Patent Licensing, Imitation, and Litigation

Aineas Mallios[*]

School of Business, Economics and Law
University of Gothenburg, Sweden

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Abstract

This paper provides an integrated framework to analyse the strategic use and litigation process of intellectual property rights (IPRs) with a focus on licensing by a patent owner of a cost-reducing technology. Although patent litigation involves a small fraction of all granted patents and only a few of them go to trial, evidence indicates that litigated patents are among the most valuable and that the volume of disputes varies among industries, institutions, judicial systems, and governments (Aoki and Hu, 1999b; Lanjouw and Schankerman, 2001; Allison et al., 2011; Hall and Harhoff, 2012). The game comprises two rival innovating firms that engage in a Cournot duopoly. First, they decide over their strategic choices. Then, they simultaneously compete in quantities of a homogeneous product. The analysis suggests that licensing, imitating, and litigating over a patented technology depend on three key factors: the size of the patented innovation, the efficacy of imitation, and the strength of the judicial system. A set of conditions and thresholds that define the equilibrium of the game are determined when both the imitation and enforcement of IPRs in a court of law are imperfect. If the reduction of the marginal production cost, because of the new technology, is sufficiently small, then ex-ante licensing will occur in equilibrium. By contrast, if the cost reduction is sufficiently large, then ex-post licensing will dominate. A patent owner benefits by taking no action against a weakly infringing imitation, which is, in fact, a highly imperfect imitation. The analysis also suggests that going to trial is determined by the expected damage award and the strength of the judicial system—or the degree to which increased litigation spending can influence the outcome of the court.

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[*]aineas.mallios@gu.se

1   Introduction

The licensing of intellectual property rights (IPRs) has witnessed an unprecedented growth in the last decade. The United States Patent and Trademark Office (USPTO) reports licensing of IPRs more than \$115 billion in 2012 spread over 28 industries in the US (ESA and USPTO, 2016). The European Union Intellectual Property Office (EUIPO) attributes to IPR-intensive industries the generation of more than 40 percent of the total economic activity in the European Union (EU), during the period 2011-2013 (EPO and EUIPO, 2016). EUIPO (2016), a survey-based study, suggests that patents and trade secrets are commonly believed to be among the most valuable assets owned by small and medium-sized innovative enterprises in the EU. This surge of licensing activities has inevitably affected the investment in research and development (R&D), technological advancement, and in turn social welfare. What is even more interesting is the fact that the use of intellectual property licences by innovating firms has diverged from the conventional economic justification of stimulating innovation and facilitating technology diffusion towards a more strategic use aiming to prevent entry, increase bargaining power, re-enforce infringement claims, and ensure participation regarding standards (Cohen et al., 2000; Kash and Kingston, 2001; Hussinger, 2006; Hall, 2007; Qian, 2007; Pepall et al., 2008; Choi and Gerlach, 2015).

A growing stream of the patent licensing literature studies how imperfect protection and weak enforcement of property rights affect the market for innovation and the strategic use of IPRs. In this paper, we focus on a particular aspect of this literature. Specifically, we study how the efficacy of imitation and the strength of the judicial system affect the strategic use of the patent licensing and litigation behaviour of an incumbent producer when the enforcement of patent protection in the court of law is imperfect (Crampes and Langinier, 2002; Llobet, 2003). We acknowledge the fact that the patent system does not provide a strong form of protection; however, we implicitly assume that the rights of the patent owner cannot be invalidated in court.[1] We set up our analysis based on earlier work conducted by Aoki and Hu (1999a,b, 2003) in this regard. The analysis in this paper departs from their work in two main respects. First, in contrast to their work, we assume that the probabilities of infringement as perceived by each firm depend on the costs of litigation, and thus, they are endogenously determined. Second, we focus on imperfect imitation and separately discuss the limiting case of perfect imitation addressed in their existing work.

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[1]For a thorough discussion concerning the incentives of firms to challenge patent validity when being accused of infringement, refer to Farrell and Merges (2004) and the references cited therein.

IPRs are not customised to specific situations and thus cannot fit all situations. In addition, the continuous progress of technology is making the enforcement of property rights more difficult over time, which thus renders IPRs an even more imperfect means of protection (Thurow, 1997; Lemley and Shapiro, 2007). Furthermore, most of the judicial systems worldwide are at least to some degree unable to resolve disputes and to enforce rights quickly and efficiently (Aoki and Hu, 1999b; Shapiro, 2010). Maskus (2006) reviews the causes of the high levels of infringement disputes in China, a problematic issue that more developed countries, on behalf of their enterprises operating in less-developed countries, have denounced at the World Trade Organisation (WTO). He concludes that these structural barriers impede progress and innovation. Granstrand (2003) argues that the ineffective use of IPRs from the perspective of competitive enterprises might be associated with distortions and side effects. These concerns become even more pronounced considering that an increasing number of enterprises value their licensing activities more than the commercial exploitation of their inventions (Mallinson, 2014). Consequently, ineffective licensing of IPRs as the result of patent hold-up and hold-out issues, lengthy patent infringement disputes, and speculative preliminary injunctions might have an adverse impact on enterprises' incentives to invest in R&D, which in turn might lead to less innovation, higher transaction costs, slower technology diffusion, and thus lower levels of social welfare (Galasso and Schankerman, 2010; Spulber, 2013; Gallini, 2017). Scholars and policy-makers, attracted to the appeal of these issues, have addressed the problem of costly litigation and settlement disputes for a long time (Lanjouw and Schankerman, 2001, 2003, 2004; Lemley and Shapiro, 2005, 2007, 2013; Lerner, 2006; Galasso and Schankerman, 2010, 2018; Hall and Harhoff, 2012; Yeh, 2016).[2] Extracting the maximal value through the effective and efficient use of intangible assets is critical to most enterprises to remain competitive, to preserve their incentive to innovate, and to secure credit (Baum and Silverman, 2004; Hsu and Ziedonis, 2008; Hall and Harhoff, 2012; Farre-Mensa et al., 2017).

We consider a litigation game between an innovating firm holding a patent on a cost-reducing technology and a rival firm producing with a less-efficient technology. In the first stage, the rival firm should decide among three available actions: to enter in a patent licensing agreement, to produce using a less-efficient technology, and to opt for costly imitation. If imitation occurs, the game proceeds in the second stage, in which the innovating firm should now decide among three available actions: to achieve an ex-post licensing agreement, to file a formal lawsuit against potential infringement, and to take no action. If a lawsuit has been filed, the third and final stage of the game unfolds, in which

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[2]See also, Hause (1989), Hay (1995), Aoki and Hu (1999a,b, 2003), Farrell and Shapiro (2008), Shapiro (2010) and Denicolo and Franzoni (2012).

the disputants can either settle out of court or lead the dispute to a costly trial. The litigation cost incurred during the trial process reflects fees for the court, the attorneys, the lawyers, and all the costly transactions related to trial. We consider a non-cooperative game with simultaneous moves and perfect information. For illustration, consider the litigation dispute in 2011 between Apple Inc. and Samsung Electronics regarding the patented design and proprietary technology used on the production of smartphones (Gil, 2017). Another more recent example is the patent infringement lawsuit filed by Qualcomm Technologies Inc. against Apple Inc. over technology protected by six patents, which were essential to the performance of the iPhone; however, Apple Inc. refused to pay for it.[3] First, we develop an integrated framework that can be used to examine how litigation is determined by the efficacy of imitation and the strength of the judicial system. Second, the baseline model is simple and suitable for studying how strategic licensing can be used effectively from the perspective of a patent owner. Third, the model can also be used to infer what types of licensing agreements are more likely to emerge under different legal regimes. Fourth, the analysis can be used to address broader policy issues and to discuss their implications.

