A Theory of Socially-Inefficient Patent Holdout*

Gerard Llobet
CEMFI and CEPR

Jorge Padilla
Compass Lexecon

October 6, 2022

Abstract

This paper proposes a framework to analyze holdout in patent licensing negotiations. We show that when the validity of a patent is probabilistic, a potential downstream user has incentives to shun to pay the price offered by a patent holder to license the technology and risk being brought to court. These incentives are exacerbated when jurisdictions are local and the downstream producer can approach courts sequentially. The informational spillovers across trials imply that this firm often finds optimal to go to court aiming to invalidate the patent in a jurisdiction due to the knock-on effect on future jurisdictions. This process results in excessive litigation compared to when the jurisdiction is global. The distortions from sequential litigation are likely to be aggravated when final competition is accounted for or when patent injunctions are not allowed.

JEL codes: L15, L24, O31, O34.
keywords: Intellectual Property, Standard Setting Organizations, Patent Licensing, Patent Holdout, Global Jurisdictions.

*We benefited from comments by the two referees, Sarah Parlane, and participants at the Northwestern University's Thirteen Annual Conference on Innovation Economics and the 2021 TILEC Workshop on the Economics of Patents and Standards. Financial support from Qualcomm is gratefully acknowledged. The first author also acknowledges the support of the Regional Government of Madrid through grant H2019/HUM-5793. The ideas and opinions in this paper, as well as any errors, are exclusively the authors'. Comments should be sent to llobet@cemfi.es and jpadilla@compasslexecon.com.

1 Introduction

Patent holders that participate in Standard Setting Organizations (SSOs) must abide by rules that reduce their leverage in the negotiation with implementers that aim to license their technologies. Many legal scholars have raised concerns that these restrictions may lead to the undercompensation of their innovations and have denoted this risk as patent holdout (see Geradin (2010), Chien (2014)). Heiden and Petit (2018) empirically document that implementers may engage in patent holdout by ignoring correspondence, postponing negotiations, or simply by making counteroffers that are inconsistent with industry practice. Other strategies include trying to affect the policies of SSOs or appealing to competition authorities. They argue that the delay and the costs associated to patent holdout may also be related to the significant decrease in licensing coverage in the mobile phone industry that has dropped from 73% to 36% between 2006 and 2016.[1]

By delaying and stalling negotiations, potential licensees aim to obtain better licensing terms. As Epstein and Noroozi (2018) note,

> By "patent holdout" we mean [...] that an implementer refuses to negotiate in good faith with an innovator for a license to valid patent(s) that the implementer infringes, and instead forces the innovator to either undertake significant litigation costs and time delays to extract a licensing payment through court order, or else to simply drop the matter because the licensing game is no longer worth the candle.

This is in contrast with the opinion of some scholars who have dismissed this concern as affecting only the distribution of surplus from innovation and that, in any case, it could be addressed through ex-post court-mandated damages (Shapiro and Lemley, 2019).

[1] Heiden and Petit (2018) consider the word "holdout" a misnomer and suggest the usage of a more descriptive name like "patent trespass." Patent holdout has often been used interchangeably with reverse holdup. However, as Epstein and Noroozi (2018) explain, reverse holdup refers to downstream users that might expropriate patent holders of their relation-specific investments by negotiating a lower royalty rate than what they would have obtained outside the rules of an SSO.

In this paper we show that patent holdout engenders social-welfare losses. Downstream producers refuse to negotiate a global license and, instead, they try to invalidate the patents by approaching courts sequentially, jurisdiction by jurisdiction. When the innovation has a moderate value, this strategy forces patent holders to lower their royalty rate offers to avoid being dragged from court to court. In contrast, patent holders with high value innovations might decide to increase their royalty rate demands even if that generates inefficient litigation. As a result, sequential litigation not only affects the way the surplus from production is allocated among firms and the corresponding incentives to innovate. It also generates social welfare losses by fostering excessive litigation and distorting downstream competition. This result does not rely on the differential legal costs that global and local litigation might entail but, rather, on informational spillovers across jurisdictions.

Patent holdout, also known as "efficient infringement," might be especially relevant in standardization contexts. Firstly, Standard Essential Patent (SEP) owners typically possess many complementary patents and, therefore, seek to license their whole portfolio to minimize transaction costs. Yet, some manufacturers refuse to negotiate in this way and choose to challenge the validity of the SEP portfolio patent by patent. Secondly, standardized products are sold globally and SEP owners' portfolios include patents from different jurisdictions. Implementers often refuse to negotiate global licenses and SEPs holders must enforce their patents jurisdiction by jurisdiction, which raises similar issues to patent-by-patent litigation. This strategy involves large litigation costs and is therefore inefficient.[2] SEP holders claim that this practice leads to royalty rates that are too low

[2]In the Unwired Planet vs Huawei case, [2017] EWHC 2988 (Pat), Judge Birss asked

> [W]hat sort of license for Unwired Planet's portfolio would be FRAND in terms of its geographical scope when applied to a multinational licensee like Huawei? I will start by asking what a willing licensor and a willing licensee with more or less global sales would do. There is only one answer. Unwired Planet's portfolio today is (and in 2014 it was) sufficiently large and has sufficiently wide geographical scope that a licensor and licensee acting reasonably and on a willing basis would agree on a worldwide license. They would regard country by country licensing as madness. A worldwide license would be far more efficient.

and, in some instances, may distort the competitive process and harm consumers by reducing the incentive and ability of SEP holders to sustain their innovation efforts.

When the upstream innovator owns a patent in a single jurisdiction, the royalty rate typically increases with the probability of success in court and the value of the innovation. Legal costs, however, have a more ambiguous effect as they dissuade the innovator from asserting the patent but, at the same time, they also provide incentives for the downstream user of the technology to settle and accept the royalty rate offered instead of challenging its validity in court. Overall, the previous forces imply that litigation only occurs when legal costs are relatively low. Otherwise, negotiation occurs in the shadow of litigation and it implies that the resulting royalty rate depends on these legal costs.

This paper compares this relatively standard setup with a situation where the innovator owns a patent (or, more precisely, a patent of the same family) in two jurisdictions. Consistent with the rules that typically apply to SSOs like like Fair, Reasonable, and Non-Discriminatory (FRAND) terms, the innovator is constrained to set the same royalty rate in both jurisdictions and to honor the offer made even after it is successful in court. The downstream producer operates in both jurisdictions and can challenge the validity of each patent in (a different) court. We assume that when litigation takes place sequentially, the outcome of the trials is related. If the patent is found valid (and it has been infringed) in one jurisdiction, this might also indicate that a second judge will reach a similar conclusion with a high probability in a future trial in the other jurisdiction. These informational spillovers imply that the incentives to go to court change between the first and the second jurisdiction, yielding an outcome different from the single jurisdiction case, which would still arise if both trials were unrelated or if they took place simultaneously.

We show that challenging both patents sequentially provides a benefit to the downstream producer. This result is due to the asymmetric effect on the second jurisdiction of the outcome of the first court case. An initial success by the downstream producer means that the probability that the second patent is invalidated and the royalty rate becomes zero increases. In contrast, an initial defeat does not allow the patent holder to increase the royalty rate in the second jurisdiction. This asymmetry engenders excessive incentives for the downstream producer to challenge the validity of the patent in court in the first jurisdiction.

The comparison with the case of a single jurisdiction, or when jurisdictions are independent, allows us to illustrate how patent holdout arises as a result. When the innovation has a moderate value compared to the cost of enforcing the patent, avoiding litigation in the first jurisdiction is always preferred by the patent holder. This can be achieved by lowering the royalty rate offered to the downstream producer which, in turn, implies lower patent holder profits in both jurisdictions.

The previous effect is amplified when the downstream producer coexists with smaller, albeit more efficient, competitors that are unlikely to challenge the patent in court. In that case, we show that sequential litigation has antitrust implications, as it provides further incentives for the downstream producer to challenge the patent in the first jurisdiction. By doing so it can discourage the patent holder from enforcing the patent in the second jurisdiction, leading to a competitive advantage against the rest of the firms in the market. To prevent litigation the patent holder needs to lower the royalty rate even further, making the patent holdout problem more severe.

When the patent is highly valuable and the informational spillovers between jurisdictions are sufficiently strong, raising the royalty rate, rather than decreasing it, might be profitable for the patent holder. Its success in court in the second jurisdiction is very likely upon success in the first one and this implies that the downstream producer would settle even if the royalty rate were high. In that case, the patent holder trades off the losses from the initial litigation with the higher royalty payment in the second jurisdiction after an initial success. As a result, when the innovation is valuable sequential litigation engenders a social cost.

Notice that this social cost is also a consequence of patent holdout. Under sequential litigation discouraging the downstream producer from going to court implies offering a lower royalty rate. The corresponding reduction in patent holder profits undermines the incentives to reach a settlement. This means that the patent holder might be willing to set a high royalty rate and go to court even if that engenders lower profits than in the single jurisdiction case.

The previous result would suggest that sequential litigation might not be chosen in situations where legal costs are incurred and both parties are worse off. When we endogenize this decision of the downstream producer after the royalty rate has been announced we show that this is never the case. Consistent with the previous discussion, when the innovation has a moderate value patent holdout makes sequential litigation preferable for the downstream producer. When the innovation has a high value, however, sequential litigation is also selected. Since in this case the patent holder chooses a high royalty rate, litigation will take place in the first jurisdiction in both scenarios and sequential litigation, by making the success probabilities in the second jurisdiction more extreme, always discourages one of the parties from going to court again.

Sequential litigation and its social cost can be prevented under a global jurisdiction. In that case, a single court determines a unique royalty rate that applies to both markets. This means that the patent holder faces the same royalty rate choice as in the single jurisdiction case, avoiding costly litigation. In contrast, voluntary global arbitration is typically irrelevant. The reason is that it implies legal costs in both jurisdictions and, after observing the royalty rate, this choice is always dominated from the point of view of the downstream producer. This firm can avoid some of these costs by either settling in the first jurisdiction — when the royalty rate is low — or going to court in the first one and settling in the second jurisdiction in case of defeat — when the royalty rate is high.

Finally, we study the usage of patent injunctions. In some jurisdictions the innovators' ability to request an injunction is restricted by law, undermining their leverage in trying to require implementers to accept a licensing deal.[3] We consider the situation in which the patent holder can (partially) prevent the downstream firm from selling the product unless an agreement is reached. Injunctions improve the patent holder's bargaining position by limiting the extent of holdout.[4] As a result, the incentives for the downstream producer to engage in sequential litigation are curtailed and injunctions can help restore efficiency.

This paper relates to the literature that assesses how the returns from innovation are allocated, particularly in the context of SSOs. The growing importance of these organizations as forums for patent holders and implementers to develop new technologies has increased the visibility of the possible distortions that could arise. While the concerns of SEP holders seem to have attracted the attention of the leadership of the US Department of Justice[5] and courts in other countries (see Unwired Planet vs Huawei [2020] UKSC 37), some authors have dismissed them as theoretically groundless, empirically immaterial and irrelevant from an antitrust perspective.[6] Instead, papers like Lemley and Shapiro (2007) have emphasized that standardization efforts might be detrimental to implementers and result in excessive rents for innovators due to the risk of patent holdup and royalty stacking. This concern has spurred extensive work aimed at designing rules for the determination of royalty rates (see, for example, Leonard and Lopez (2014) or Lerner and Tirole (2015)). In contrast to the typical presumption, our work rationalizes a high royalty rate, particularly for valuable innovations, as a patent holder's response to the risk of holdout.

Although there is a very extensive literature on patent litigation, few papers have

[3]As explained by Golden (2007), in the US this is particularly the case for firms that are not active downstream competitors, like Patent Assertion Entities (PAEs). Chien (2014) argues that PAEs might arise precisely to enforce patents when implementers may rebuff all payment requests. See eBay Inc. v. MercExchange, L.L.C., 126 S.Ct. 1837 (2006).

[4]Patent injunctions in the case of SEPs could be considered an abuse of dominant position. The European Court of Justice in the Huawei vs ZTE [2015] (C-170/13) established that injunctions should be allowed if two conditions were met. First, patent holders should alert the user of the alleged infringement and present an offer in FRAND terms. Second, the downstream producer should not have responded to that offer according to recognized commercial practices and in good faith.

[5]see, for example https://www.justice.gov/opa/speech/assistant-attorney-general-makan-delrahim-delivers-remarks-19th-annual-berkeley-stanford.

