

MPEG LA's one-stop licenses have been widely adopted across the consumer electronics and software industries. Today it manages programs encompassing over 25,000 patents from over 280 licensors, with some 7,300 licensees worldwide.[9] Virtually every major manufacturer of DVD/Blu-ray players, TVs, cameras, and smartphones, as well as software vendors (for media codecs), has taken licenses.

In general, MPEG LA achieved broad participation for its early pools, but in later video standards some major patent holders chose not to join. A prime example is the HEVC standard: several significant SEP owners (including GE, Dolby, Philips, Mitsubishi Electric, and Technicolor) opted not to enter MPEG LA's HEVC pool, and instead formed a rival pool (HEVC Advance, launched April 2015) to license their H.265 patents.[10] These companies were reportedly dissatisfied with MPEG LA's royalty structure and sought higher or differently structured rates, leading to a fragmented licensing landscape for HEVC.

Industry analysts have pointed out that unlike the one-stop MPEG LA pools for earlier codecs, the split between MPEG LA's HEVC pool and the alternative "Advance" pool (and some solo licensors) created confusion and higher cumulative royalties—"an unmitigated disaster for the industry at large," in the words of one commentator.[11]

B.2 Via Licensing (Audio & Wireless)

Via Licensing Corporation formed one of the first Wi-Fi (IEEE 802.11) patent pools between 2003 and 2005, and later launched pools for audio codecs like Advanced Audio Coding (AAC)

[8] https://en.wikipedia.org/wiki/MPEG_LA.

[9] https://www.businesswire.com/news/home/20220316006120/en/MPEG-LA-Expands-AVC-License-to-Include-Complete-MVC-Coverage

[10] https://www.streamingmedia.com/Articles/ReadArticle.aspx?ArticleID=105402

[11] https://www.sisvel.com/insights/editorial-response-on-via-exit-leaving-sisvel-as-the-only-patent-po

and standards like LTE. Its Wi-Fi pool attracted only 5 licensors (covering 35 patents).[12] Via's wireless programs struggled to gain industry-wide traction. By April 2022, Via decided to wind down its wireless pools (LTE/5G) and refocus on its successful audio codec pools, ultimately contributing its wireless patents to a new 5G pool under Sisvel.[13]

In 2023, Via merged with MPEG LA to form the Via Licensing Alliance, combining dozens of pool programs under one administration.

Overall, Via's greatest licensing success has been in audio and video codec programs, where many firms in the entertainment and tech sectors rely on its pools for technologies like AAC and MPEG-H 3D Audio.

Many of the major SEP holders chose not to participate in Via's pools. Industry observers note that "the biggest patent holders—Ericsson, Nokia, InterDigital, and Qualcomm—prefer in-house licensing and have never joined a [wireless] pool focused on the mobile devices market."[14]

For the LTE pools, neither Via's nor Sisvel's LTE pools included Qualcomm, Nokia (as a licensor), Samsung, or Huawei. These giants likely believed they could secure better terms through bilateral licensing of their cellular portfolios, and they were reluctant to be "first on the red carpet" of an unproven pool.[15] The absence of such key players ultimately limited the coverage of Via's wireless pools and contributed to their shutdown. In contrast, Via's AAC audio pool did manage to assemble most key patent owners in that field (Dolby, Fraunhofer, etc.), so there were fewer holdouts for audio.

B.3 Avanci (IoT & Automotive)

Avanci is a relatively new patent licensing platform (launched in 2016) conceived as an independent one-stop marketplace for Internet of Things and automotive connectivity patents, particularly cellular SEPs (2G/3G/4G and now 5G) needed in connected devices.[16] By 2017, it pivoted strongly to the automotive sector: BMW became the first automaker licensee in 2017, followed soon by Volvo, Audi, Porsche, and VW.[17] Avanci's model offers vehicle manu-

[12] https://www.essentialpatentblog.com/wp-content/uploads/sites/64/2014/03/2013.09.26-169-Plaintiff-Rea (page 19).

[13] https://www.sisvel.com/insights/editorial-response-on-via-exit-leaving-sisvel-as-the-only-patent-po

[14] https://www.sisvel.com/insights/editorial-response-on-via-exit-leaving-sisvel-as-the-only-patent-po

[15] https://www.mobileeurope.co.uk/sisvel-launches-lte-patent-pool.