The main findings in the paper are as follows. First, we find that licensing and litigation depend on three key parameters: the size of the reduction in cost due to the new patented technology, the efficacy of imitation, and the extent that the litigants can influence the court's outcome through increased litigation spending. Second, the analysis suggests that if settlement out of court is expected to occur in equilibrium and the efficacy of imitation is sufficiently high, then there might be more licensing before imitation (ex-ante licensing) of sufficiently small-sized patented innovations and more licensing after imitation (ex-post licensing) of sufficiently large-sized patented innovations. Third, if settlement out of court is more likely to occur in equilibrium, but the efficacy of imitation is sufficiently low, then there might be no litigation over a large-sized patented innovation, as it is optimal for the patent owner not to litigate. Fourth, we find that in equilibrium, litigation might also be resolved in court regardless of the magnitudes of innovation and imitation. This, in fact, seems to be driven by the magnitude of the damage award and the extent that litigants can influence the decision of the court.

Section 2 reviews some of the related literature on the litigation of patent licensing. Section 3 describes the basic model, introduces Nash Bargaining to determine the optimal settlement fee, and uses backward induction to characterise the equilibrium of the game. Section 4 suggests suitable extensions of the baseline model, discusses some policy implications, and concludes the paper. All proofs are given in the Appendix.

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[3]For more information regarding this specific case, see www.qualcomm.com.

2 Literature Review

This section reviews the theoretical and empirical literature on strategic patent licensing and litigation that is related to this paper. It also covers current discussions on the key imperfections in the patent system and their implications in litigants' strategic conduct, as well as suggestions to policy-makers on how to improve the patent act. In particular, the review focuses mostly on disputes between a patent owner and a single potential infringer. It highlights the role of the court and other important factors in technology transfer through patent licensing.[4]

2.1 Theoretical Literature

Prior intellectual property literature has addressed various issues related to patent licensing and litigation. For instance, Meurer (1989) presents a bargaining model of litigation and finds that a patent owner refuses to license a valid patent, whereas the holder of an invalid patent settles under certain conditions (a signal of invalidity) and refuses when these conditions are not meet (a bluff). In his setup, turning to the court is a failure to settle and not an intended choice. His model differs from the common litigation models in a number of ways. First, the author introduces common information bargains shared between both players, as well as the private information bargain held only by the patent owner. Second, the antitrust policy considered in his study varies and affects the settlement differently. Third, in Meurer (1989), litigation depends on the outcome of litigation and the terms of settlement. Likewise, in our paper, the probability of infringement has a common exogenous part, which is determined by the strength of the court, and a private endogenous part, which is determined by the litigation spending of each firm. Our results suggest that litigation depends on whether settlement prevails in equilibrium, as well as on the expected damage award.

Hause (1989) presents an influential model to emphasise the importance of different perceived probabilities of winning in court between the plaintiff and the defendant. The author assumes that the probability that the plaintiff wins in trial increases with his/her own legal cost and decreases with the defendant's cost. He shows that the court, which determines the distribution of the litigation costs, affects the settlement rates and the magnitude of trial expenditures. For instance, the English indemnity rule, where attorney fees are awarded to the winning party, might induce more settlement and less litigation

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[4]Additional useful surveys that cover this area are Branstetter (2004), Hall (2007, 2009), Hall and Helmers (2010), and Hall and Harhoff (2012).

than the American rule, where each litigant pays only its own attorney fees. However, litigation lawsuits that go to trial might be significantly more expensive for both litigants.

Hay (1995) develops a two-stage litigation model to determine the factors that lead disputes to trial rather than settlement. The author argues that asymmetric information is only one of the reasons that may lead disputes to trial. Hence, he introduces another factor that might explain why the benefits of settling out of court are often forgone, precisely the preparation strength of a legal dispute. He argues that litigating to completion might arise due to informational asymmetries concerning jointly exogenous and endogenous factors of the case strength. For example, an exogenous factor might be the quality of the claim's evidence, while an endogenous factor might be the effort invested in the preparation of the case. It appears that there is no equilibrium involving pure strategies. In fact, the litigants randomise among different strategies in equilibrium.[5] Likewise, the model developed here considers both exogenous and endogenous factors that might affect the outcome of the game. For instance, we assume the expected damage award to be an endogenous factor, while the cost spent on litigation by both parties to be an endogenous one. Furthermore, we take the strength of the judicial system to be a joint function of exogenous and endogenous factors.

Aoki and Hu (1999a) extend Hause (1989)'s work concerning how the distribution rules of litigation cost affect the behaviour of litigants by modelling settlement as a Nash Bargaining game. The authors are consistent with previous literature in that the avoidance of litigation costs are likely the main factor to induce settlement. They model litigation by assuming both exogenous and endogenous probabilities of winning infringement lawsuits, under both American and English law systems. In a companion paper, Aoki and Hu (1999b) find that in a cooperative approach to litigation and settlement, turning to trial may be Pareto efficient comparatively to a non-deliberate outcome in line with Meurer (1989). They recognise that the court cannot enforce patent rights perfectly, and thus, patent protection is not perfect. Their analysis suggests that the imperfect nature of patent protection might induce more licensing, which in turn can be used as a barrier to entry. In another follow-up paper, Aoki and Hu (2003) focus on the effect of the time factor, namely, the imitation and litigation periods of time, on patent protection and licensing behaviour. Their findings indicate that settlement through ex-post licensing is negatively related to the time to imitate, but it is positively related to the time to litigate. In addition, their findings suggest that high litigation costs might induce more ex-ante than ex-post patent licensing. By contrast, low imitation costs seem to discourage licensing because the bargaining power of the imitator might increase, therefore making

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[5]The unique subgame Nash equilibrium has the litigants following a mixed-strategy Nash equilibrium.

licensing a less desirable choice. The framework developed here extends in a number of ways in which the models by Aoki and Hu (1999a,b, 2003) were developed, which focus on the impact of the court or the effect of the time factors on strategic licensing and litigation. We develop an integrated framework that analyses the joint impact of the strength of the court, the size of the patented innovation, and the efficacy of imitation on litigants' strategic conduct.

Crampes and Langinier (2002) investigate the reaction of a patent owner to infringement with a focus on the monitoring effort to detect infringement, as well as on the enforcement cost of patent claims. In their model, if imitation takes place and infringement is successfully detected, then there could be three costly outcomes: settlement out of court (settle), litigation to completion (sue), and entry acceptance (accommodate). The outcome of the bargaining process between the two litigants is given by the Nash Bargaining solution. The findings do not provide a clear answer on what is the best reaction to infringement. In a simultaneous game, where both players make their monitoring and entry decisions at the same time, the likelihood of entry increases with the increase of infringement damages and decreases with the rise of legal efficiency. In a sequential game, where the patent owner's monitoring decision is made before the rival's entry decision, the commitment value of monitoring seems to have a stronger entry deterrence impact than in the simultaneous game. When the potential entrant acts first, entry occurs less often than in the simultaneous game, thus probably making the patentee better off. In fact, the sequential option seems to increase the efficiency of decision-making for both parties.

Llobet (2003) develops a patent litigation model to study how the enforcement of property rights affects the decisions to license, litigate, and innovate. He argues that the enforcement approach of courts endogenously determines the licensing and litigation decisions of innovative firms. On one hand, strong patent protection implies more chances from the perspective of a patentee to win in trial. On the other hand, strong enforcement of patent rights implies less willingness of rival firms to improve on protected innovation and thus less licensing in the future. Consequently, it seems that policy-makers should grant weak patent protection to valuable inventions to induce patent owners to license, which might preserve or even increase the incentives to invest in R&D. It appears that the possibility of litigation, due to the imperfect enforcement of property rights or asymmetric information, significantly influences the decisions of firms to enter, patent, and invest in R&D. In Llobet (2003), litigation might arise due to imperfect enforcement of patent rights and infringer's private information on the quality of inventions. Likewise, we show that litigation to completion, or failure to settle, might also occur owing to imperfect

patent protection and owing to litigants' different expectations about the outcome of the trial.