[6]See https://www.competitionpolicyinternational.com/wp-content/uploads/2018/05/DOJ-patent-holdup-letter.pdf.

studied the strategic implications of sequential trials and how they may elicit information about patent validity. Choi (1998) studies a patent holder facing a sequence of potential imitators. He shows that the incentives to go to court are affected by the information that the court outcome might reveal on the strength of the patent. Bernhardt and Lee (2014) study a similar setup where a defendant engages in initial litigation to prevent future potential plaintiffs to file a lawsuit. Choi and Gerlach (2018) study the decision of a non-practicing entity to sue a potential user of the technology to establish a reputation against future users.[7] Our model also assumes that court trials reveal information but our focus is on the repeated interaction between a patent holder and a licensee and abstracts from asymmetric information and entry-deterrence motivations. Bourreau et al. (2016) study the licensing and sequential litigation of two downstream competitors and analyze the interaction with final market outcomes.

Finally, this paper is related to a growing literature on patent enforcement and the interplay between different jurisdictions. Horn (2020) studies how FRAND terms are interpreted simultaneously in different countries depending on the weight that consumers, producers, and technology developers have in the social welfare function. Contreras (2019) emphasizes the advantages of global rate setting and provides a roadmap for establishing a court that determines it.

The rest of the paper is structured as follows. In section 2 we propose a model of royalty negotiations under patent holdout. Section 3 analyzes the implications of sequential litigation in a model with two local jurisdictions. Section 4 explores the effects of global litigation and arbitration. Section 5 shows how the distortions are magnified when downstream competition is considered. Section 6 introduces patent injunctions and shows that they reduce the gains of downstream producers from engaging in sequential litigation. Section 7 discusses the robustness of the results and section 8 concludes.

[7] Other papers like Briggs et al. (1996) or Daughety and Reinganum (2002) study sequential litigation in contexts of asymmetric information, where the initial trial conveys information about the strength of the defendant's case.

2 The Model

Consider a patent holder, denoted as firm P, that licenses its intellectual property to a downstream monopolist producer, firm D. Firm P has obtained a patent for the same innovation in two different markets. In each of them, a continuum of buyers of mass 1 are willing to pay an amount v for a unit of the final good produced by D. We normalize the marginal cost of production of the good to 0 so that the only cost incurred by the downstream producer is the royalty rate required to license the intellectual property, denoted as r. As a result, D will set a final market price for the good equal to v and produce as long as $r \leq v$.

In each market, the downstream producer can either accept the royalty rate r or refuse to pay for a license. In the latter case, P decides whether to take D to court or not. Litigation implies a legal cost $l > 0$ for each of the parties. The ex-ante probability that the court determines that the patent is valid is known and equal to $p \in (0, 1)$.[8]

Litigation can take place simultaneously in both markets or jurisdictions. It can also be sequential, when the outcome of the first trial is revealed before the second one starts. In that case, we assume that the unconditional probability of success of the patent holder, p, may change once information about the first trial emerges. If the patent is considered valid in one jurisdiction the probability that a court finds it valid in the second jurisdiction increases. The opposite occurs if the patent is invalidated in the first jurisdiction. The extent of this informational spillovers across trials and jurisdictions is measured by the parameter $\delta \in [0, 1]$. In particular, we assume that the probability that the patent holder wins the trial in the second jurisdiction contingent on losing in the first one is $q \leq p$, while this probability increases to $q + \delta \geq p$, in case of a first success. We assume that $p(q + \delta) + (1 - p)q = p$ so that sequential litigation does not have any

[8]In practice, the downstream producer wins if the court determines that the patent is invalid or that it has not been infringed. Because these two events have identical effects in our model, in the rest of the paper we will assume that all patents if valid are infringed. Hence, we will refer to the success of the patent holder as a court ruling determining that the patent is valid.

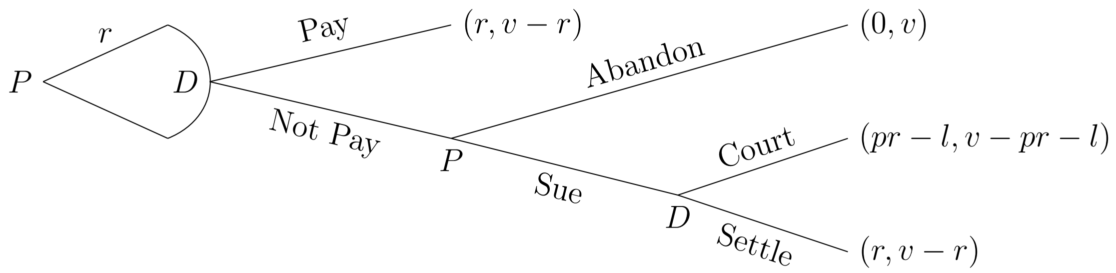

Figure 1: Structure of the Single Jurisdiction Game with payoffs for the patent holder and the downstream producer.

impact on the unconditional probability of success in court. The two extreme cases will be useful throughout the paper. When $\delta = 0$ there is no linkage between jurisdictions and $q = p$. At the other extreme, when $\delta = 1$ the outcome of the first jurisdiction completely determines the outcome in the second one and, thus, $q = 0$.

We start by analyzing the case where each market is a local jurisdiction. We then study the implications of patents being litigated sequentially in the two jurisdictions. We use these benchmarks to evaluate a recent proposal to establish a global jurisdiction that determines the royalty rate in both markets or the availability of mandatory (and global) arbitration.

2.1 The Single Market Case

Suppose that P has a patent in only one market. The timing of the game is illustrated in Figure 1. First, the patent holder sets the royalty rate r. Second, the downstream producer decides whether to pay for the use of the innovation covered by P's patent or not. Third, if no payment is made, the patent holder can decide whether to pursue the infringement in court (sue) or not (abandon). Fourth, if the patent holder has decided to sue for nonpayment, the downstream producer can either settle and pay the royalty rate r or argue in court that the patent is invalid. If no settlement agreement is reached a court decides that the patent is valid according to a probability p at a legal cost l for each of the parties. If the patent is ruled valid, the court compels the reluctant licensee to pay r. Otherwise, no payment is requested.

The payoffs are constructed as follows. If the patent holder abandons, the total surplus v accrues to the downstream producer. If the patent holder decides to sue for nonpayment and a settlement is reached, the amount corresponding to the royalty rate r is transferred to this agent, while the downstream producer obtains a net surplus $v - r$. Finally, if the case reaches a court, the patent is upheld with probability p and the patent holder obtains an expected profit of $pr - l$. The expected profits of the downstream producer are, consequently, $v - pr - l$.

Notice that the previous structure implies that if the downstream producer settles after being sued by the patent holder it will obtain the same payoff it could have obtained by paying upfront. As a result, in the remaining of the paper we will assume without loss of generality that the downstream producer will not pay unless it is sued.[9] It is also important to point out that the patent holder cannot revise the royalty rate after the court outcome. This option is only relevant when the patent is considered valid and the patent holder might be interested in raising the royalty rate. In practice, such a change would be problematic particularly in a standard-setting context, where it would be used as an indication of patent holdup. This friction might give raise to equilibrium litigation even in the absence of private information. See Section 7 for a discussion.

As usual, the equilibrium r is characterized by backwards induction. The royalty rate offered by P is restricted to be lower or equal than v as, otherwise, the downstream producer would refuse to produce. In the last stage, the downstream producer prefers to go to court, instead of settling, if the royalty rate is sufficiently high, $r > \frac{l}{1-p}$.[10] The patent holder prefers to sue the downstream producer (as opposed to abandon) if either D is expected to settle or if a court trial ensues and $r > \frac{l}{p}$.

The combination of these two thresholds spawns three different regions, which determine the equilibrium royalty rate in the first stage. The next proposition characterizes it

[9] In Appendix B we show that the results broadly hold when paying upfront is sometimes preferred to reaching a settlement.

[10] We assume that if indifferent the downstream producer prefers to settle. Similarly, if indifferent the patent holder prefers to abandon.

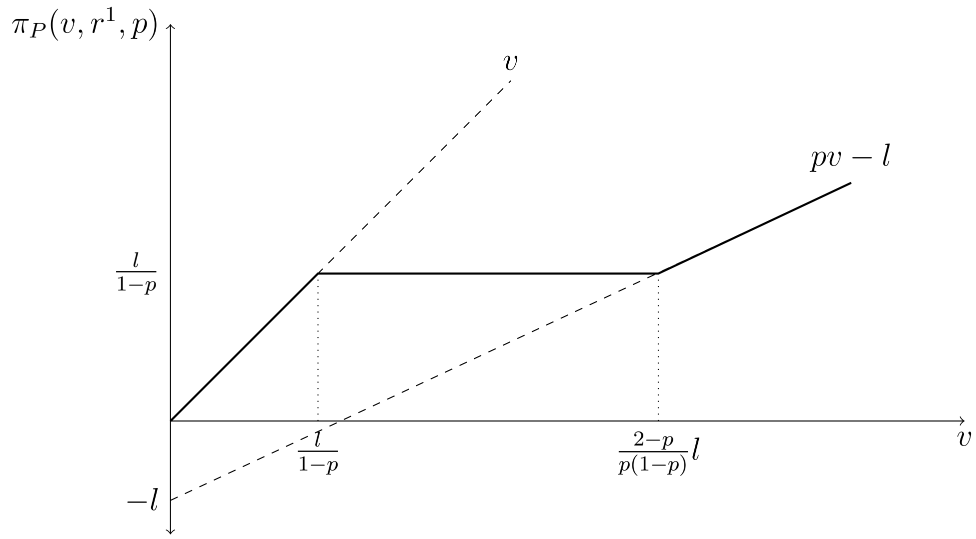

Figure 2: Equilibrium profits of the patent holder, $\pi_P(v, r^1, p)$, as a function of v in the single jurisdiction case.

as a function of the value of the innovation and the legal costs involved.

Proposition 1. *The equilibrium royalty rate in the single market case can be characterized as*

$$r^1 = \begin{cases} v & \text{if } \frac{v}{l} \leq \frac{1}{1-p}, \\ \frac{l}{1-p} & \text{if } \frac{v}{l} \in \left(\frac{1}{1-p}, \frac{2-p}{p(1-p)}\right], \\ v & \text{if } \frac{v}{l} > \frac{2-p}{p(1-p)}. \end{cases}$$

Settlement arises in equilibrium when $\frac{v}{l} \leq \frac{2-p}{p(1-p)}$*. Litigation occurs otherwise.*

The equilibrium payoff of the patent holder resulting from r^1 in the previous proposition — the superindex is used to indicate the single market case — as a function of the value v is displayed in Figure 2. The intuition for the equilibrium is as follows. If v takes a low value, even if the patent holder charges the highest possible royalty rate, $r^1 = v$, the downstream producer will always settle, as the probability of success and invalidation of the patent does not compensate for the legal costs involved. As v increases, however, setting a high royalty rate may induce the downstream producer to go to court. For this reason, the patent holder has to decide whether to engage in a sort of limit pricing (i.e. to charge the highest possible royalty rate for which settlement is preferred by the downstream producer) or choose a rate equal to v and go to court. The second option dominates when v is high — profits are $pv - l$, increasing in v —, while profits from limit pricing, $\frac{l}{1-p}$, are higher for lower values of v. Notice that inefficiencies only arise when v is high since it is in this situation when legal costs are incurred. For lower values of v the royalty rate only affects the ex-post division of surplus from the innovation.[11]

This proposition also indicates that the threshold on the value above which litigation will emerge in equilibrium depends on p in a non-monotonic way. That is, for a given value of v litigation is less likely to arise when p takes an extreme value. This is due to the cost of going to court, l. The patent holder will offer a very low r when p is small in order to avoid litigation. Similarly, the downstream producer will settle if p is high and it faces bad prospects from going to court.

In the rest of the paper we will focus on the intermediate region for the value of innovation so that in the single market case litigation does not arise in equilibrium. For this reason, we make the following assumption.

Assumption 1. $v \in \left(\frac{l}{1-p}, \frac{2-p}{p(1-p)}l\right]$.

This is the most relevant case, as the royalty rate and the way the surplus is split between the patent holder and the downstream producer depends on the probability of success. When v is very low, the royalty rate does not affect the incentives for the downstream firm to go to court and, therefore, the existence of sequential trials will not change the outcome in a meaningful way.

3 Sequential Litigation in Two Jurisdictions

We now turn to the case where each market corresponds to a different local jurisdiction and court procedures take place sequentially. The timing illustrated in Figure 1 changes as follows. Initially, the patent holder determines a royalty rate that applies to both identical markets.[12] The downstream producer decides whether to pay or not in the first

[11] Of course, from an ex-ante point of view welfare also depends on the allocation of this surplus. Innovation incentives are shaped, among other things, by the returns from the investment of P and D.