[16] https://www.avanci.com/2016/09/14/avanci-launches-one-stop-licensing-platform-accelerate-wireless-c

[17] https://en.wikipedia.org/wiki/Avanci.

facturers a single license covering a portfolio of cellular SEPs from dozens of patent owners, at a flat per-vehicle rate. As of 2023, Avanci reports 80+ automotive brands licensed (including Audi, BMW, Ford, GM, Honda, Mercedes-Benz, Nissan, Toyota, Volkswagen, Volvo, and many more) which accounts for roughly 80–85% of connected cars globally. On the licensor side, Avanci's pool grew to include 50+ patent holders such as Ericsson, Nokia, Qualcomm, InterDigital, Sharp, ZTE, and others.

In its early years, Avanci had to navigate the absence of some top SEP holders, but over time most have joined. For example, Samsung—one of the largest wireless SEP owners—initially licensed its patents independently and did not participate in Avanci's 4G program; Samsung finally joined Avanci as a licensor in April 2023, marking its first-ever inclusion in a patent pool. Another was Huawei, a major 4G/5G SEP contributor, which for several years stayed outside the pool.

A few notable companies remain outside. For instance, Apple is not an Avanci licensor (Apple holds some SEPs but as a smartphone maker it participates more as a licensee in other contexts). Generally, Avanci's holdouts were companies with large SEP portfolios and established bilateral licensing programs—they were initially cautious about pool pricing or giving up individual licensing freedom.

B.4 One-Blue (Blu-ray Disc)

One-Blue was created as the joint patent pool for Blu-ray Disc technology. In its first year (by mid-2012), One-Blue assembled 15 licensor companies representing the leading providers of Blu-ray, DVD, and CD optical storage tech.[18] One-Blue initially offered licensing for Blu-ray and backwards coverage for DVD/CD patents, and later expanded to cover Ultra HD Blu-ray as that 4K format emerged (launching a UHD Blu-ray pool program in 2017). From the start, One-Blue saw widespread uptake by manufacturers in the optical disc industry. Essentially, any company producing Blu-ray Disc players, Blu-ray drives, or Blu-ray discs would require a license, and the vast majority opted to secure coverage through the One-Blue pool. This included large Japanese and Korean electronics makers (many of whom were also licensors, like Panasonic or Samsung, but they would also license others' patents via cross-license in the pool) as well as numerous smaller OEMs and ODMs that produce drives or media. PC makers integrating Blu-ray drives (e.g. in laptops) and disc replication firms also became licensees.

[18] https://www.one-blue.com/press/16/one-blue-celebrates-successful-first-year-of-worldwide-blu-ray-di

While One-Blue achieved impressive unity, there were a few outsiders tied to the defeated HD DVD camp. Notably, Toshiba—the main company behind HD DVD—did not join One-Blue at inception. Instead, Toshiba attempted to form a competing Blu-ray pool called "Premier BD" in collaboration with Warner Bros., Mitsubishi, and Thomson (Technicolor). These entities presumably controlled certain patents essential to optical disc technology (for example, Mitsubishi and Thomson had been contributors to DVD technology, and Warner had some disc-related IP). The choice to form Premier BD suggested they hoped to license their patents separately rather than via One-Blue, perhaps to secure different financial terms or out of reluctance to collaborate with the Blu-ray founders.

On the licensee side, given One-Blue's comprehensive coverage and reasonable rates, manufacturers had little incentive to avoid the pool; if any tried to free-ride without a license, they faced infringement actions (as One-Blue did pursue enforcement, e.g., suing Imation in 2013 for selling unlicensed Blu-ray products).

C EXTRA MATERIAL

C.1 Example $T = 2$ when $\lambda = 1$

Pursuant to proposition 1, we know that if $\rho < \frac{\bar{\rho}}{2}$, there is a multiplicity of equilibria where patentee's may INITIATE or RTL (or mix). In all of these equilibria, each patentee earns a payoff of ρ.

We also know that if $\rho > \bar{\rho}$, then there is an efficient equilibrium where all patentees INITIATE and the implementer picks B. With coalition bargaining, each would get paid $\frac{\beta\bar{\rho}}{2}$. There is also an inefficient equilibrium where all patentees RTL and the implementer picks A. In this equilibrium, the patentees each earn 0.