Lemley and Shapiro (2005) coin the term probabilistic patents after observing that the risk of litigated patents to be found invalid in court is substantially high and positively related to patents' imperfect enforceability and the element of uncertainty (i.e. patent validity and scope).[6] The authors argue that invalidating patents often generates positive externalities. For example, patent invalidation might induce more licensing than litigation in the future. Farrell and Shapiro (2008) focus on a particular type of probabilistic patents. In particular, they model the licensing and litigation of weak small-sized patents. They find that licensing weak patents to rival downstream firms might induce larger royalties than corresponding licences to firms that are not rivals. What is more important for our analysis is their finding that weak patents are often associated with negative social externalities, such as costly litigation disputes, hold-up and hold-out problems, and a defensive patenting tendency.[7] Encaoua and Lefouili (2009) extend Farrell and Shapiro (2008)'s model to a more general framework that covers protected inventions of any size and licensing contracts that are not necessarily accepted by every downstream firm. Duchene and Serfes (2012), in turn, extend these models by increasing the number of players to three: a patent holder, an infringer, and a potential entrant. They show that an agreement to settle, especially at a high fee, between the two holders of the proprietary technology, might serve as a strong signal of patent validity, which in turn might be used strategically to deter entry in the future. Although these studies focus on patent validity, which we assume to be unquestionable in our paper, the key insights derived from their analyses are significant and they are thus partly adapted in our analysis.

Other studies on patent litigation focus on the weaknesses and fragility of the patent act, thus motivating the need to reform and restructure the system. For instance, Bailey et al. (2011) address the issue of unreasonably large infringement damages and suggest an alternative to conventional apportionment rules, precisely an economically valid approach to calculate damages through market-based negotiation among the parties. Their analysis is particularly useful in two respects. First, it highlights the importance of damage awards in patent litigation disputes. Second, it suggests an approach to calculate damage awards that limit excessive rates and that maintain the incentives to innovate. Throughout our analysis, we also discuss how the damage award and other factors affect the litigation conduct of firms.

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[6]Lemley and Shapiro (2005) state that "roughly half of all litigated patents are found to be invalid, including some of great commercial significance".

[7]For useful models on patent validity and the strategic licensing behaviour of firms, refer to Choi (2010) and Choi and Gerlach (2015).

Eckert and Langinier (2014) argue that courts, through their adapted practices of assessing infringement damages, might induce patent troll conduct. The authors provide an overview of the theoretical and empirical literature on the main problems associated with the surge of patenting activity during the last decades. They suggest that the increased litigation can partly be attributed to the granting of patents for software and business methods and partly to the strategic use of patents to defend against infringement claims and benefits from cross-licensing negotiations. Other concerns that urge for an improved patent system are the increased backlogs and pendency times, the quality of granted patents, the behaviour of applicants and examiners of patents, the impact of third parties, and the different avenues for challenging patent validity (e.g. pre-grant opposition in India, post-grant review in the EU, and litigation in the USA). Eckert and Langinier (2014) urge caution in evaluating the effectiveness of policies that attempt to improve the quality of patents, since assessing the impact of the main actors (applicants, examiners, and third parties) in the patent system is difficult and complicated. Chien (2014) focuses mainly on hold-up and hold-out patent issues and argues that only when both issues are studied together, a contribution towards a better patent system might be achieved.[8] Schankerman and Schuett (2017) address the impact of screening policies on the effectiveness of patents. The framework that they develop to study the quality of existing patent screening practices by incorporating policy instruments seems to be useful for potential extensions of our baseline model. In our model, we focus on the strategic conduct of the litigants, and we take patent validity as unquestionable; thus, we do not consider the prior examination of the patent claims by a patent office. However, relaxing the validity assumption, introducing multiple potential entrants, considering a private screening effort to detect infringement, and accounting for a public monitoring effort that can be reflected in patent fees are, in fact, suitable extensions of our model.

This review of the theoretical literature on patent licensing and litigation has shown that it is widely accepted among scholars to consider the threat of litigation against patent infringement as a strategic means to discourage entry and gain private benefit. The imperfect process of enforcement and the probabilistic nature of intellectual property is positively associated with the emergence of intellectual property litigation disputes and the increased number of claims that go to court, which might inevitably lead to a costly drain in the economy. These relationships, in fact, require an understanding of the economics behind patent licensing, litigation, and settlement through negotiation.

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[8]For a review of the literature on FRAND licensing and an analysis of standard essential patents (SEP), hold-up and hold-out issues, as well as royalty stacking, refer to Lemley and Shapiro (2013), Lerner and Tirole (2015), and Layne-Farrar (2016).

2.2 Empirical Literature

The early empirical literature on innovation has shown that IPRs, such as patents, provide imperfect protection of new industrial technology (Taylor and Silberston, 1973). Consequently, the owners of intellectual property, such as licensors, are often unable to completely appropriate the returns of their intellectual property holdings. An immediate result of the imperfect nature of patent protection is imitation by competitors of protected proprietary technology in a number of industries. Mansfield et al. (1981) find that over half of their sampled patents were imitated within four years of introduction, which is well before patent expiration and complete appropriation of rents. Trying to understand why imitation of new technology happens so quickly, Mansfield (1985) studies the speed at which technological information leaks out. Using firm-level data, he shows that information concerning the nature and operation of new technology in general leaks out in less than fifteen months. This relatively quick information spread might help to explain the increase in the imitation rate and speed, as well as the difficulty that innovating firms have in appropriating the benefits from their inventions. In this paper, we consider the impact of costly litigation due to potential imitation on firm behaviour. In an effort to explain why firms turn to courts to resolve patent litigation disputes, we focus on the factors that determine imitation and litigation.

Following the progress of the early literature on imitation discussed above, the attention has spanned in many directions. For instance, a more recent body of empirical work has focused on litigation as a direct result of imitation. Lerner (1995) studies the effect of litigation costs on patenting behaviour of new biotechnology firms. He finds that firms with high litigation costs are less likely to patent in areas dominated by firms with low litigation costs and existing patent holdings. Lanjouw and Lerner (1996) explore the features of preliminary injunction to alter the direction and size of litigation damages. They find that the option to request injunction in general encourages settlement. This is because injunction, as a more aggressive litigation behaviour, increases the willingness of the plaintiff to settle and favours large firms over small firms, as it increases the legal costs to both parties.[9] The important consideration, which is also incorporated in this paper, is the interest that each party has in increasing the litigation cost of the other, when the dispute turns into a formal filing. Lanjouw and Lerner (1998) discuss the empirical literature on patent litigation considering a general model that unifies the key results of the patent dispute resolution. The empirical evidence suggests that the magnitude

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[9]The underlying assumption here is that the plaintiff is often significantly larger than the defendant. Hence, the plaintiff, as opposed to the defendant, can afford the substantial cost increase and thus might use injunction to achieve better settlement terms.

of parameters and the expected legal costs determines whether disputes are settled or resolved in the court of law and thus are important features of the IPR system.

Lanjouw and Schankerman (2001), using information on filed cases in the US, find that disputes are most likely to go to court when patented inventions compose the base of a cumulative chain of subsequent innovations, as well as when the patented technology is mostly cited by rival firms operating in the same industry. In a follow-up paper, Lanjouw and Schankerman (2004) study the litigation risk and determinants of formal patent lawsuits and settlements. First, the evidence suggests that firms with large portfolios of intellectual property, such as patent holdings, tend to settle rather than pursue litigation, mainly because large portfolios permit the trade of intellectual property, which thus induces settlement. Second, repeated interaction before proceeding to formal litigation increases the incentive to settle. In other words, firms active in more concentrated industries are correspondingly less involved in lawsuits, as compared with firms operating in less cooperative environments.[10] These findings imply that the inability of small firms to avoid litigation is more pronounced than that of large firms.