[12] This assumption is natural in standardization contexts were firms are offered similar conditions in different countries. Assuming that the royalty rate is the same in both markets also allows us to abstract from determining an endogenous litigation order under which firms might decide to go to court if licensing conditions differed.

jurisdiction and the corresponding legal procedure ensues. After an outcome in the first jurisdiction is reached the legal procedure in the second jurisdiction starts.

In this section we focus on the case where $\delta > 0$ and there is a meaningful linkage between jurisdictions. However, it is useful to recall that when the outcomes of the two jurisdictions are independent, $\delta = 0$, the sequence of court procedures is irrelevant and the results in the single jurisdiction case apply to both markets. This case is also equivalent to the situation where litigation takes place simultaneously in both jurisdictions. For this reason, we identify the sequential litigation case with $\delta > 0$ and use the comparison with $\delta = 0$ to uncover its implications.

The next result shows that the royalty rate characterized in Proposition 1 will not arise as part of an equilibrium when litigation takes place sequentially.

Lemma 2. *A royalty rate $r^1 = \frac{l}{1-p}$ cannot be part of a subgame perfect equilibrium under sequential litigation for any $\delta > 0$.*

When jurisdictions are independent, r^1 makes the downstream producer indifferent between settling and going to court. However, when the probability of success in the second trial depends the outcome of the first case, $\delta > 0$, litigation has an additional value for the downstream producer. This is due to its asymmetric effect on profits in the second jurisdiction. If the patent holder succeeds in the first trial the royalty rate would still be r^1, leading to profits of $v - r^1$, as in the case in which there had been no litigation. In contrast, if the patent is considered invalid in the first jurisdiction, the probability of success of the downstream producer when going to court again in the second jurisdiction increases, leading to an expected payment lower than r^1, since

$$v - r^1 = v - pr^1 - l < v - qr^1 - l.$$

To access this option value, the downstream producer finds it worthwhile to go to court in the first jurisdiction in circumstances where in the single jurisdiction case settlement would be preferred. It is worth to mention that this result also arises if the patent holder, after losing the first trial, can revise the royalty rate downwards in the second jurisdiction, as discussed in Section 7.

The patent holder might discourage litigation in the first jurisdiction by offering a royalty rate sufficiently lower than r^1. In that case, P will always collect lower revenues compared to when jurisdictions are independent. Alternatively, the patent holder could seek to raise the royalty rate above r^1. Doing so implies a trade-off between the two jurisdictions. In the first one, a higher r surely fosters litigation, leading to legal costs l and reducing expected profits. In the second jurisdiction, the increase in the royalty rate should be low enough to discourage litigation after an initial success of the patent holder. The reason is the following. In the case where jurisdictions are independent the patent holder prefers to avoid litigation. To the extent that the unconditional probability of success in the second jurisdiction is also p, expected profits from going to court in both jurisdictions must be lower than in the simultaneous case. Thus, a necessary condition for an increase in the royalty rate above r^1 to yield higher profits for the patent holder in the sequential litigation case is that the downstream producer settles in the second jurisdiction after the patent was ruled to be valid in the first one, i.e. $r \leq \frac{l}{1-p-q}$.

The previous discussion also implies that, among the royalty rates higher than r^1, the profit maximizing one must be $\bar{r} = \min\left\{v, \frac{l}{1-q-\delta}\right\}$. Any royalty rate higher than r^1 but below $\bar{r}$ would still give raise to litigation in the first jurisdiction but would lead to a less profitable settlement for the patent holder in the second one in case of an initial success.

The next result characterizes the conditions under which inducing litigation in the first jurisdiction increases profits for the patent holder under sequential litigation.

Proposition 3. *Under sequential litigation, patent holder profits increase in equilibrium compared to when jurisdictions are independent only if $\delta > 1 - \frac{l}{(1-p)v}$ and $v > \tilde{v}$, where*

$$\tilde{v} \equiv \begin{cases} \frac{4-3p+p^2}{(1-p)(1+(1-p)q)} l & \text{if } q \geq \frac{l}{v}, \\ \frac{3-p}{2p(1-p)} l & \text{otherwise.} \end{cases}$$

This equilibrium is sustained by a royalty rate $\bar{r} = \min\left\{v, \frac{l}{1-q-\delta}\right\} > r^1$.

The interpretation of this result arises from the definition of $\bar{r}$, increasing in δ and v. The stronger the informational spillover and/or the higher the price that the product will command in the final market the higher the royalty rate that D will be willing to accept in the second jurisdiction after an initial loss in court. Furthermore, litigation always takes place in the first jurisdiction and profits become $p\bar{r} - l$, increasing in $\bar{r}$.

The effect in the second jurisdiction is compounded by the fact that, as discussed in the single market case, when the initial probabilities of success are extreme litigation will not occur, as one of the parties will always take the necessary steps to avoid it. Under the conditions of the previous proposition, although litigation in the first jurisdiction reduces welfare, the patent holder can appropriate a much larger proportion of the total surplus if p is high and P is not expected to abandon in the second jurisdiction even after an initial loss.

To understand better the implications of the previous results we consider next the case with $\delta = 1$ (and, thus, $q = 0$) so that the outcome of the first jurisdiction completely determines the outcome in the second one. This case also allows us to characterize the optimal royalty rate, which will become useful later in the paper. We also briefly discuss the general case that we develop in detail in Appendix A.

3.1 Optimal Royalty Rate when $\delta = 1$

As explained in the previous section, any royalty rate $r \geq r^1$ will lead to litigation in the first jurisdiction. However, litigation in the second jurisdiction will never take place when $\delta = 1$. The patent holder will abandon in the second jurisdiction after the first patent was considered invalid and the downstream producer will prefer to settle when it was considered valid. Contingent on raising the royalty rate above r^1, it is always optimal for the patent holder to choose $\bar{r} = v$. As a result, payoffs for the patent holder and the downstream producer in the second jurisdiction are v and 0, respectively, after a success of the former in the first trial. The payoffs are reversed when the downstream firm wins in court.

Given the royalty rate $\bar{r} > r^1$, D always prefers to go to court in the second jurisdiction if no litigation took place before. This implies that D prefers to go to court in the first jurisdiction rather than settling, since total profits are

$$\Pi_D^s(v) = (v - p\bar{r} - l) + (v - p\bar{r}) > (v - \bar{r}) + (v - p\bar{r} - l),$$

where the s superindex stands for the sequential litigation case and the terms in brackets indicate the expected profits in the first and second jurisdictions, respectively. Under $\bar{r} = v$, total profits for the patent holder become $\Pi_P^s(v) = 2pv - l$, which exceed those accrued when $\delta = 0$, $\Pi_P(r^1) = \frac{2l}{1-p}$, if $v \geq \frac{3-p}{2p(1-p)}l$. When $v \leq \frac{1+p}{2p(1-p)}l$ the downstream producer is better off under sequential litigation. Interestingly, the patent holder is worse off in that case even though the royalty rate it quotes is higher than under simultaneous litigation. Finally, when the innovation takes an intermediate value, $v \in \left(\frac{1+p}{2p(1-p)}l, \frac{3-p}{2p(1-p)}l\right)$, both the patent holder and the downstream producer are worse off, since the additional costs associated to equilibrium litigation are higher than the gains they can individually obtain.

When v is low the patent holder might still prefer to engage in limit pricing, in this case by offering to license at a rate lower than r^1. By doing so, it might avoid expensive litigation in the first jurisdiction, the cost of which cannot be recouped upon success in court later on. The comparison of both cases — that is, r higher and lower than r^1 — gives raise to the following optimal royalty rate in the sequential case, r^s.

Proposition 4. *Assume $\delta = 1$. The equilibrium royalty rate can be characterized as*

$$r^s = \begin{cases} \underline{r}^s & \text{if } v \leq \underline{v}^s, \\ v & \text{otherwise,} \end{cases}$$

where $\underline{r}^s = \max\left\{l, \frac{l}{2(1-p)}\right\} < r^1$ and $\underline{v}^s = \max\left\{\frac{3l}{2p}, \frac{2-p}{2(1-p)p}l\right\}$. This royalty rate is weakly increasing in v. Litigation occurs when $v > \underline{v}^s$ and firms settle otherwise.

The limit-pricing strategy under sequential litigation, identified by a royalty rate $\underline{r}^s$, accounts for the two cases that can arise in the second jurisdiction after the downstream producer won the first trial. If $r \leq l$ the patent holder prefers to sue the downstream producer anticipating that this firm will settle to avoid paying the legal cost l. If $r > l$ the patent holder abandons because the downstream producer would go to court if sued. In this last case, D will prefer to reach a settlement in the first jurisdiction if

$$\Pi_D^s(v) = 2(v - r) \geq v - pr - l + p(v - r) + (1 - p)v. \qquad (1)$$

That is, the downstream producer must obtain higher profits from settling in both jurisdictions than by going to court in the first one and settling in the second one in case of defeat or obtaining the whole surplus when the patent holder loses and abandons. The previous constraint is satisfied if $r \leq \frac{1}{2(1-p)}$. This royalty rate is higher than l if $p > \frac{1}{2}$. By Proposition 3, both limit-pricing cases are dominated if v is sufficiently large.

The case $\delta = 1$ also provides additional insights on the conditions under which the downstream producer benefits from the informational spillovers that arise when trials take place sequentially. By comparing the profit expression with the case when $\delta = 0$, it is immediate that sequential litigation yields higher profits for D if

$$r^1 = \frac{l}{1-p} > pv + \frac{l}{2}.$$

The expression on the left is the payment for each patent when jurisdictions are unrelated. The expression on the right computes the expected cost per patent under sequential litigation when $r^s = v$. In that case, the downstream producer pays the expected value of each patent, accounting for the legal cost of trying to invalidate the first patent. This cost is split between the two jurisdictions, as the second patent is never challenged in court. The lower the value of the innovation the more likely it is that sequential litigation pays to for the downstream producer.

In Appendix A we discuss the general case when $\delta \in (0, 1)$. We show that δ has an effect qualitatively similar to v. When δ is low the patent holder prefers to choose a royalty rate $r < r^1$ and avoid litigation. To the extent that a higher δ increases the incentives of the downstream producer to go to court this also implies that the optimal royalty rate is decreasing in δ. However, when δ is sufficiently high — in the same way as when v is high — the patent holder can charge a high royalty rate and prevent litigation in the second jurisdiction after success in the first one. This means that, eventually, a royalty rate $\bar{r} > r^1$ increasing in δ becomes optimal. These results indicate that, for a sufficiently high value of v, δ has a non-monotonic effect on the royalty rate and patent holder profits.

3.2 Strategic Litigation Choice

The previous section has characterized the equilibrium royalty rate that arises when patents litigation is exogenously determined as a sequential process in the two jurisdictions. This case has been compared to the situation where there are no spillovers across trials either because $\delta = 0$ or, equivalently, because patents are litigated at the same time. We have showed that when litigation is sequential the patent holder faces two options. One possibility is to choose a low royalty rate, $\underline{r}^s$ — as defined in Proposition 4 for the case with $\delta = 1$ — and always engage in limit pricing. This option avoids litigation in equilibrium and, as a result, whether litigation is simultaneous or sequential has no impact on welfare. However, since $\underline{r}^s < r^1$, sequential litigation transfers rents from the patent holder to the downstream producer. Alternatively, the patent holder can increase the royalty rate to $r^s = v > r^1$, fostering welfare-decreasing litigation in the first jurisdiction while increasing P's second-jurisdiction profits in case of an initial success. Proposition 3 shows that if the informational complementarities between jurisdictions are significant (δ is high) and the valuation of the technologies is high (v is large), this choice might lead to higher overall profits for the patent holder in the sequential case. The downstream producer in that case would be better off if litigation took place simultaneously.

These arguments, however, presume that the patent holder chooses the royalty rate after litigation has been determined to be either simultaneous or sequential. This is not a realistic assumption. As discussed in the introduction, downstream producers can achieve a specific timing of litigation by delaying negotiations in some jurisdictions more than in others. Importantly, this choice is made after the patent holder has proposed the royalty rate.

To accommodate for this choice, the timing of the model is expanded as follows. In the first stage, the patent holder decides on the royalty rate. In the second stage the downstream producer decides whether to engage in simultaneous or sequential litigation. After that, the structure of the game proceeds as in previous sections. To simplify the exposition in the rest of the section we focus on the case where $\delta = 1$.