The remaining case is where $\frac{\varrho}{2} < \rho < \bar{\rho}$. Here, there are two pure strategy equilibria. In each of these equilibria, one patentee INITIATE and earns $\beta(\bar{\rho} - \rho)$ and the other RTL and earns ρ. The latter payoff is larger, so each patentee would prefer to be the one that RTL. There is also a mixed-strategy equilibrium where each patentee RTL with probability ℓ^*. If one patentee plays this strategy, the other patentee is indifferent between INITIATE and RTL when

$$\ell^* r_1 + (1 - \ell^*) r_2 = (1 - \ell^*)\rho \qquad \Leftrightarrow \qquad \ell^* = \frac{\rho - r_2}{\rho + r_1 - r_2},$$

Under coalition bargaining, the royalties are:

$$r_1 = \beta(\bar{\rho} - \rho), \qquad r_2 = \frac{\beta\bar{\rho}}{2}.$$

Note that $r_2 > r_1$ when $\frac{\varrho}{2} < \rho < \bar{\rho}$. Intuitively, when just one patentee INITIATE, it is in a very difficult licensing spot because the other patentee is RTL. Thus, the INITIATE patentee earns a very low royalty. The implied equilibrium mixing probability is then

$$\ell^* = \frac{\rho - \frac{\beta\bar{\rho}}{2}}{\rho(1 - \beta) + \frac{\beta\bar{\rho}}{2}}.$$

This value is clearly strictly positive and less than 1. In this equilibrium, each patentee expects a payoff of

$$(1 - \ell^*)\rho = \left(\frac{\beta(\bar{\rho} - \rho)}{\rho(1 - \beta) + \frac{\beta\bar{\rho}}{2}} \right) \rho.$$

It is easy to show that

$$\beta(\bar{\rho} - \rho) \leq \left(\frac{\beta(\bar{\rho} - \rho)}{\rho(1 - \beta) + \frac{\beta\bar{\rho}}{2}} \right) \rho < \rho.$$

Thus, the equilibrium payoff in the mixed strategy equilibrium lies between the INITIATE and RTL payoffs from the pure-strategy equilibria. Also, as $\rho \to \bar{\rho}$ we have $\ell^* \to 1$ and the mixing payoff goes to 0 (and equals the INITIATE payoff in the pure-strategy equilibrium); as $\rho \to \frac{\bar{\rho}}{2}$ we have $\ell^* \to 1 - \beta$ and the mixing payoff goes to $\frac{\beta\bar{\rho}}{2}$ (and again equals the INITIATE payoff in the pure-strategy equilibrium).

Remark. *The total payoff to the patentees under the pure-strategy equilibrium exceeds the total expected payoff to the patentees under mixing,*

$$(\rho + \beta(\bar{\rho} - \rho)) > 2\left(\frac{\beta(\bar{\rho} - \rho)}{\rho(1-\beta) + \frac{\beta\bar{\rho}}{2}}\right)\rho.$$

Proof: First rewrite the $1 - \ell^*$ term so that we have

$$(\rho + \beta(\bar{\rho} - \rho)) > 2\left(\frac{\beta(\bar{\rho} - \rho)}{\rho + \beta(\bar{\rho} - \rho) - \frac{\beta\bar{\rho}}{2}}\right)\rho.$$

Multiplying out, we have

$$\rho^2 + \rho\beta(\bar{\rho} - \rho) - \frac{\beta\bar{\rho}\rho}{2} + \rho\beta(\bar{\rho} - \rho) + \beta^2(\bar{\rho} - \rho)^2 - \beta^2(\bar{\rho} - \rho)\frac{\bar{\rho}}{2} > 2\beta(\bar{\rho} - \rho)\rho.$$

The $\rho\beta(\bar{\rho} - \rho)$ terms cancel, so we can then write

$$\rho^2 - \frac{\beta\bar{\rho}\rho}{2} + \beta^2(\bar{\rho} - \rho)^2 - \beta^2(\bar{\rho} - \rho)\frac{\bar{\rho}}{2} > 0,$$

or

$$\rho\left(\rho - \frac{\beta\bar{\rho}}{2}\right) > \beta(\bar{\rho} - \rho)\left(\frac{\beta\bar{\rho}}{2} - \beta(\bar{\rho} - \rho)\right).$$

The result then follows from the fact that $\rho > \beta(\bar{\rho} - \rho)$ and that $\rho - \frac{\beta\bar{\rho}}{2} > \frac{\beta\bar{\rho}}{2} - \beta(\bar{\rho} - \rho)$. Both hold whenever $\rho > \frac{\bar{\rho}}{2}$. **QED**

Thus, the patentees are jointly worse off under mixing. They would both be better off if they agreed to first hold a 50/50 lottery to determine which party would INITIATE, and to share royalty payments evenly.

Note that this total payoff is also superior to an agreement to both INITIATE, as it is obvious that

$$\rho + \beta(\bar{\rho} - \rho) > \beta\bar{\rho}.$$

If we interpret an agreement for both patentees to bargain as a coalition as capturing the formation of a patent pool, this suggests a possible reason firms holding SEPs covering the same standard do not want to form pools.