Galasso and Schankerman (2010) analyse the settlement of patent infringement disputes using an ownership fragmentation perspective (see, also, Lerner and Tirole, 2004).[11] They show that the fragmentation of property rights shortens the time to settle and that it increases the effectiveness of the market for innovation. Their model might help understand how the settlement behaviour of litigants is determined through multiple periods of bargaining before the proceeding to trial. In our model, there are only two rounds of litigation, and no time factor is included in the analysis. However, extending our baseline model to incorporate a multiperiod finite negotiation process might be a useful direction for further theoretical and empirical research. Galasso et al. (2013), using the Lanjouw and Schankerman (2001, 2004) patent litigation data, study how trading patent rights affect the enforcement of IPRs. In particular, they examine whether litigation can be reduced through the reallocation of patent rights to parties that are more effective at resolving disputes 'non-litigiously' (see, also, Hall and Ziedonis, 2001). Their findings suggest that traded patents—that is, patent rights that have changed ownership—are much more litigated than patents that are not traded. Moreover, the study addresses the impact of patent transactions on social welfare and discusses noteworthy policy implications. In a more recent study, Galasso and Schankerman (2018) analyse how invalidating patent rights affects firms' subsequent innovative and patenting activities; they find that

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[10]Concentrated industries have few firms holding most of the patented technology. Thus, it is very likely that more litigation occurs between the 'usual' firms. Consequently, resolution out of court might be more preferable to both litigants.

[11]Fragmentation measures the ownership dispersion of property rights.

patent invalidation might, on average, cause a 50 percent decrease in patenting over a five-year window. In addition, patents affect the level of future innovation associated with small- and medium-sized firms, but they have no significant effect on subsequent innovation by large firms.[12] Moreover, patent invalidation might increase the probability that a small firm exits from patent competition, but it does not affect the exit probability of a large firm. Finally, the analysis suggests that the effectiveness of patent protection depends on the size of the firm, the competitive environment, and the nature of the technology. Likewise, in our analysis, the size of cost reduction due to the protected new technology and the effectiveness of the court in enforcing patent rights characterise the strategic behaviour of innovating firms.

Empirical evidence is necessary to examine the theoretical propositions regarding the main determinants of technology transfer and the regulatory policy implications of technological change. Studying patent litigation and its impact on firm behaviour might improve our understanding of the relationship between technology transfer through IPRs and the incentives of firms to invest in innovation.

3   The Model

This section introduces the baseline model. We consider two firms with different marginal production costs that play a three-stage litigation game before competing in quantities of a standard product. Each firm makes an output quantity decision assuming that the behaviour of the competing firm is fixed; the two firms thus engage in Cournot duopoly competition (Cournot and Fisher, 1929). We acknowledge that often the imitation of new technology is imperfect and that the enforcement of patent rights is not absolute. Moreover, we assume rational firms, non-cooperative bargaining, and a discount factor equal to one. Solving the simultaneous game with backward induction, we characterise the equilibrium for both, drastic and non-drastic inventions (Arrow, 1962).[13] A drastic invention drives the firm producing with the old technology out of the market if the technology transfer does not happen. In contrast, both firms produce a positive quantity of output if the invention is non-drastic.

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[12]The reduction in small firms' level of future innovation might be a result of the reduced access to capital and the strong competition from large firms.

[13]A cost-reducing invention is drastic if the monopoly price with the new technology is less than or equal to the marginal production cost with the old technology (Wang, 1998).

3.1 The Cournot Duopoly Equilibrium

We begin with a basic framework. There is a market for a standard good produced by two firms, Firm i for $i = \{1, 2\}$. Initially, the two firms have identical technologies. Now, suppose that Firm 1 patents a new technology that reduces the per-unit production cost, relative to the initial cost c, by an amount ϵ, where $0 < \epsilon < c$. Thus, the per-unit production cost of Firm i, when it has the new technology, becomes $c_i = c - \epsilon$ for $i = \{1, 2\}$. Given that patent rights are imperfect, the cost-reducing technology can also be developed by Firm 2. Let ϵ' denote the per-unit cost reduction achieved by Firm 2 through potential imitation, where $0 \leq \epsilon' < c$. In addition, assume that the technology developed by Firm 2 can achieve a reduction in the per-unit cost less than or equal to the cost reduction achieved by the patented technology, i.e. $0 \leq \epsilon' \leq \epsilon$. In other words, acknowledging the fact that firms are bounded in their ability to imitate, we consider imitation to be imperfect, and we rule out any technological imitation that leads to a per-unit cost reduction larger than ϵ (Posen et al., 2013).

The inverse demand function for the product is described by $P = a - (q_i + q_j)$ for $i, j = \{1, 2\}$ and $i \neq j$, where P is the market price, q_i is the quantity produced by Firm i, and a is a parameter that characterises the market demand for the product, where $a > c$. We have already assumed that firms compete in quantities and produce simultaneously according to Cournot competition. On the one hand, Firm 1 always produces using the new patented technology at a per-unit cost $c_1 = c - \epsilon$. On the other hand, Firm 2 has different per-unit costs depending on the efficiency of the technology in use. Specifically, the per-unit production cost of Firm 2 varies from a maximal rate $c_2 = c$ when it produces with the old technology, to an intermediate rate $c_2 = c - \epsilon'$ when it imitates, down to a minimal rate $c_2 = c - \epsilon$ when a technology transfer occurs. Evidently, there are three possible combinations of the production costs of Firms 1 and 2 that have to be considered when solving for the Cournot equilibrium.

First, suppose that Firm 2 produces with the old technology, $c_2 = c$. Let π_i^d for $i = \{1, 2\}$ be the equilibrium payoff of Firm i in a Cournot duopoly with asymmetric costs. Then, the Cournot equilibrium payoffs are $\pi_1^d = \frac{1}{9}(a - c + 2\epsilon)^2$ and $\pi_2^d = \frac{1}{9}(a - c - \epsilon)^2$. Let us now consider the value of π_2^d when $\epsilon \geq a - c$. Clearly, the payoff of Firm 2 becomes zero, meaning that Firm 2 is driven out of the market, while Firm 1 collects the monopoly rent, π^m. In general, the invention is drastic if $\epsilon \geq a - c$, in which case Firm 1 earns $\pi^m \equiv \pi_1^d = \frac{1}{4}(a - c + \epsilon)^2$ and Firm 2 earns $\pi_2^d = 0$.

Second, suppose that both firms have the patented technology and thus have equal per-unit production costs, $c_1 = c_2 = c - \epsilon$. Let π^d be the equilibrium payoff for each firm

in a Cournot duopoly with symmetric costs. Then, solving for the Cournot equilibrium gives $\pi^d = \frac{1}{9}(a - c + \epsilon)^2$.

Third, suppose that Firm 2 imitates the patented technology and produces with a probabilistic per-unit cost $c_2 = c - \epsilon'$. Let π_i^i for subscript $i = \{1, 2\}$ and superscript i denoting imitation be the equilibrium payoff of Firm i in a Cournot duopoly with asymmetric costs, which is also characterised by imitation. Solving for the Cournot equilibrium, we obtain $\pi_1^i = \frac{1}{9}(a - c + 2\epsilon - \epsilon')^2$ and $\pi_2^i = \frac{1}{9}(a - c - \epsilon + 2\epsilon')^2$. Consider the equilibrium payoff of each firm when $\epsilon' = 0$. Clearly, the payoffs correspond to a Cournot duopoly with asymmetric costs and no imitation, i.e. $\pi_i^i = \pi_i^d$. Likewise, consider the equilibrium payoffs when $\epsilon' = \epsilon$. In this case, the payoffs correspond to a Cournot duopoly with symmetric costs, i.e. $\pi_i^i = \pi^d$. Let us now consider the per-unit cost reduction achieved by Firm 2 through imitation when $0 < \epsilon' < \epsilon$. In this case, the Cournot equilibrium payoff of Firm i always satisfies $\pi^d < \pi_i^i < \pi_1^d$ for $i = 1$, and $\pi_2^d < \pi_i^i < \pi^d$ for $i = 2$. In general, the relations among all the possible Cournot payoffs in equilibrium are: $\pi_1^d \geq \pi_1^i \geq \pi^d \geq \pi_2^i \geq \pi_2^d \geq 0$.