The next result shows that, in equilibrium, the outcome will coincide with that of sequential litigation, with the associated social inefficiencies arising from excessive litigation. This is the case even when the downstream producer would be better off in the (exogenously determined) simultaneous case.

Proposition 5. *Suppose $\delta = 1$. For any royalty rate, the downstream producer will always weakly prefer to induce sequential litigation. As a result, the equilibrium royalty rate will be r^s as defined in Proposition 4.*

The intuition for this result is as follows. When $r \leq \underline{r}^s$ settlement always takes place and the way litigation is structured has no effect on the final outcome. When $r \in (\underline{r}^s, r^1)$ litigation occurs in equilibrium only in the sequential case. Using Lemma 2 we know that D is better off in this case. Finally, if $r^s = v > r^1$ both cases lead to equilibrium litigation. However, simultaneous litigation leads to legal costs in both jurisdictions, whereas in the sequential case there is only one trial. The loser then prefers to settle or abandon in the second jurisdiction.

The previous result has important implications for the firms' incentives to innovate. As the strategic use of sequential litigation reduces the returns from the patent holder's investment, innovation by this firm is likely to be negatively affected. Furthermore, to the extent that sequential litigation engenders legal costs associated to the trial in the first jurisdiction, total profits are also reduced, undermining the overall incentives to invest.

4 Policy Interventions

The analysis in the previous section explains the prevalence of sequential litigation, particularly when v is high. This choice results in excessive litigation. The cost of these procedures has lead scholars and practitioners to propose alternative arrangements to mitigate its associated costs. In this section we discuss two possibilities: global litigation and voluntary arbitration.

4.1 Global Litigation

Consider now the case where the validity of both patents is determined by the same court. Global litigation differs from the benchmark case discussed earlier in that the downstream producer cannot choose the timing of the trials. Equilibrium profits can be obtained from the single jurisdiction case where the payoffs have been doubled. As a result, the equilibrium royalty rate will remain unchanged at $r^1 = \frac{l}{1-p}$ and no litigation will take place. Total profits are $\Pi_D(r^1) = 2(v - r^1)$ and $\Pi_P(r^1) = 2r^1$ for the downstream producer and the patent holder, respectively.

Notice that we are implicitly assuming that the legal costs of global litigation applying to two markets are twice the cost of one market. There are many reasons to believe that global litigation might lead to a total cost higher than l. It can arise if there are two jurisdictions but the royalty rate determined in one of them also applies to the other, as in the Unwired Planet vs Huawei case. It can also occur under a global jurisdiction. In that case, a supranational tribunal determines the royalty rate that applies to all markets, as proposed in Contreras (2019). Most importantly, this assumption means that the global litigation case is not superior to enforcing the patents in local jurisdictions simply due to the economies of scale in the legal process that it entails.

The next result is a direct consequence of Proposition 5. Global litigation is more efficient than a system where each patent is independently tried in each jurisdiction. The reason is that it prevents sequential litigation when it might lead to a royalty rate equal to v that fosters litigation.

Remark 1. *When $\delta = 1$ local jurisdictions lead to socially inefficient litigation compared to a global jurisdiction if $v > \underline{v}^s$.*

This discussion is relevant to understand the impact of court-mandated global licensing deals. In *Unwired Planet v Huawei*, the UK court imposed an injunction on Huawei to sell its products in its jurisdiction unless it agreed to a global licensing royalty rate with Unwired Planet in other jurisdictions.[13] In light of our model, this kind of global licensing requirements, to the extent that they prevent further litigation, could have a positive effect on social welfare.

4.2 Global Arbitration

Global litigation removes the dynamic component of the sequential litigation setup that may foster an increase in the royalty rate of the patent holder to benefit in the second jurisdiction. It has been argued that arbitration could play a similar role. Licensees unwilling to pay the royalty rate proposed by a patent holder could voluntarily submit their pledge to an arbitrator that would produce a globally binding ruling. In this section we explore this case.

To analyze this case we modify the sequential litigation model in the following way. We assume that in the first jurisdiction and after the patent holder has offered a royalty rate, the downstream producer can decide whether to go to court, to settle, or to request an arbitration. As in the benchmark model, after a court decision or a settlement the process will start in the second jurisdiction. In the case of arbitration, the patent is declared valid with probability p. However, this ruling applies to both jurisdictions and no further litigation is possible. To avoid distortions due to the different legal costs, we assume, as in the global litigation case, that the cost of arbitrage is $2l$.

The next result shows that voluntary arbitration will never arise in equilibrium.

[13] See Unwired Planet vs Huawei [2020] UKSC 37.

Proposition 6. *From the perspective of the downstream producer, when $\delta = 1$, arbitration is (weakly) dominated by settlement when $r \leq r^1$ or by litigation when $r > r^1$.*

When the royalty rate is lower than r^1, the downstream producer faces the same trade-offs as in the simultaneous litigation model, since arbitration leads to payoffs identical to those of going to court in both jurisdictions. Hence, settlement is preferred. If r is higher than r^1 arbitration is dominated by going to court in the first jurisdiction. The reason is that this option implies legal costs l but it avoids further legal costs. After the court outcome, the losing party is willing to settle in the second jurisdiction.

When the costs of arbitration are lower than $2l$ the results could change for mechanical reasons. Settlement is less likely to be preferred for values of r close to r^1. However, it is worth to notice that for arbitration to prevent litigation in the first jurisdiction — that is, when $r > r^1$ — its costs would have to be lower than l. This is precisely the case where litigation leads to a social welfare cost.

5 Downstream Competition

In the benchmark model the downstream producer is implicitly interpreted as a monopolist in the final market and, due to the inelastic demand, litigation generated no distortion in consumption because the price was always equal to v. We now relax this assumption and study the implications of sequential litigation for competition and efficiency.

We model competition by considering the interaction between the downstream producer and a competitive fringe. As in the benchmark case, a continuum of consumers of size 1 is exclusively served by the downstream producer. We assume, however, that there is a second segment of the market with a continuum of consumers of size $\beta > 0$ that can also be served by a continuum of identical firms. The downstream producer has a comparative disadvantage on these contested consumers vis-a-vis the firms in the competitive fringe, that we measure by the parameter $s \in (0, v)$.

To simplify the analysis and consistent with usual practice in the case of SEPs, we

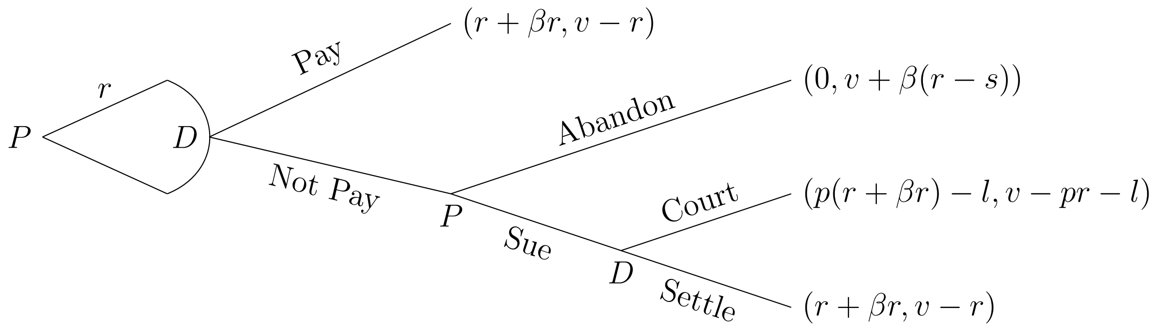

Figure 3: Structure of the one jurisdiction game when $r > s$.

assume that the competitive fringe and the downstream producer are offered the same royalty rate by the patent holder. This means that by accepting to pay for the license the downstream producer will never profitably undercut the competitive fringe in the contested segment of the market. Similarly, if the patent is invalidated in one jurisdiction, none of the firms will need to license it. However, if the downstream producer refuses to pay and is not brought to court, the competitive fringe will still pay the royalty rate r. As a result, the downstream producer will profitably undercut the competitive fringe as long as $s < r$.[14]

We start by studying the single market case. The payoffs of the stage game are described in Figure 3. Compared to the benchmark model, two differences emerge. First, the payoffs of the downstream producer remain unchanged unless the patent holder decides not to sue D for lack of payment. In that case the downstream producer undercuts the competitive fringe in the contested part of the market and charges a final price $r - s$.[15] Second, the payoffs of the patent holder increase in the amount βr unless the competitive fringe does not produce in equilibrium. This occurs when the patent holder decides not to fight the infringement of the downstream producer.

Solving this game by backwards induction we obtain similar results as in the benchmark case. The downstream producer will prefer not to pay for the license and go to court

[14] We implicitly assume that firms in the competitive fringe face prohibitively high legal costs, compared to their revenues from production, so that they would never go to court and they will always prefer to pay upfront for the license.

[15] If $s > r$ the competitive fringe produces and the payoffs of the downstream producer are identical to those the benchmark case. As we will see next this case is uninteresting.

if $r > \frac{l}{1-p}$. The patent holder, however, due to the larger size of the total market is less likely to abandon, since a court trial is now profitable if $r > \frac{l}{p(1+\beta)}$. That is, the higher the size of the contested part of the market the higher the revenues from succeeding in court.

The equilibrium royalty rate is similar to the one characterized in Proposition 1. The only difference is that limit pricing now arises when $v \in \left(\frac{l}{1-p}, \frac{l}{p(1-p)} + \frac{l}{1+\beta}\right]$. The larger the contested segment of the market the less likely it is that limit pricing emerges in equilibrium and the larger is the range of parameters under which litigation occurs.

We now turn to the two markets case and compare the outcome under global and sequential litigation. As in the benchmark model we focus on the region where limit pricing arises in the single market case.

Global litigation coincides with the case of a single jurisdiction and it yields the same total profits in each market, $\Pi_D(v) = 2\left(v - \frac{l}{1-p}\right)$, independently of β. Since in equilibrium the patent holder never abandons and always sues for nonpayment, the downstream producer never produces in the contested part of the market.

Interestingly, in the sequential litigation case an additional effect emerges that benefits the downstream producer. In particular, suppose that the patent holder sets a royalty rate $r^1 = \frac{l}{1-p}$, as in the case of simultaneous trials. In the benchmark model we saw that this royalty would typically lead to litigation, since going to court provided an option value in the second jurisdiction. When there is downstream competition, litigation in the first jurisdiction provides an additional gain to the downstream producer. When successful, it might benefit from the patent holder deciding not to enforce the patent in the second jurisdiction if $r^1 < \frac{l}{q(1+\beta)}$. In that case the downstream producer would obtain additional profits by undercutting the competitive fringe and selling also in the contested part of the market. This means that, compared to the benchmark case, the patent holder would have to lower the royalty rate even further to discourage litigation in the first jurisdiction. The next result also shows that a trial is more likely to arise in equilibrium the larger is the contested segment of the market, increasing the inefficiency arising from sequential litigation.

Proposition 7. *Assume $\delta = 1$ and $s < \frac{l}{2(1-p)}$. Under downstream competition when litigation is sequential the equilibrium royalty rate can described as*

$$r^d = \begin{cases} \underline{r}^d & \text{if } v \leq \underline{v}^d, \\ v & \text{otherwise,} \end{cases}$$

where $\underline{r}^d = \max\left\{l, \frac{l+(1-p)\beta s}{(2+\beta)(1-p)}\right\}$ and $\underline{v}^d = \max\left\{\frac{3l}{2p}, \frac{l+(1-p)\beta s}{(2+\beta)(1-p)p} + \frac{l}{2p}\right\}$ are weakly decreasing in β. As a result, the range of values of v for which litigation arises in equilibrium is increasing in β.

To interpret the result, first notice that the case $\beta = 0$ coincides with the characterization of r^s in Proposition 4. As β increases, and consistent with the previous discussion, undercutting the competitive fringe becomes increasingly profitable for D. The patent holder must lower the royalty rate further if it wants to prevent litigation in the first jurisdiction. As a result, the higher is β the more likely it is that the alternative, increasing the royalty rate to v, is preferred by the patent holder in spite of the inefficient litigation it might bring about.