3.2   The Litigation Game

We can now introduce the basic model. Consider a three-stage litigation game, in which the sequence of actions with the corresponding payoffs to be described below are summarised in Figure 3.1.
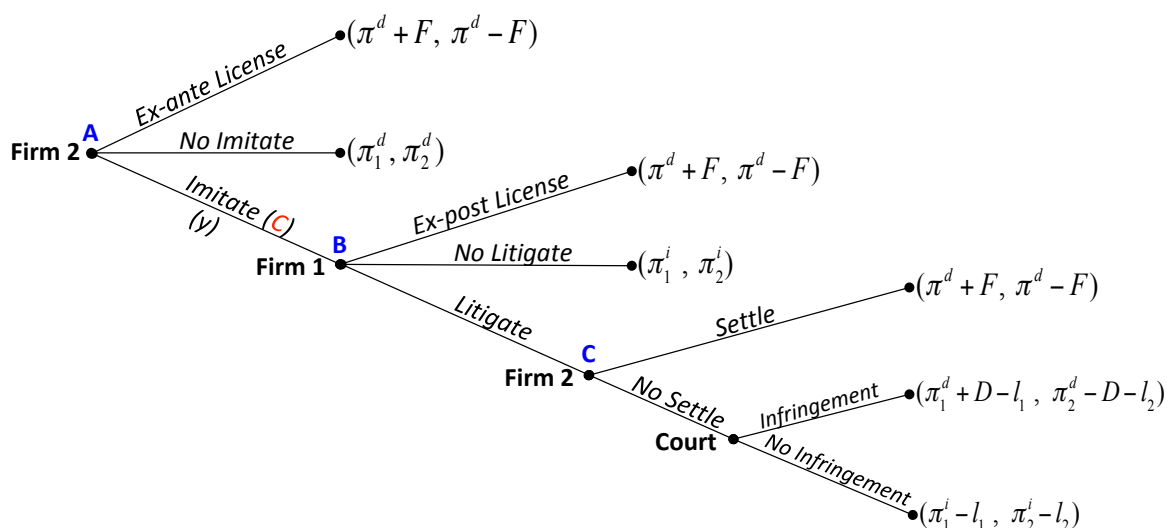

Figure 3.1: The decision tree with payoffs.

In the first stage, subgame A in Figure 3.1, Firm 2 should decide among three available actions. First, Firm 2 can enter in a licensing agreement about the patent rights of the new technology owned by Firm 1 (*Ex-ante License*). If this event occurs, the market becomes a symmetric duopoly, where each firm earns a payoff π^d. In addition, Firm 2 should transfer a fixed licence fee F for $F > 0$, to Firm 1 in exchange for the use of the patent rights. Let an ordered pair of entries denote the allocation of payoffs that corresponds to each outcome of the game, where the first entry represents the payoff of Firm 1 and the second entry the payoff of Firm 2. Then, the payoff outcome of this case is $(\pi^d + F, \pi^d - F)$.

Second, Firm 2 can decide to take no action regarding the new technology (*No Imitate*). This action results in an asymmetric duopoly regime, where Firm 1 uses the new technology and earns π_1^d, while Firm 2 relies on the existing technology and earns π_2^d. Evidently, the payoff outcome of this case is (π_1^d, π_2^d).

Third, Firm 2 can opt for costly imitation (*Imitate*). Let the imitation cost be $C = \frac{1}{2}\alpha y^2$, where α characterises the difficulty to imitate and y reflects the likelihood of successful imitation. Additionally, assume that α is a sufficiently large positive number to ensure that the probability of successful imitation is always between zero and one, i.e. $0 \leq y \leq 1$. This structure implies that with a success probability of imitation y, Firm 2 reduces its production cost by ϵ', in which case the second stage of the game is reached, subgame B in Figure 3.1. Likewise, Firm 2 fails to imitate with probability $1 - y$, and thus, it should decide whether to produce with the existing technology (*No Imitate*) or reach a licensing agreement with Firm 1 ex-ante imitation (*Ex-ante License*).

In the second stage, the patent owner should now decide among three actions. First, Firm 1 can achieve a licensing agreement with the competing firm ex-post imitation (*Ex-post License*). In this case, likewise licensing in the first stage of the game, the payoff outcome is $(\pi^d + F, \pi^d - F)$.

Second, Firm 1 can decide to take no action regarding the imitative behaviour of Firm 2. Basically, this action implies that Firm 1 prefers not to file a formal lawsuit about a potential infringement of its patented technology (*No Litigate*). However, imitation has occurred, thus the payoff outcome is (π_1^i, π_2^i), where the superscript i denotes a duopoly regime characterised by imitation.

Third, Firm 1 can launch a formal infringement lawsuit against Firm 2 (*Litigate*), in which case the equilibrium is determined in the third and last stage of the game, subgame C in Figure 3.1. We assume a costless lawsuit challenge in the second stage of the game, as nearly always this phase occupies a negligible fraction of the litigation cost involved

during the trial process.

In the third stage, subgame C in Figure 3.1, there are two cases to be considered. First, the litigants can bargain over a fixed licence fee and settle out of court (*Settle*). Likewise, in the licensing outcomes described above, the payoff outcome of settlement is $(\pi^d + F, \pi^d - F)$.

Second, the firms can litigate to completion. We assume that failure to settle at this stage immediately ends up at trial (*No Settle*). In this case, Firm i bears its own legal cost l_i for $i = \{1, 2\}$, where $l_i > 0$. Let the probability of Firm 1 winning the trial, as seen by Firm i be $\theta_i = \theta_{0i} + \theta[l_1/(l_1 + l_2)]$ for $i = \{1, 2\}$ (see, Hause, 1989; Aoki and Hu, 1999a). This functional form implies that the probability of the plaintiff prevailing in trial is increasing in its own legal cost and decreasing in the legal cost incurred by the defendant. It also implies that θ_i is a function of θ_{0i} for $i = \{1, 2\}$, a subjective mean probability of Firm 1 winning the trial as perceived by Firm i, where $0 \le \theta_{0i} \le 1$. Finally, θ_i depends also on θ, which reflects the extent that the court is influenced by the level of costs spent in litigation, where $0 \le \theta \le 1$. For instance, a value of θ close to zero means that the litigants can hardly affect the optimal mean perceived probabilities of the plaintiff winning the dispute, i.e. a nearly 'insensitive' court. Likewise, a value of θ close to one means that the litigants can, in fact, affect the mean subjective winning probabilities through the legal costs spent in litigation, i.e. a highly 'sensitive' court. The subjective mean probability of the plaintiff winning the lawsuit θ_i and the sensitivity parameter of the court θ, should always satisfy $0 \le \theta_{0i} + \theta \le 1$ for $i = \{1, 2\}$.

Clearly, the outcome of the game depends on the verdict of the trial. First, consider that the verdict is in favour of Firm 1. In other words, Firm 2 is found to have infringed the patented technology (*Infringement*). In this event, assume that the infringer is forced to pay a damage D.[14] Then, the payoff outcome of the game is $(\pi_1^d + D - l_1, \pi_2^d - D - l_2)$, where $D \ge 0$ is a transfer of a lump sum amount from the infringer to the patent owner.[15]

Second, consider that the court finds Firm 2 not liable for infringement (*No Infringement*). In this event, the payoff outcome is $(\pi_1^i - l_1, \pi_2^i - l_2)$, which in fact seems more like independent rediscovery instead.

---

[14] In this paper, there is no discounting; therefore, the damage award reflects mostly a way to punish the defendant for intended imitation (punitive damage) rather than to compensate for plaintiff's loss of profit (compensatory damage).

[15] The damage award is often in a form of royalties based on the realised market price of the produced outcome by the infringer or a lump sum amount that should recover at least the loss of profit incurred to the patent owner during the time period that the invention was used by the infringer.

3.3   The Decision to Settle

Now that we have already described the litigation game, we can solve the model by backward induction beginning with the third stage, with subgame C in Figure 3.1.