6 Patent Injunctions

The results of the previous sections compare the outcome under global and local litigation. However, it could be argued that the outcome in the single market case is not necessarily the right benchmark, as it determines a specific allocation of the surplus between the patent holder and the downstream producer. Patent holders facing licensees that refuse to pay for a license often request a motion for an injunction to be imposed on the sale of the product that embeds the innovation (Denicolò et al., 2008). Courts frequently see these injunctions as a way to balance the risk of holdout by downstream producers and holdup by patent holders. In this section we explore how injunctions can change the

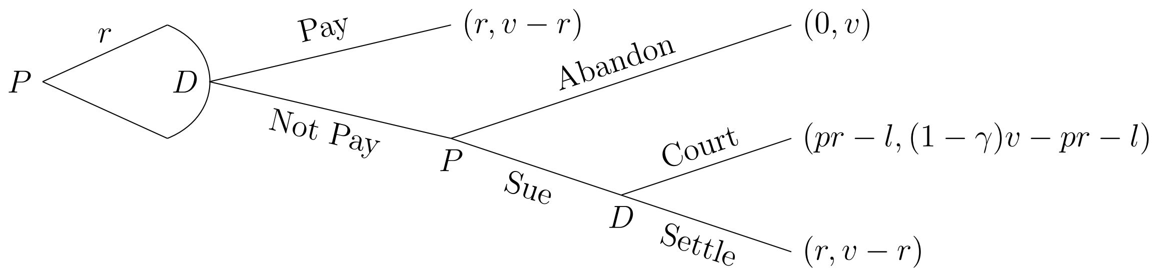

Figure 4: Stage game when the patent holder can ask for an injunction.

previous results and, in particular, the social-welfare implications of sequential litigation, arising under local jurisdictions.[16]

We assume that the patent holder can obtain an injunction when the downstream producer refuses to pay for a license while the case is resolved in court. As a result, the innovation generates a value for D of $(1 - \gamma)v$ where $\gamma \in [0, 1]$. This parameter can be interpreted as value destruction that an injunction brings about due to the temporary prohibition to sell the good that embeds the technology. Our assumption captures the fact that this cost falls mainly on the downstream producer who sees its production disrupted while the legal process is resolved in court, affecting also the relation with customers and suppliers. Compared to the benchmark model, the rest of the payoffs remain unchanged. Figure 4 summarizes the modified stage.[17]

In the single market case, for a given licensing payment r, the downstream producer will prefer to go to court if $r > \frac{\gamma v + l}{1 - p}$. Compared to the benchmark model, a higher patent value or a stronger injunction increases the value for D of reaching a settlement and being able to sell the product. The patent holder decides to sue either if D is expected to settle or if $r > \frac{l}{p}$. The next result characterizes the counterpart of Proposition 1 under a patent injunction.

Lemma 8. *In the subgame-perfect equilibrium of the single jurisdiction case, the optimal*

[16] We do not aim to determine how courts should modulate patent injunctions. Doing so requires a model of ex-ante innovation that is beyond the scope of this paper.

[17] Notice that we are abstracting from the time dimension in the resolution of the injunction. If after a court decision the product could only be sold during a proportion $\omega < 1$ of the time, the value and the licensing payment would also carry a weight $1 - \omega$ and ω, respectively, in the profit function of the patent holder and the downstream producer.

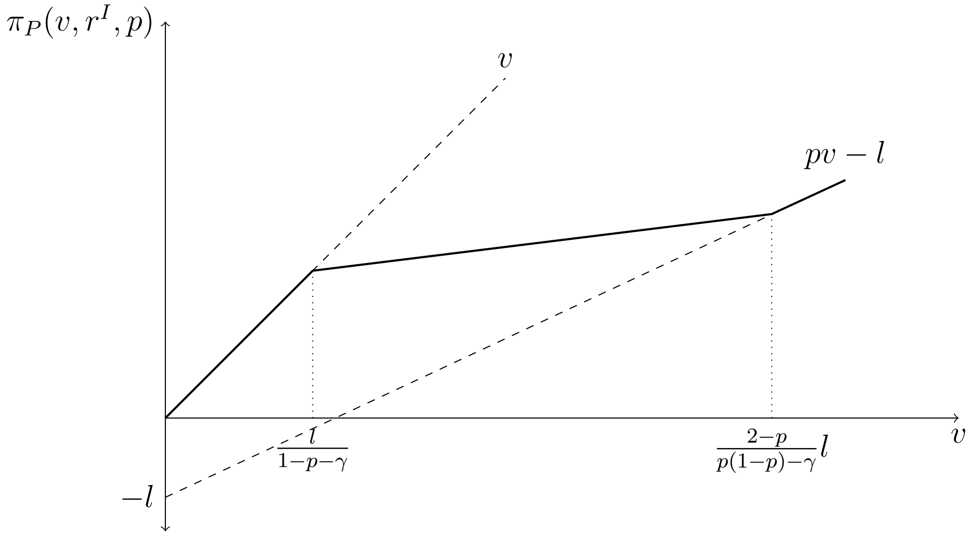

Figure 5: Equilibrium profits of the patent holder in the one-jurisdiction case under an injunction of strength $\gamma \leq p(1-p)$.

royalty rate for the patent holder when an injunction is obtained, r^I, takes the following form, depending on the strength of $\gamma \in [0,1]$:

- *If $\gamma < p(1-p)$, then*

$$r^I = \begin{cases} v & \text{if } v \leq \frac{l}{1-p-\gamma}, \\ \frac{\gamma v + l}{1-p} & \text{if } v \in \left(\frac{l}{1-p-\gamma}, \frac{2-p}{p(1-p)-\gamma}l\right], \\ v & \text{if } v > \frac{2-p}{p(1-p)-\gamma}l. \end{cases}$$

- *If $p(1-p) < \gamma \leq 1-p$, then*

$$r^I = \begin{cases} v & \text{if } v \leq \frac{l}{1-p-\gamma}, \\ \frac{\gamma v + l}{1-p} & \text{if } v > \frac{l}{1-p-\gamma}. \end{cases}$$

- *If $\gamma > 1-p$ then $r^I = v$.*

Firms only go to court if $v > \frac{2-p}{p(1-p)-\gamma}l$ and $\gamma < p(1-p)$.

Figure 5 shows the payoff of the patent holder when the injunction is *weak* — a low value of γ — and has a small effect on sales. By continuity with the benchmark case, the optimal royalty can be defined as a function of v spawning the three original segments. The thresholds that define these regions are affected positively by the injunction. First, the region in which a royalty rate equal to v can be charged and D accepts it (when v is low) expands when γ increases. Second, the royalty rate that P offers in the limit-pricing region also increases. Finally, and related to the previous effect, as the downstream producer is more willing to accept a high royalty rate, the litigation region contracts.

Interestingly, the previous lemma also shows that as γ increases some of the previous regions might collapse. In particular, when $\gamma \geq p(1-p)$ litigation never arises in equilibrium. This is due to the fact that when injunctions are sufficiently strong the downstream producer loses more from going to court through the impossibility of selling the product than the potential savings when it succeeds.

We now briefly turn to the case of two markets under sequential litigation, which arises in the case of local jurisdictions. We focus on the case in which $\gamma < p(1-p)$ so that litigation is a relevant concern. Furthermore, as in previous sections, we focus our discussion for the case where the outcome of the second trial is completely determined by the first court decision.

Proposition 9. *Suppose that $\delta = 1$ and $\gamma < p(1-p)$. Under sequential litigation, firms go to court when $v > \underline{v}^I(\gamma)$, where this threshold is increasing in the strength of the injunction, γ. Furthermore, the lowest value of v for which the patent holder prefers sequential litigation to global litigation, $\tilde{v}_P(\gamma)$, is increasing in γ. The highest value of v for which the downstream producer prefers sequential litigation, $\tilde{v}_D(\gamma)$, is increasing (decreasing) in γ if p is sufficiently high (low), where $\tilde{v}_D < \tilde{v}_P$.*

First of all, notice that this result embeds the case discussed in Section 3.1 as the situation with $\gamma = 0$. As expected, for some intermediate values of v (between $\tilde{v}_D$ and $\tilde{v}_P$) sequential litigation is detrimental to the profits of both the patent holder and the downstream producer. This is due to the legal costs incurred in equilibrium under sequential litigation, which reduce total surplus. For low values of v the lower royalty rate chosen by P benefits the downstream producer. For high values of v, sequential litigation allows the patent holder to charge a higher royalty rate and this might increase profits.

Changes in γ introduce an interesting comparative statics exercise to the previous discussion. It turns out that, from the patent holder's point of view, the strength of the injunction is complementary with global litigation. In that case, the patent holder can increase the royalty rate as γ increases, which applies to both patents and jurisdictions. In contrast, under sequential litigation the strength of the injunction does not affect the decision of D of going to court in the second jurisdiction.

In the case of the downstream producer, the effect is more nuanced and it depends on the value of p. Both in the sequential and the global litigation case, the injunction leads to lower profits. While under sequential litigation a higher γ decreases profits linearly, when litigation is global the effect is higher when p is smaller. This means that when p is low increases in γ favor sequential litigation while the opposite is true when p is large.

Finally, the previous results suggest an important trade-off related to injunctions. On the one hand, they reduce litigation in equilibrium in the sequential case and its associated inefficiencies. On the other hand, injunctions reduce patent holdout at the cost of preventing the product from being sold in the final market for some time.

7 Revised Royalty Rates

Throughout the paper we have assumed that the royalty rate initially chosen by the patent holder is not revised neither after the court decision in the first jurisdiction nor in the second jurisdiction. We now discuss these possibilities.

Regarding the first situation, consider the single jurisdiction case. It is easy to see that after success the patent holder would prefer to raise the royalty rate from r^1 to v. However, as mentioned earlier, in standardization contexts this increase in the royalty rate would most likely lead to legal scrutiny amid accusations of patent holdup.

The second situation is potentially more relevant in practice. Increases in the royalty rate in the second jurisdiction after an initial success would most likely be restricted when patents are licensed according to FRAND commitments. Furthermore, in many instances — particularly when $\delta = 1$ — this option is unlikely to be used even if allowed, since in equilibrium litigation already arises precisely when the patent holder finds optimal to choose the highest relevant royalty rate, $r^s = v$.

Alternatively, after the patent has been invalidated in the first jurisdiction, the patent holder might decide to lower the royalty rate in the second one. FRAND requirements are not likely to be relevant. In particular, a royalty $r_2 = \frac{l}{1-q}$ would avoid further litigation and increase patent holder profits compared to abandoning in the second jurisdiction. Solving by backwards induction, the optimal royalty rate in the second jurisdiction is characterized in Proposition 1 with p replaced by q.

As in the benchmark model, when $\delta > 0$ a royalty in the first jurisdiction equal to r^1 leads to litigation. In this case profits for D from a court decision that invalidates the first patent are even larger, since it implies a lower royalty in the second jurisdiction.

The next result characterizes a counterpart of Proposition 4 when the patent holder can revise the royalty rate upwards or downwards in the second jurisdiction.

Proposition 10. *Assume $\delta = 1$. Suppose that the patent holder can revise the royalty rate in the second jurisdiction after the patent is invalidated in the first jurisdiction. The equilibrium royalty rate in that case can be characterized as*

$$r^s = \begin{cases} \underline{r}^s & \text{if } v \leq \underline{v}^s, \\ v & \text{otherwise,} \end{cases}$$

where $\underline{r}^s = \frac{2-p}{2(1-p)}l$ and $\underline{v}^s = \frac{2-p^2}{2(1-p)p}l$. This royalty rate is weakly increasing in v. Litigation occurs when $v > \underline{v}^s$.

8 Concluding Remarks

The goal of this paper was to provide a framework to understand the incentives for downstream producers to engage in sequential litigation as part of a patent holdout strategy (or efficient patent infringement), its implications on the royalty revenues that a patent holder would obtain, and the effects of the regulatory framework. The results suggest that sequential litigation, facilitated by local jurisdictions, generates social welfare losses, particularly when the innovation has a high value and the outcomes across jurisdictions are highly correlated. When innovations have a lower value, however, the threat of sequential litigation is used by downstream producers to extract a lower royalty rate from patent holders. This result is likely to occur in the case of SEPs, for which licensing restrictions like FRAND requirements might limit the flexibility of patent holders to adjust the royalty rate to market conditions.

The rigidity behind this last effect can be the result of many mechanisms. This paper is mainly motivated by the negotiation of technologies resulting from standardization processes. In that context, FRAND obligations and, particularly, non-discrimination clauses might reduce the room for offering different contracts in different jurisdictions. More generally, while litigation might be chosen to be sequential, the initial negotiations might not be, and the patent holder could be initially facing two similar markets for which the same royalty rate would be optimal. It is unlikely that courts would allow the royalty rates specified in licensing contracts to be renegotiated upwards as a result of previous litigation in another jurisdiction.