In this stage of the game, Firm 2 should decide whether to settle the infringement lawsuit. First, consider that settlement is not reached (*No Settle*), and thus, the allocation of payoffs is determined by the court. Therefore, each firm bears its own legal cost. In this case, Firm 1 expects to either win the lawsuit a probability θ_1 and gain $\pi_1^d + D$ or to lose with a probability $1 - \theta_1$ and receive π_1^i. Likewise, Firm 2 expects to either outlast the dispute with probability $1 - \theta_2$ and earn π_2^i or lose with probability θ_2 and attain $\pi_2^d - D$. Summing up the events described above, we find that the perceived expected payoff outcome is $(\theta_1[\pi_1^d + D] + [1 - \theta_1]\pi_1^i - l_1, \theta_2[\pi_2^d - D] + [1 - \theta_2]\pi_2^i - l_2)$, which can be simplified as $(\pi_1^i + \theta_1[\pi_1^d - \pi_1^i + D] - l_1, \pi_2^i - \theta_2[\pi_2^i - \pi_2^d + D] - l_2)$.

Imitation occurs with probability y; as a result, each outcome in this stage is probabilistic. However, the success probability of imitation y does not affect firms' strategic decision related to subgame C in Figure 3.1. Therefore, we have not considered y in the analysis described above. Likewise, imitation cost C incurred by Firm 2 is a sunk cost, and thus, it is not relevant for the decision-making of this specific subgame. Returning to the question posed in the beginning of this section, whether to settle, it is now possible to address it.

First, we maximise the expected payoff of each firm with respect to its own legal cost. Second, we solve the system of the best response function. Let superscript $*$ denote the value of a variable in equilibrium—for example, the equilibrium legal cost of Firm i is l_i^* for $i = \{1, 2\}$. Third, we substitute the equilibrium legal costs l_i^* in the likelihood function θ_i and obtain the expectation of Firm i regarding the plaintiff's probability of winning in equilibrium, θ_i^* for $i = \{1, 2\}$. Let the equilibrium legal costs of litigation and perceived probabilities of infringement be expressed as an ordered pair of entries, where the first entry corresponds to Firm 1 and the second entry corresponds to Firm 2; then, we can establish the following result:

Lemma 1 *The equilibrium legal costs spent by the litigants in trial are as follows:*

$$(l_1^*, l_2^*) \equiv \left(\theta([\pi_2^i - \pi_2^d + D] \Big[\frac{\pi_1^d - \pi_1^i + D}{\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D} \Big]^2, \quad \theta[\pi_1^d - \pi_1^i + D] \Big[\frac{\pi_2^i - \pi_2^d + D}{\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D} \Big]^2 \right).$$

$$(3.1)$$

Therefore, the litigants' perceived probabilities of infringement in equilibrium are:

$$(\theta_1^*, \theta_2^*) \equiv \left(\theta_{01} + \theta \Big[\frac{\pi_1^d - \pi_1^i + D}{\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D} \Big], \quad \theta_{02} + \theta \Big[\frac{\pi_1^d - \pi_1^i + D}{\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D} \Big] \right). \quad (3.2)$$

Proof *See Appendix.*

From Lemma 1, we derive the following corollary:

Corollary 1 *The equilibrium legal costs and litigants' perceived probabilities of infringement have the following properties: $\partial l_i^*/\partial \theta > 0$, $\partial l_i^*/\partial D > 0$, $\partial \theta_i^*/\partial \theta_{0i} > 0$ and $\partial \theta_i^*/\partial \theta > 0$ for $i = \{1, 2\}$. When $\pi_1^i + \pi_2^i > \pi_1^d + \pi_2^d$, which is equivalent to $\epsilon' > \frac{8}{5}\epsilon - \frac{2}{5}(a - c)$, $\partial \theta_i^*/\partial D > 0$ for $i = \{1, 2\}$; otherwise, i.e. when $\epsilon' < \frac{8}{5}\epsilon - \frac{2}{5}(a - c)$, $\partial \theta_i^*/\partial D < 0$ for $i = \{1, 2\}$.*

Proof *See Appendix.*

Corollary 1 suggests that the equilibrium legal costs increase with the sensitivity parameter of the court (θ) and the expected damage award (D). This also implies that the litigants' perceived probabilities of infringement in equilibrium increase with the mean subjective probabilities of infringement (θ_{0i}) and the sensitivity parameter of the court (θ). Finally, Corollary 1 indicates that a change in the expected damage award (D) might have an ambiguous effect on the expectations regarding the probability of the plaintiff winning in equilibrium (θ_i^*). In particular, when ϵ' is sufficiently large, a change in D seems to have an increasing effect on θ_i^*; otherwise, it has a decreasing effect.

Let π_i^{NS} for $i = \{1, 2\}$ be the profit of Firm i when there is no settlement (*No Settle*). According to Lemma 1, when a settlement is not reached, the profits of Firms 1 and 2 valued at the equilibrium legal costs are as follows:

$$\begin{aligned}
\pi_1^{NS}(l_1^*) &= \pi_1^i + \theta_1^*(\pi_1^d - \pi_1^i + D) - l_1^*, \\
\pi_2^{NS}(l_2^*) &= \pi_2^i - \theta_2^*(\pi_2^i - \pi_2^d + D) - l_2^*,
\end{aligned} \quad (3.3)$$

or equivalently:

$$\begin{aligned}
\pi_1^{NS}(l_1^*) &= \pi_1^i + (\pi_1^d - \pi_1^i + D)\left[\theta_{01} + \theta \Big(\frac{\pi_1^d - \pi_1^i + D}{\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D} \Big)^2 \right], \\
\pi_2^{NS}(l_2^*) &= \pi_2^i - (\pi_2^i - \pi_2^d + D)\left[\theta_{02} + \theta \Big(1 - [\frac{\pi_2^i - \pi_2^d + D}{\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D}]^2 \Big) \right].
\end{aligned} \quad (3.4)$$

Second, consider that an agreement to settle has been reached between the litigants (*Settle*), it is evident that a settlement occurs when it benefits each firm more than going to trial. Precisely, the litigants settle if $2\pi^d \geq \pi_1^i + \pi_2^i + \theta_1^*(\pi_1^d - \pi_1^i + D) - \theta_2^*(\pi_2^i - \pi_2^d + D) - (l_1^* + l_2^*)$; otherwise, the trial prevails. Let us now establish the following result:

Theorem 1 *The Nash equilibrium of subgame C in Figure 3.1 is characterised as follows.*

A. *Firms 1 and 2 settle (Settle) if and only if:*

    (1) $\theta < \hat{\theta}$ *and* $D < \hat{D}$*, or*

    (2) $\theta \geq \hat{\theta}$ *and* $D > \hat{D}$*.*

B. *Firms 1 and 2 go to trial (No Settle) if and only if:*

    (1) $\theta < \hat{\theta}$ *and* $D > \hat{D}$*, or*

    (2) $\theta \geq \hat{\theta}$ *and* $D < \hat{D}$*.*

    Where thresholds $\hat{\theta}$ *and* $\hat{D}$ *are defined to be:*

$$\hat{\theta} \equiv \frac{(2\pi^d - [\pi_1^i + \pi_2^i] - \theta_{01}[\pi_1^d - \pi_1^i + D] + \theta_{02}[\pi_2^i - \pi_2^d + D])(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)}{(\pi_1^d - \pi_1^i + D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)},$$
(3.5)

    and

$$\hat{D} \equiv (\pi_1^d - \pi_1^i) - 2(\pi_2^i - \pi_2^d) = (4\epsilon - 2[a - c] - 3\epsilon')\epsilon'. \quad (3.6)$$

According to Equation 3.6, $\hat{D}$ is negative when $\epsilon' > \frac{4}{3}\epsilon - \frac{2}{3}(a - c)$. In this case, only conditions A(2) and B(1) are relevant to characterise the Nash equilibrium of subgame C in Figure 3.1. It follows that the litigants settle if $\theta \geq \hat{\theta}$; otherwise, they go to trial.