The stylized model we propose in this paper emphasizes the social costs of holdout while abstracting from the consequences of holdup. As it has been discussed in the literature, holdup can generate a social cost when, unlike in our paper, demand is downward sloping. In that case, a higher royalty rate engenders an additional deadweight loss that needs to be balanced with the investment incentives that the innovation brings about. Similarly, in the model the patent holder is not allowed to condition the royalty rate on whether litigation takes place simultaneously or sequentially due to the FRAND non-discrimination commitments. Relaxing these assumptions would reduce the social value of patent injunctions in restoring the balance between holdup and holdout, and the analysis of its consequences is left for future research.

This paper leaves open other relevant questions. As explained before, while litigation may be sequential, negotiations might be simultaneous. It would be worth to explore whether, once we allow for jurisdictions to be different, downstream producers might endogenously determine in which one they prefer to go to court first and how this might impact the distribution of surplus and the litigation inefficiencies that might arise.

References

Bernhardt, Dan and Frances Zhiyun X. Lee, "Trial Incentives in Sequential Litigation," *American Law and Economics Review*, 08 2014, *17*(1), pp. 214–244.

Bourreau, Marc, Rafael C. de M. Ferraz and Yanne Ménière, "Licensing Standard-Essential Patents with Costly Enforcement," 2016, mimeo.

Briggs, Hugh C., Kathleen D. Huryn and Mark E. McBride, "Treble Damages and the Incentive to Sue and Settle," *The RAND Journal of Economics*, 1996, *27*(4), pp. 770–786.

Chien, Colleen V., "Holding Up and Holding Out," *Michigan Telecommunications and Technology Law Review*, Fall 2014, *21*(1), pp. 1–41.

Choi, Jay Pil, "Patent Litigation as an Information-Transmission Mechanism," *American Economic Review*, 1998, *88*(5).

Choi, Jay Pil and Heiko Gerlach, "A Model of Patent Trolls," *International Economic Review*, 2018, *59*(4), pp. 2075–2106.

Contreras, Jorge L., "Global Rate Setting: A Solution for Standard- Essential Patents?" *Washington Law Journal*, 2019, *94*, pp. 701–757.

Daughety, Andrew F. and Jennifer F. Reinganum, "Informational Externalities in Settlement Bargaining: Confidentiality and Correlated Culpability," *The RAND Journal of Economics*, 2002, *33*(4), pp. 587–604.

Denicolò, Vincenzo, Damien Geradin, Anne Layne-Farrar and A. Jorge Padilla, "Revisiting Injunctive Relief: Interpreting Ebay in High-tech Industries with Non-Practicing Patent Holders," *Journal of Competition Law and Economics*, 2008, *4*(3), pp. 571–608.

Epstein, Richard A. and Kayvan B. Noroozi, "Why Incentives for "Patent Holdout" Threaten to Dismantle FRAND and why it matters," *Berkeley Technology Law Journal*, 2018, *32*(1381-1432).

Geradin, Damien, "Reverse Hold-ups: The (Often Ignored) Risks Faced by Innovators in Standardized Areas," in *The Pros and Consof Standard Setting*, Konkurrensverket Swedish Competition Authority, 2010 pp. 101–143.

Golden, John M., ""Patent Trolls" and Patent Remedies," *Texas Law Review*, 2007, *85*, pp. 2111–2161.

Heiden, Bowman and Nicolas Petit, "Patent "Trespass" and the Royalty Gap: Exploring the Nature and Impact of Patent Holdout," *Santa Clara High Technology Law Journal*, 2018, *34*(2), pp. 179–249.

Horn, Henrik, "International Jurisdiction over Standard-Essential Patents," 2020, eUI Working Paper RSCAS 2020/02.

Lemley, Mark A. and Carl Shapiro, "Patent Holdup and Royalty Stacking," *Texas Law Review*, 2007, *85*, pp. 1991–2049.

Leonard, Gregory K. and Mario A. Lopez, "Determining RAND Royalty Rates for Standard-Essential Patents," *Antitrust*, 2014, *29*(1), pp. 86–94.

Lerner, Josh and Jean Tirole, "Standard-Essential Patents," *Journal of Political Economy*, 2015, *123*(3), pp. 547–586.

Shapiro, Carl and Mark A. Lemley, "The Role of Antitrust in Preventing Patent Holdup," *University of Pennsylvania Law Review*, 2019, *168*, pp. 2019–2058.

A Optimal Royalty for $\delta < 1$

In Section 3.1 we characterized the optimal royalty rate under sequential litigation when $\delta = 1$. This section studies how the equilibrium royalty rate looks like in the generic case. In order to simplify the discussion, it is useful to start by analyzing separately the optimal royalty rate, r, contingent on being lower or higher than r^1.

We start with the case where $r < r^1$. A necessary condition for this royalty to be optimal is that it avoids litigation in the first jurisdiction. In that case, and given that the ex-ante probability of success of the downstream producer is the same in the second jurisdiction, settlement will also be reached there. The downstream producer compares this outcome with the result of going to court in the first jurisdiction. If the patent holder succeeds in that case, the downstream producer will also settle in the second jurisdiction, since $r < r_1 < \frac{l}{1-q-\delta}$. Otherwise, if the downstream producer wins in the first jurisdiction, the downstream producer will be interested in litigating if $r > \frac{1}{1-q}$ and the patent holder will decide to abandon if $r < \frac{l}{q}$ or if D is expected to settle.

The optimal royalty rate for the patent holder, contingent on $r < r_1$, has to guarantee that the downstream producer prefers to settle in both jurisdictions. The next result characterizes this optimal royalty rate.

Lemma 11. *Contingent on $r < r^1$, the optimal royalty rate for the patent holder in the sequential litigation case is*

$$r^* = \begin{cases} \frac{(2-p)l}{(2-(1-\delta)p)(1-p)} & \text{if } \delta \leq \frac{5p-2p^2-2}{p(3-2p)}, \\ \frac{l}{1-(1-\delta)p} & \text{if } \delta \in \left(\frac{5p-2p^2-2}{p(3-2p)}, \frac{1-p}{p}\right), \\ \frac{l}{2(1-p)} & \text{otherwise.} \end{cases}$$

The optimal royalty and profits are decreasing in δ.

The previous result shows that the optimal royalty rate when the patent holder wants to avoid litigation is decreasing in δ. The reason is that the stronger the linkage between the two jurisdictions the higher the profits of the downstream producer in the second jurisdiction from going to court after success in the first one. To prevent this litigation the patent holder must lower the royalty rate.

We now turn to the case where $r \geq r^1$. When the royalty is high, the downstream producer prefers to go to court in the first jurisdiction. It will also want to go to court in the second jurisdiction after an initial success. If the patent holder won, however, the downstream producer would only go to court if $r > \frac{l}{1-q-\delta}$. As in Proposition 3, the outcome will depend on whether the previous threshold is higher or lower than v.

Lemma 12. *Contingent on $r \geq r^1$, the optimal royalty rate for the patent holder in the sequential litigation case is*

$$r^* = \begin{cases} v & \text{if } v < \frac{l}{(1-\delta)(1-p)}, \\ \frac{l}{(1-\delta)(1-p)} & \text{if } v \in \left[\frac{l}{(1-\delta)(1-p)}, \tilde{v}\right], \\ v & \text{otherwise,} \end{cases}$$

where $\tilde{v}$ is weakly increasing in δ. Profits are increasing in δ.

The combination of the previous results indicate that, for a given v a royalty rate $r < r_1$ is optimal for the patent holder when δ is small, whereas the opposite is true when the linkage between jurisdictions is strong.

B When Lawsuits are Costly

Throughout the paper we have assumed that the profit of both P and D are identical when the downstream producer pays upfront or when a settlement is reached in the last stage. This assumption simplified the model as it implied that we could, without loss of generality, assume that firm P would always sue.

In this section we relax this assumption. We assume that if the patent holder sues an extra cost $\tau > 0$ is incurred by both firms. This parameter captures the costs of filing a lawsuit or the consequences of the delays originated by litigation and it is not incurred when P abandons. This assumption implies that if firm D anticipates that it will eventually settle, a license will be accepted upfront. Figure 6 illustrates the payoffs in this case.

The next result characterizes the equilibrium royalty rate in the single-jurisdiction case.

Proposition 13. *Suppose that $\tau \leq \frac{l}{1-p}$. When lawsuits are costly, the equilibrium royalty rate in the single-jurisdiction case is characterized as,*

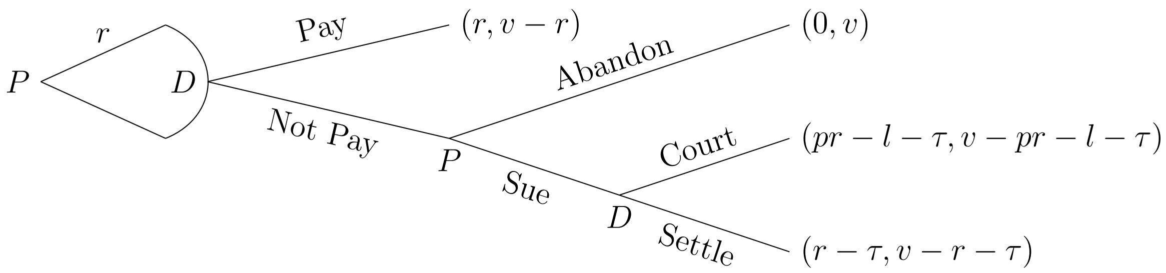

Figure 6: Stage game when the patent holder can ask for an injunction.

- *If* $p \leq \frac{1}{2}$,

$$r^1 = \begin{cases} v & \textit{if } v \leq \frac{l}{1-p}, \\ \frac{l}{1-p} & \textit{if } v \in \left(\frac{l}{1-p}, \frac{2-p}{p(1-p)}l + \frac{\tau}{p}\right], \\ v & \textit{if } v > \frac{2-p}{p(1-p)}l + \frac{\tau}{p}. \end{cases}$$

Firm D pays upfront as long as $v < \frac{2-p}{p(1-p)}l + \frac{\tau}{p}$. *Otherwise, firms go to court.*

- *If* $p \in \left(\frac{1}{2}, \frac{l+\tau}{2l+\tau}\right]$,

$$r^1 = \begin{cases} v & \textit{if } v \leq \frac{l}{1-p}, \\ \frac{l}{1-p} & \textit{if } v \in \left(\frac{l}{1-p}, \frac{l+\tau}{p}\right], \\ v & \textit{if } v \in \left(\frac{l+\tau}{p}, \frac{l+\tau}{1-p}\right], \\ \frac{l+\tau}{1-p} & \textit{if } v \in \left(\frac{l+\tau}{1-p}, \frac{2-p}{p(1-p)}(l+\tau)\right], \\ v & \textit{if } v > \frac{2-p}{p(1-p)}(l+\tau). \end{cases}$$

Firm D pays upfront as long as $v < \frac{2-p}{p(1-p)}(l+\tau)$. *Otherwise, firms go to court.*

- *If* $p > \frac{l+\tau}{2l+\tau}$,

$$r^1 = \begin{cases} v & \textit{if } v \leq \frac{l+\tau}{1-p}, \\ \frac{l}{1-p} & \textit{if } v \in \left(\frac{l+\tau}{1-p}, \frac{2-p}{p(1-p)}(l+\tau)\right], \\ v & \textit{if } v > \frac{2-p}{p(1-p)}(l+\tau). \end{cases}$$

Firm D pays upfront as long as $v < \frac{2-p}{p(1-p)}(l+\tau)$. *Otherwise, firms go to court.*

Several features of the previous equilibrium are worth highlighting. First, both low and high values of v yield an equilibrium royalty rate $r = v$. As in the benchmark model, when the innovation has a low value, it is not worth for D to go to court. When the innovation has a high value, litigation arises in equilibrium and, for this reason, P offers the highest possible royalty rate. Second, settlement never arises in equilibrium. When D anticipates that if sued a settlement will be reached, it prefers to pay upfront, saving τ. As a result, firm D pays before being sued unless v is very large. In that case, $r^1 = v$ and litigation takes place in equilibrium.

Although settlement does not arise in equilibrium, for all values of p it is still optimal for P to engage in limit pricing for intermediate values of v, as it turns out, using the same royalty rate, $\frac{l}{1-p}$. Firm D pays upfront when the royalty rate would make settlement desirable. This result indicates that the findings in the benchmark model still go through in this case. Furthermore, for high and low values of p the region under which limit pricing takes place expands when τ increases making the limit pricing case that is central to our analysis more prevalent.

In the intermediate region, however, other royalty rates that amount to variations of the limit pricing result can arise. They arise because by choosing $r^1 = \frac{l+\tau}{1-p}$ firm D is indifferent between paying upfront or going to court in the same way as a royalty rate $r^1 = \frac{l+\tau}{1-p}$ induces indifference between settling and going to court.

C Proofs

Define the profits of the patent holder and the downstream producer in one jurisdiction as a function of v and r and the probability of success in court as $\pi_P(v,r,p)$ and $\pi_D(v,r,p)$, respectively. The total profits from two jurisdictions are defined as $\Pi_P(r)$ and $\Pi_D(r)$, respectively.

The main results of the paper are proved here.

Proof of Proposition 1: To characterize the optimal royalty rate we need to distinguish two cases depending on whether p is greater or smaller than 1/2.

If $p \geq \frac{1}{2}$ then $\frac{l}{p} \leq \frac{l}{1-p}$. As a result, two regions emerge. If $r \leq \frac{l}{1-p}$, D will find optimal to settle and, in anticipation, P will always sue. Hence, $\pi_P(v,r,p) = r$ and $\pi_D(v,r,p) = v - r$. If $r > \frac{l}{1-p}$, D will prefer to go to court and P will sue. Hence, $\pi_P(v,r,p) = pr - l$ and $\pi_D(v,r,p) = v - pr - l$.

If $p < \frac{1}{2}$ then $\frac{l}{p} > \frac{l}{1-p}$. As a result, three regions emerge now. If $r \leq \frac{l}{1-p}$, D prefers to settle and P decides to sue. Hence, $\pi_P(v,r,p) = r$ and $\pi_D(v,r,p) = v - r$. If $\frac{l}{1-p} < r \leq \frac{l}{p}$, D is expected to go to court and P accommodates. Hence, $\pi_P(v,r) = 0$ and $\pi_D(v,r,p) = v$. Finally, if $r > \frac{l}{p}$, D prefers to go to court and P sues. Hence, $\pi_P(v,r,p) = pr - l$ and $\pi_D(v,r,p) = v - pr - l$.

The previous results, imply that if $v \leq \frac{l}{1-p}$ it is optimal for the patent holder to choose $r^1 = v$ so that P extracts all the surplus. If $\frac{l}{1-p} < v \leq \frac{2-p}{p(1-p)}l$, then $r^1 = \frac{l}{1-p}$ since settlement is preferred to litigation. Finally, if $v > \frac{2-p}{p(1-p)}l$, then $r^1 = v$. $\square$

Proof of Lemma 2: First notice that the threshold for which the downstream producer will be indifferent in the second jurisdiction between going to court and accepting the settlement is $\frac{l}{1-q}$ after winning the first trial and $\frac{l}{1-q-\delta}$ after losing, where $\frac{l}{1-q} < \frac{l}{1-p} < \frac{l}{1-q-\delta}$. Hence, it is immediate that under r^1 in the second jurisdiction a settlement will occur if the patent holder won the first trial. Instead, if the downstream producer won, accommodation would occur if $r < \frac{l}{q}$ or the patent holder would sue otherwise.

As a result, the downstream producer will always prefer to go to court in the first jurisdiction, since

$$2(v - r^1) < v - pr^1 - l + p(v - r^1) + (1 - p)\pi_D(r^1)$$

where $\pi_D(r^1)$ is the profit associated to second period litigation when D succeeded in the first trial and it is equal to $v - qr^1 - l$ when $r^1 \geq \frac{l}{q}$ and v otherwise. □

Proof of Proposition 3: In the simultaneous case $r^1 = \frac{l}{1-p}$ maximizes total surplus as it never induces litigation. Hence, in the sequential case, under a royalty $r < \frac{l}{1-p}$ the downstream producer can always guarantee total profits higher than in the simultaneous case by settling in both trials. The patent holder must be worse off in this case.

Hence, for the patent holder to be better off under sequential litigation it has to be the case that $r > \frac{l}{1-p}$. Furthermore, notice that a royalty above v would never be optimal as it would result in no production or in litigation, whereas a royalty rate of v would guarantee at least the same expected profits.

We can also rule out royalty rates $r > \frac{l}{1-p-\delta} = \frac{lp}{1-p}$. The reason is that they induce litigation in the second jurisdiction regardless of the outcome in the first. In particular, if $q > \frac{l}{r}$ patent holder profits become

$$\Pi_P^S(r) = pr - l + p\left[(q + \delta)r - l\right] + (1 - p)\left[qr - l\right] = 2(pr - l) < 2r^1.$$

When $q \leq \frac{l}{r}$ then

$$\Pi_P^S(r) = pr - l + p\left[(q + \delta)r - l\right] \leq 2(pr - l) < 2r^1.$$

Hence, if there is a royalty rate that makes the patent holder better off under sequential litigation and maximizes profits it has to be $\bar{r} = \min\left\{\frac{lp}{(1-p)q}, v\right\}$. Any royalty between r^1 and $\frac{lp}{(1-p)q}$ would still lead to litigation in the first jurisdiction and generate lower profits in the second. As a result, expected profits for P become

$$\Pi_P^S(\bar{r}) = 2p\bar{r} - l + (1 - p)\max\{0, q\bar{r} - l\}.$$

When $\delta \le 1 - \frac{l}{(1-p)v}$ or, equivalently, $v \ge \frac{l}{1-q-\delta} = \frac{lp}{(1-p)q}$ we have $\bar{r} = \frac{lp}{(1-p)q}$. Since, by Assumption 1, $v \le \frac{2-p}{p(1-p)}l$ this implies $q \ge \frac{p^2}{2-p}$. If $p > \frac{1}{2}$ then $q\bar{r} > l$ and total profits for the patent holder are

$$\Pi_P^S(\bar{r}) = 2\frac{p^2 l}{(1-p)q} - 2(1-p)l < 2r^1.$$

Instead, if $p \le \frac{1}{2}$ then $q\bar{r} < l$ and profits are

$$\Pi_P^S(\bar{r}) = 2\frac{p^2 l}{(1-p)q} - l < 2r^1.$$

Hence, an increase in the royalty rate will never yield higher profits.

When $\delta > 1 - \frac{l}{(1-p)v}$ or, equivalently, $v < \frac{lp}{(1-p)q}$ we have $\bar{r} = v$. D will always go to court in the second jurisdiction after winning in the first. Hence, P will sue if $qv > l$. Second jurisdiction profits for P and D are

$$\pi_P(v, r^*, q) = \begin{cases} 0 & \text{if } q < \frac{l}{v}, \\ qv - l & \text{otherwise.} \end{cases}$$
$$\pi_D(v, r^*, q) = \begin{cases} v & \text{if } q < \frac{l}{v}, \\ v(1-q) - l & \text{otherwise.} \end{cases}$$

Notice that $\frac{pl}{(1-p)v} > q > \frac{l}{v}$ requires $p > \frac{1}{2}$.

In the first trial, after being sued, D always prefers to go to court since

$$v - pr^* - l + p(v - r^*) + (1-p)\pi_D(v, r^*, q) \ge v - r^* + v - pr^* - l.$$

In particular, it implies

$$(1-p)\pi_D(v, r^*, q) \ge (1-p)(v - r^*) = 0,$$

which is satisfied regardless of whether q is higher or lower than $\frac{l}{v}$.

Anticipating that D will go to court, P always prefers to sue for nonpayment since

$$pr^* - l + pr^* + (1-p)\pi_P(v, r^*, q) \ge pr^* - l.$$

Total profits for P can be computed when $q \ge \frac{l}{v}$ (replacing $r^* = v$) as $\Pi_P(r^*) = 2pv - l + (1-p)(qv - l)$, which are higher than those in the simultaneous case, $2\frac{l}{1-p}$, if $v \ge l\frac{4-3p+p^2}{(1-p)(2+(1-p)q)}$. Notice that this threshold satisfies Assumption 1 and it is lower than $\frac{(1+(1-p)^2)l}{p(1-p)}$ if p is sufficiently low.

When $q < \frac{l}{v}$, $\Pi_P(r^*) = 2pv - l$. These profits are higher than $2\frac{l}{1-p}$ if $v > \frac{3-p}{(1-p)2p}l$ which is possible, given that this threshold is lower than $\frac{2-p}{p(1-p)}l$. $\square$

Proof of Proposition 4: We need to consider two possibilities. First, from Proposition 3, if the optimal royalty is higher than r^1 it must be equal to v and lead to expected profits for the patent holder of $\Pi_P(v) = 2pv - l$. Notice that by Assumption 1 $v > l$ and, therefore, the winner of the first trial always obtain a positive utility from going to court in the second jurisdiction.

Second, suppose now the patent holder chooses a royalty rate lower than r^1 to avert litigation. If $r > l$, profits for the patent holder are $\pi_P(v, r, 1) = r$ and $\pi_P(v, r, 0) = 0$ after a victory and a loss in the first jurisdiction, respectively. For the downstream producer profits are $\pi_D(v, r, 1) = v - r$ and $\pi_D(v, r, 0) = v$. In the first jurisdiction, the downstream producer will prefer to settle if (1) holds, which occurs if $r \leq \frac{l}{2(1-p)}$ and this highest value is optimal. This royalty rate is higher than l if $p > \frac{1}{2}$. Total profits for the patent holder are $\Pi_P\left(\frac{l}{2(1-p)}\right) = \frac{l}{1-p}$.

If $r \leq l$, profits after a first jurisdiction victory of the patent holder are identical, $\pi_P(v, r, 1) = r$ and $\pi_D(v, r, 1) = v - r$. However, if the downstream producer won, this firm would not be willing to go to court in the second jurisdiction since the costs of litigation are higher than the royalty payment. Hence, in that case, $\pi_P(v, r, 0) = r$ and $\pi_D(v, r, 0) = v - r$. In this case, it is optimal to choose $r = l$ and total profits for the patent holder become $\Pi_P(l) = 2l$. The comparison of the three profit levels gives raise to the thresholds on v in the proposition. □

Proof of Proposition 5: For the proof it is enough to show that for any value of r sequential litigation always yields higher profits for the downstream producer than the simultaneous one.

Suppose first that $r > r^1$. This implies that $r > l$, meaning that in sequential litigation, after an initial success, litigation is always a relevant threat but it does not emerge in equilibrium, given that $\delta = 1$. In that case profits for the downstream producer are higher under sequential litigation,

$$\Pi_D^s(r) = v - pr - l + v - pr > 2(v - pr) = \Pi_D(r).$$

Consider now the case $r \leq \bar{r}$. In that case, sequential and simultaneous litigation yield the same payoffs, since both firms decide to settle.

Finally, if $r \in (\bar{r}, r^1]$, sequential litigation is strictly preferred by the downstream producer, since it yields profits

$$\Pi_D^s(r) = v - pr - l + v - pr > 2(v - r) = \Pi_D(r).$$

for all $r > \bar{r}$. $\square$

Proof of Proposition 6: We first compare global arbitration with settlement in the first jurisdiction when $r \leq r^1$. After settlement in the first jurisdiction, it is also optimal for D to settle in the second jurisdiction. Profits are equal to $2(v - r)$ and this option is preferred by D to arbitrage.

By Assumption 1, $v > l$ meaning that because $r^1 > l$ litigation in the second jurisdiction is always worthwhile for the downstream producer when $r > r^1$. As a result, P abandons in the second jurisdiction after losing the first trial. This means that profits for P from litigation in the first jurisdiction are higher than those from global arbitration.

$$vpr - l + v - pr > 2(v - pr - l)$$

$\square$

Proof of Proposition 7: The characterization of the equilibrium royalty rate mimics Proposition 4. To establish the effect of β, notice that when $p > \frac{(2+\beta)l-\beta s}{(1+\beta)l-\beta s}$,

$$\frac{\partial \underline{r}^d}{\partial \beta} = \frac{2s - (1-p)l}{(2+\beta)^2(1-p)} < 0$$
$$\frac{\partial \underline{v}^d}{\partial \beta} = \frac{2s - (1-p)l}{(2+\beta)^2(1-p)p} < 0$$

under the assumption on s. Otherwise, the effect of β is 0. $\square$

Proof of Lemma 8: When $\gamma < p(1-p)$ the structure of the proof is identical to the one in Proposition 1. Instead, when $\gamma > p(1-p)$ it is easy to see that the profits for the downstream patent holder from going to court grow with v at a lower rate than those from limit pricing. For $\gamma > 1 - p$ the profits from limit pricing are always lower than those from setting $r = v$. $\square$

Proof of Proposition 9: Suppose that $\delta = 1$. As in the benchmark case, $r = \frac{l}{1-p-\gamma}$ cannot be an equilibrium in the sequential litigation case. For this reason, suppose that $r^* = v > \frac{\gamma v + l}{1-p}$. If D wins the first trial, in second one P abandons and second jurisdiction profits are $\pi_D(v, v, 0) = v$ and $\pi_P(v, v, 0) = 0$. If P wins the first trial, in the second one D always settles and profits are $\pi_D(v, v, 1) = 0$ and $\pi_P(v, v, 1) = v$.