Theorem 1 suggests that the decision to settle or not is primarily characterised by the sensitivity of the court to the legal expenditures of litigation (θ) and the expected damage award (D). Not surprisingly, it does not depend on the settlement fee (F), as the fee is simply a transfer from the infringer to the patent owner that occurs with certainty. We establish the following corollary:

Corollary 2 *The court's sensitivity threshold given by Equation 3.6 has the following properties: When* $D < \hat{D}$*,* $\partial\hat{\theta}/\partial\theta_{01} < 0$ *and* $\partial\hat{\theta}/\partial\theta_{02} > 0$*; otherwise, i.e. when* $D > \hat{D}$*,* $\partial\hat{\theta}/\partial\theta_{01} > 0$ *and* $\partial\hat{\theta}/\partial\theta_{02} < 0$*. The sign of* $\partial\hat{\theta}/\partial D$ *is ambiguous.*

Proof *See Appendix.*

Corollary 2 suggests that when the expected damage award is smaller than $\hat{D}$, the

court's sensitivity threshold is inversely related to the plaintiff's perceived probability of infringement (θ_{01}) and positively related to the defendant's perceived probability of infringement (θ_{02}). Relatedly, when the expected damage award is larger than $\hat{D}$, the court's sensitivity threshold is increasing in θ_{01} and decreasing in θ_{02}. Finally, the effect on the court's sensitivity threshold due to a change in the damage award (D) cannot be determined.

Let us now use Nash Bargaining to determine the settlement fee in equilibrium, F^*. Suppose that the litigants agree on a settlement fee according to bargaining shares ($\beta, 1-\beta$) for $0 \leq \beta \leq 1$, where β represents the negotiation power of Firm 1. Assume that the disagreement point of the bargaining game is the litigants' profit when settlement is not reached at the value of equilibrium legal costs, $\left(\pi_1^{NS}(l_1^*), \pi_2^{NS}(l_2^*)\right)$. It follows that the bargaining problem is:

$$\max_{F \geq 0} \quad \left(\pi^d + F - [\pi_1^i + \theta_1^*(\pi_1^d - \pi_1^i + D) - l_1^*]\right)^{\beta}\left(\pi^d - F - [\pi_2^i - \theta_2^*(\pi_2^i - \pi_2^d + D) - l_2^*]\right)^{1-\beta}. \quad (3.7)$$

The settlement fee in equilibrium that results from the above maximisation problem is as follows:

$$\begin{aligned} F^* = &\pi_1^i - \pi^d + \beta(2\pi^d - \pi_1^i - \pi_2^i) + \beta(l_1^* + l_2^*) - l_1^* \\ &+ \theta_1^*(\pi_1^d - \pi_1^i + D) - \beta(\theta_1^*[\pi_1^d - \pi_1^i + D] - \theta_2^*[\pi_2^i - \pi_2^d + D]), \end{aligned} \quad (3.8)$$

or equivalently:

$$\begin{aligned} F^* = &\pi_1^i - \pi^d + \beta(2\pi^d - \pi_1^i - \pi_2^i) + \theta_{01}(\pi_1^d - \pi_1^i + D) - \beta(\theta_{01}[\pi_1^d - \pi_1^i + D] - \theta_{02}[\pi_2^i - \pi_2^d + D]) \\ &+ \frac{\theta\left([\pi_1^d - \pi_1^i + D]^2 - \beta[\pi_1^d - \pi_1^i - 2(\pi_2^i - \pi_2^d) - D][\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D]\right)(\pi_1^d - \pi_1^i + D)}{(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)^2}. \end{aligned} \quad (3.9)$$

We can now establish the following corollary:

Corollary 3 *The equilibrium settlement fee given by Equation 3.9 has the following properties: $\partial F^*/\partial\theta_{0i} > 0$ for $i = \{1, 2\}$, $\partial F^*/\partial\theta > 0$, and $\partial F^*/\partial\beta > 0$. When $\beta \geq \frac{1}{2}$, $\partial F^*/\partial D > 0$; otherwise, i.e. when $\beta < \frac{1}{2}$, the sign of $\partial F^*/\partial D$ is ambiguous.*

Proof *See Appendix.*

Corollary 3 suggests that the equilibrium settlement fee F^* is positively related to

the mean subjective probabilities of infringement (θ_{0i}) and to the sensitivity parameter of the court (θ), as well as the plaintiff's negotiation power β. It also implies that the settlement fee is increasing in the expected damage award (D) when the plaintiff's negotiation power is higher than or equal to that of the defendant; otherwise, the effect cannot be determined.

Let π_i^S for $i = \{1, 2\}$ be the profit of Firm i when a settlement agreement is reached (*Settle*). Then, the profits of Firms 1 and 2 valued at the equilibrium settlement fee are:

$$
\begin{aligned}
\pi_1^S(F^*) &= \pi^d + F^*, \\
\pi_2^S(F^*) &= \pi^d - F^*.
\end{aligned}
\tag{3.10}
$$

3.4 The Decision to Litigate

Given that we have determined the Nash equilibrium of the third stage (see, Theorem 1), we can now move back to the second stage of the game, subgame B in Figure 3.1. Clearly, the equilibrium of this subgame depends on the Nash equilibrium of subgame C in Figure 3.1. Therefore, there are two cases that have to be considered.

First, suppose that settlement out of court (*Settle*) characterises the equilibrium in the last stage of the game. It is evident that licensing (*Ex-post License*) and settlement (*Settle*) result in the same payoff allocation, in which case Firm 1 is indifferent between the two actions.[16] In this context, let us assume that firms prefer a licence (*Ex-post License*) instead of litigation (*Litigate*).[17]

In this stage, Firm 1 has also another choice to consider before taking a decision. It can decide to take no action regarding potential imitation from Firm 2 (*No Litigate*). Clearly, Firm 1 prefers to become a licensor when it is better off by transferring the technology at an equilibrium fixed fee (F^*). However, we have to ensure that it benefits and that Firm 2 becomes a licensee; otherwise, licensing would not arise. In other words, a licensing agreement would occur if $2\pi^d \geq \pi_1^i + \pi_2^i$. This is equivalent to saying that technology transfer makes each firm better off if $\epsilon' \geq \frac{3}{5}\epsilon - \frac{2}{5}(a - c)$, or $\epsilon' = \epsilon$ (perfect imitation). Let π_i^{PL} for $i = \{1, 2\}$, be the profit of Firm i when a licensing agreement has been reached in subgame B in Figure 3.1 (*Ex-post License*). Then, the profits of Firms 1

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[16]Firm 1 is indifferent between the two choices, as we have assumed that carrying on a lawsuit in the second stage of the game is costless.

[17]There are many plausible reasons that firms would avoid a formal lawsuit. For example, litigation might damage their reputation.

and 2 valued at the equilibrium licensing (settlement) fee are as follows:

$$
\begin{aligned}
\pi_1^{PL}(F^*) &= \pi^d + F^*, \\
\pi_2^{PL}(F^*) &= \pi^d - F^*.
\end{aligned}
\tag{3.11}
$$

Consider now that the condition that ensures licensing does not hold, i.e. $2\pi^d < \pi_1^i + \pi_2^i$. In this event, Firm 1 prefers to take no action instead of offering a licence or pursuing litigation. Let π_i^{NL} for $i = \{1, 2\}$ denote the profit of Firm i when the patent owner takes no action in the second stage of the game (*No Litigate*). Then, when no litigation characterises the equilibrium of this subgame, the profits of Firms 1 and 2 are as follows:

$$
\begin{aligned}
\pi_1^{NL} &= \pi_1^i, \\
\pi_2^{NL} &= \pi_2^i.
\end{aligned}
\tag{3.12}
$$

Second, consider that going to trial (*No Settle*) characterises the equilibrium of subgame C in Figure 3.1. Evidently, licensing ex-post imitation (*Ex-post License*) cannot be part of a Nash equilibrium, as it does not make any firm better off. Moreover, Firm 1 prefers to resolve the dispute in a court of law (*No Settle*) instead of taking no action (*No Litigate*), i.e. $\pi_1^{NS}(l_1^*) > \pi_1^{NL}$. We can now establish the following result:

Theorem 2 *The Nash equilibrium of subgame B in Figure 3.1 is characterised as follows:*

A. *Firms 1 and 2 reach a licensing agreement ex-post imitation (Ex-post License) if and only if conditions (1) and (4) are satisfied.*

B. *Firm 1 takes no action against infringement (No Litigate) if and only if conditions (1) and (3) are satisfied.*

C. *Firm 1 litigates (Litigate) if and only if condition (2) is satisfied.*

Where conditions (1) to (4) are defined to be:

(1) $\{\theta < \hat{\theta}$ and $D < \hat{D}\}$, or
  $\{\theta \geq \hat{\theta}$ and $D > \hat{D}\}$,

(2) $\{\theta < \hat{\theta}$ and $D > \hat{D}\}$, or
  $\{\theta \geq \hat{\theta}$ and $D < \hat{D}\}$,

(3) $\epsilon' < \dfrac{3}{5}\epsilon - \dfrac{2}{5}(a - c)$,

(4) $\epsilon' \geq \dfrac{3}{5}\epsilon - \dfrac{2}{5}(a - c)$, or
  $\epsilon' = \epsilon$.