In the first stage, D decides to go to court, since

$$(1-\gamma)v - pr^* - l + v - pr^* > v - r^* + (1-\gamma)v - pr^* - l.$$

As a result, total profits for P are identical to the case without an injunction $\Pi_P(r^*) = 2pv - l$. Profits for D become $\Pi_D(r^*) = (2(1-p) - \gamma)v - l$.

Regarding the preference for sequential litigation, notice that P will be better off if $2pv - l > \frac{2}{1-p-\gamma}l$ which occurs for $v > \tilde{v}_P(\gamma) = \frac{3-p-\gamma}{1-p-\gamma}$ which is increasing in γ. Firm D will prefer sequential litigation if

$$(2(1-p)-\gamma)v - l > 2v - \frac{2l}{1-p-\gamma} \longrightarrow v < \tilde{v}_D(\gamma) \equiv \frac{1+p+\gamma}{(1-p-\gamma)(2p+\gamma)}l.$$

We can compute

$$\frac{\partial \tilde{v}_D}{\partial \gamma} = \frac{p^2+2\gamma p+4p+\gamma^2+2\gamma-1}{(1-p-\gamma)^2(2p+\gamma)^2}l.$$

The numerator is increasing in p. It can also be shown that $\left.\frac{\partial \tilde{v}_D}{\partial \gamma}\right|_{p=0} < 0 < \left.\frac{\partial \tilde{v}_D}{\partial \gamma}\right|_{p=1-\gamma}$ which proves the result.

Using the same arguments in the proof of Proposition 4, the royalty rate that discourages litigation by the downstream producer is the maximum between l and the solution to

$$(1-\gamma)v - pr - l + v - pr = 2(v-r),$$

or $\underline{r} = \max\left\{l, \frac{l+\gamma v}{2(1-p)}\right\}$. The comparison with the case where $r = 2$ means that litigation arises in equilibrium when $v > \underline{v}^I(\gamma) = \max\left\{\frac{3l}{2p}, \frac{2-p}{2(1-p)p-\gamma}l\right\}$, weakly increasing in γ. $\square$

Proof of Proposition 10: As in the benchmark model, the patent holder has two options. First, it can offer $r = v$. This will foster litigation in the first jurisdiction. Upon P's success, D will settle. If P loses, it can revise the offer and choose $r_2 = l$ to avoid litigation. Hence, $\Pi_P^S(v) = pv - l + pv + (1-p)r_2$.

Second, it can offer a limit pricing royalty rate $\underline{r} < r^1$ so that D prefers to settle in the first jurisdiction. The optimal value will, therefore, satisfy

$$v - \underline{r} + v - \underline{r} = v - p\underline{r} - l + p(v-r) + (1-p)(v-r_2),$$

or $\bar{r} = \frac{2-p}{2(1-p)}l$. Notice that we are assuming that after an initial settlement, the royalty rate in the second jurisdiction is also $\underline{r}$. The reason is that P would like to increase it to r^1 if that were possible, rather than decrease it. Patent holder profits become in that case $\Pi_P(\underline{r}) = \frac{2-p}{1-p}l$.

The comparison of the profits yields the threshold value $\underline{v}^s$. $\square$

Proof of Lemma 11: First notice that if $r \leq \frac{l}{1-q}$ the downstream producer does not go to court in the second jurisdiction even after an initial success. As a result, settlement in both jurisdictions is always optimal since it yields higher profits than first jurisdiction litigation. That is,

$$2(v-r) \geq v - pr - l + v - r.$$

In that case, the optimal royalty is the highest value, $\frac{l}{1-q}$, and profits for the patent holder are $\Pi_P\left(\frac{l}{1-q}\right) = \frac{2l}{1-q}$.

If the patent holder chooses $r > \frac{l}{1-q}$ the downstream producer will be willing to go to court in the second jurisdiction after an initial success. The outcome in this case will be a patent holder's abandonment if $r < \frac{l}{q}$ or a settlement otherwise. We need to distinguish two cases. Suppose first that $q \geq \frac{2(1-p)}{3-2p}$. If P chooses a royalty $r > \frac{l}{q}$, D will settle in the first jurisdiction if

$$2(v-r) \geq v - pr - l + p(v-r) + (1-p)(v - qr - l),$$

or $r \leq r^* = \frac{(2-p)l}{(2-q)(1-p)}$. The highest royalty is higher than $\frac{l}{q}$ if $q \geq \frac{2(1-p)}{3-2p}$ and in that case, it is optimal. Notice also that $r^* > \frac{l}{1-q}$.

Suppose now that $q < \frac{2(1-p)}{3-2p}$. There is no royalty that promotes settlement in the first jurisdiction by D while, at the same time, it fosters P to go to court in the second jurisdiction after an initial defeat. In that case D will be willing to settle in the first jurisdiction if

$$2(v-r) \geq v - pr - l + p(v-r) + (1-p)v.$$

or $r \leq r^* = \frac{l}{2(1-p)}$. The optimal royalty will be in that case, equal to $\max\left\{r^*, \frac{l}{1-q}\right\}$. Replacing $q = (1-\delta)p$ we obtain the result.

To show that r^* is decreasing in δ, first notice that the first two segments are decreasing in δ, while the last is independent of δ. It can be verified that $\frac{(2-p)l}{(2-(1-\delta)p)(1-p)}$ is higher than $\frac{l}{1-(1-\delta)p}$ when evaluated at $\delta \leq \frac{5p-2p^2-2}{p(3-2p)}$ if $p > \frac{1}{2}$ which is a necessary condition for $\delta > 0$. $\square$

Proof of Lemma 12: We have two parameter regions to consider. Suppose first that $v < \frac{l}{(1-\delta)(1-p)}$. The royalty rate $r = v$ is optimal since a higher one would lead to no sales and P will not be brought to court in the second jurisdiction if it won in the first one. Profits become

$$\Pi_P(v) = pv - l + pv + (1-p)\max\{(1-\delta)pv - l, 0\}.$$

Suppose now that $v \geq \frac{l}{(1-\delta)(1-p)}$. Two possible optimal royalty rates emerge in this case depending on whether P finds optimal to go to court against D after winning in the first jurisdiction. If $r = v$ profits differ from the previous case in that they lead to litigation.

$$\Pi_P(v) = \begin{cases} pv - l & \text{if } (1-\delta)pv + \delta < l \\ p(1+\delta+(1-\delta)p)v - (1+p)l & \text{if } (1-\delta)pv < l \leq (1-\delta)pv + \delta \\ 2pv - l & \text{otherwise} \end{cases}$$

These profits are increasing in v and weakly increasing in δ.

If $r = \tilde{r} \equiv \frac{l}{(1-\delta)(1-p)}$, when P wins in the first jurisdiction, firm D settles in the second one. Hence, profits become

$$\Pi_P\left(\tilde{r}\right) = p\frac{l}{(1-\delta)(1-p)} - l + p\frac{l}{(1-\delta)(1-p)} + (1-p)\max\left\{l\frac{p}{1-p} - l, 0\right\}.$$

These profits are weakly increasing in δ and independent of v. Hence, there exists a threshold value $\tilde{v}$ such that $\Pi_P(v) > \Pi_p(\tilde{r})$ if and only if $v > \tilde{v}$.

To compare profits depending on the royalty rate we need to distinguish two cases. Suppose first that $p > \frac{1}{2}$. In that case, when $v \geq \frac{l}{(1-\delta)(1-p)}$ we have that $(1-\delta)pv > l$ and profits when $r = v$ can be written as $\Pi_p(v) = 2(pv - l)$. The comparison with the case where $r = \frac{l}{(1-\delta)(1-p)}$ allows us to define

$$\tilde{v} = \frac{l}{(1-\delta)(1-p)} + \frac{l}{p},$$

increasing in δ.

When $p < \frac{1}{2}$ a royalty $r = \frac{l}{(1-\delta)(1-p)}$ will always yield profits $\Pi_P(\tilde{r}) = 2p\frac{l}{(1-\delta)(1-p)} - l$. It is immediate that when $(1-\delta)pv > l$ then $\Pi_P(v) > \Pi_P(\tilde{r})$. Hence, $\tilde{v}$ is defined as

- $\tilde{v} = \frac{2l}{(1-\delta)(1-p)}$ if $(1-\delta)pv + \delta < l$ and it is, therefore, independent of δ.
- $\tilde{v} = \frac{2-(1-\delta)(1-p)}{[1+\delta+(1-\delta)p](1-\delta)(1-p)}$ if $(1-\delta)pv < l \leq (1-\delta)pv + \delta$, which is increasing in δ.

□

Proof of Proposition 13: Suppose first that $r \leq \tau$. In that case it is immediate that P will always abandon and, therefore, D will decide not to pay. For this reason, we now focus on the case where $r > \tau$.

If $p \geq \frac{l+\tau}{2l+\tau}$ then $\frac{l+\tau}{p} \leq \frac{l}{1-p}$. As a result, two regions emerge. If $r \leq \frac{l}{1-p}$, D will find optimal to settle and, in anticipation, P will sue. In this case, D decides to pay upfront, as this would save τ and lead to a higher payoff. Hence, $\pi_P(v,r,p) = r$ and $\pi_D(v,r,p) = v - r$. If $r > \frac{l}{1-p}$, D will prefer to go to court and P will sue. In the previous stage, D will decide to pay upfront if $r \leq \frac{l+\tau}{1-p}$, yielding profits of $\pi_P(v,r,p) = r$ and $\pi_D(v,r,p) = v - r$ and not pay, leading to litigation, if $r > \frac{l+\tau}{1-p}$ with payoffs $\pi_P(v,r,p) = pr - l - \tau$ and $\pi_D(v,r,p) = v - pr - l - \tau$. If $p < \frac{l+\tau}{2l+\tau}$ then $\frac{l+\tau}{p} > \frac{l}{1-p}$. As a result, three regions emerge now. If $r \leq \frac{l}{1-p}$, D prefers to settle and P decides to sue. Anticipating this outcome, D prefers to pay upfront and payoffs become $\pi_P(v,r,p) = r$ and $\pi_D(v,r,p) = v - r$. If $\frac{l}{1-p} < r \leq \frac{l+\tau}{p}$, D is expected to go to court and P would choose to accommodate. Hence,

D prefers not to pay and payoffs are $\pi_P(v, r) = 0$ and $\pi_D(v, r, p) = v$. Finally, if $r > \frac{l+\tau}{p}$, contingent on D not paying upfront firms go to court. In that case, D will prefer to pay upfront if $v - r \geq v - pr - l - \tau$ or $r \leq \frac{l+\tau}{1-p}$. For higher values of r litigation takes place in equilibrium and $\pi_P(v, r, p) = pr - l - \tau$ and $\pi_D(v, r, p) = v - pr - l - \tau$.

We now turn to the optimal royalty rate chosen in the first stage. We need to consider two cases. Suppose first that $p \geq \frac{l+\tau}{2l+\tau}$. When $v \leq \frac{l}{1-p}$ firm D will pay whenever $r \leq v$ and, therefore, $r^1 = v$ is optimal. For higher values of v, firm P prefers to choose the highest royalty rate that prevents litigation, $r_1 = \frac{l}{1-p}$ if $v \leq \frac{2-p}{p(1-p)}(l + \tau)$.

Second, when $p < \frac{l+\tau}{2l+\tau}$, using the previous arguments, we have that $r^1 = v$ for $v \leq \frac{l}{1-p}$. For values of $v \in \left(\frac{l}{1-p}, \frac{l+\tau}{p}\right]$, P chooses $r^1 = \frac{l}{1-p}$ to foster payment and avoid accommodating. When $p \leq \frac{1}{2}$, P prefers to sue when $v > \frac{2-p}{p(1-p)}l + \frac{\tau}{p}$ and $r^1 = v$ is optimal. However, when $p > \frac{1}{2}$ there exists a region where $v \in \left(\frac{l+\tau}{p}, \frac{l+\tau}{p}\right]$ and D is willing to pay upfront $r^1 = v$ to avoid litigation. For $v > \frac{l+\tau}{p}$ firm P prefers to sue and choose $r^1 = v$ if $v > \frac{2-p}{p(1-p)}(l + \tau)$ and engage in limit pricing, $r^1 = \frac{l+\tau}{1-p}$, otherwise.