Theorem 2 suggests that when going to trial prevails in subgame C in Figure 3.1, then litigation characterises the Nash equilibrium of this stage. Conversely, when settlement out of court is reached in the last stage of the game, then the Nash equilibrium of subgame B in Figure 3.1 depends on the magnitude of the cost reduction due to imitation (ϵ'). In particular, when ϵ' is sufficiently small, then it is optimal for Firm 1 to take no action against imitation. However, if ϵ' increases and becomes sufficiently large, all else equal, licensing in the second stage of the game makes both firms better off.

3.5   The Decision to Imitate

In this section, we focus on subgame A in Figure 3.1, in which case Firm 2 should decide among becoming a licensee (*Ex-ante License*), taking no action with regard to the new protected technology (*No Imitate*) and should opt for imitation (*Imitate*). We have already determined the payoff outcome related to each action described above, as well as the Nash equilibrium of subgame B in Figure 3.1, which unfolds when Firm 2 decides to imitate.

First, suppose that imitation does not occur. This implies that Firm 2 should decide only between paying Firm 1 in exchange for the patented technology and producing with its existing technology. A technology transfer makes both firms better off if $0 < \epsilon < \frac{2}{3}(a-c)$. In turn, when $\frac{2}{3}(a-c) \leq \epsilon < a-c$, Firm 1 does not maximise its profit through a technology transfer, and thus, licensing does not occur. In this case, each firm produces a positive quantity of output by relying on its own technology. Finally, when $\epsilon \geq a-c$ and the invention is drastic, Firm 2 is driven out of the market and earns $\pi_2^d = 0$, while Firm 1 becomes a monopolist and earns $\pi^m = \frac{1}{4}(a-c+\epsilon)^2$.

Let us now consider imitation. We have assumed that Firm 2 succeeds in imitating with a probability y and fails to imitate with a probability $1-y$, as well as that imitation requires a cost $C = \frac{1}{2}\alpha y^2$. In this stage of the game, the cost incurred in imitation affects the decision-making of Firm 2, as a result the choice of the cost is relevant in characterising the Nash equilibrium of the game. In sum, there are three cases that have to be considered.

Case I $\{0 < \epsilon < \frac{2}{3}(a-c)\}$: In this interval of ϵ, taking no action regarding the patented technology (*No Imitate*) cannot be part of a Nash equilibrium; therefore, we should consider only two potential actions in order to determine the equilibrium: licensing in the first stage of the game (*Ex-ante License*) and imitating (*Imitate*). The probability of imitation y is chosen by Firm 2, which aims at maximising its profit. Successful imitation

leads to the second stage of the game, subgame B in Figure 3.1, which is characterised by the Nash equilibrium defined in Theorem 2.

It is evident that taking no action against infringement (*No Litigate*) cannot be part of a Nash equilibrium, as condition (3) in Theorem 2 is not satisfied in this specific interval of the magnitude of innovation ϵ. Likewise, it does not benefit Firm 2 to enter a licensing agreement ex-post imitation (*Ex-post License*), since Firm 2 can save any positive cost spent to imitate and earn no less by becoming a licensee in the first stage of the game. In particular, solving the optimisation problem of Firm 2:

$$\max_{y \geq 0} \quad y(\pi^d - F^*) + (1 - y)(\pi^d - F^*) - \frac{1}{2}\alpha y^2, \tag{3.13}$$

yields a zero probability of imitation in equilibrium. This result implies that imitation does not benefit Firm 2. Let π_i^{AL} for $i = \{1, 2\}$ be the profit of Firm i when a licensing agreement occurs in subgame A in Figure 3.1 (*Ex-ante License*). Then, the profits of Firms 1 and 2 valued at the equilibrium licensing fee are as follows:

$$\begin{aligned} \pi_1^{AL}(F^*) &= \pi^d + F^*, \\ \pi_2^{AL}(F^*) &= \pi^d - F^*. \end{aligned} \tag{3.14}$$

Finally, suppose that litigation (*Litigate*) dominates in subgame B in Figure 3.1. Then, the optimal imitation effort is determined as the solution to:

$$\max_{y \geq 0} \quad y\pi_2^{NS}(l_2^*) + (1 - y)(\pi^d - F^*) - \frac{1}{2}\alpha y^2, \tag{3.15}$$

which gives a probability of imitation in equilibrium equal to $\frac{1}{\alpha}[\pi_2^{NS}(l_2^*) - (\pi^d - F^*)]$. This, in turn, implies that Firm 2 incurs an optimal imitation effort if litigation results in trial. Let y^* denote the probability of imitation in equilibrium; then, the expected profits in equilibrium of Firms 1 and 2 are as follows:

$$\begin{aligned} \pi_1^{NS}(l_1^*, y^*, F^*) &= y^*(\pi_1^i + \theta_1^*[\pi_1^d - \pi_1^i + D] - l_1^*) + (1 - y^*)\pi_1^{AL}(F^*), \\ \pi_2^{NS}(l_2^*, y^*, F^*) &= y^*(\pi_2^i - \theta_2^*[\pi_2^i - \pi_2^d + D] - l_2^*) + (1 - y^*)\pi_2^{AL}(F^*) - \frac{1}{2}\alpha(y^*)^2, \end{aligned} \tag{3.16}$$

where

$$y^* = \begin{cases} \frac{1}{\alpha}[\pi_2^{NS}(l_2^*) - (\pi^d - F^*)] & \text{when part C in Theorem 2 holds,} \\ 0 & \text{otherwise.} \end{cases} \qquad (3.17)$$

Case II $\{\frac{2}{3}(\mathbf{a} - \mathbf{c}) \leq \epsilon < \mathbf{a} - \mathbf{c}\}$: The analysis used in *Case I*, in order to characterise the Nash equilibrium of the game, can also be applied in this case. In this specific interval of ϵ, Firm 2 prefers to produce with the protected technology (*Ex-ante License*) rather than with the old technology (*No Imitate*); however, a licensing agreement does not make Firm 1 better off. As a result, licensing ex-ante imitation does not occur in equilibrium, and thus, only two actions need to be considered in order to determine the Nash equilibrium of the game, taking no action regarding the new cost-reducing technology (*No Imitate*) and imitating the patented technology (*Imitate*).

First, suppose that a technology transfer through a patent licence (*Ex-post License*) dominates in subgame B in Figure 3.1. Then, the optimal imitation effort of Firm 2 is determined as the solution to:

$$\max_{y \geq 0} \quad y(\pi_2^d - F^*) + (1 - y)\pi_2^d - \frac{1}{2}\alpha y^2, \qquad (3.18)$$

which gives a probability of imitation in equilibrium equal to $\frac{1}{\alpha}(\pi^d - \pi_2^d - F^*)$. This result suggests that although a licensing agreement cannot be reached in the first stage of the game, because it does not benefit Firm 1, it can arise ex-post imitation. This is because the expected profit of Firm 2, at the optimal imitation effort when it becomes a licensee in the second stage of the game, is higher than or equal to the profit derived when it takes no action in the first stage.

Second, suppose that no action against potential infringement (*No Litigate*) prevails in subgame B in Figure 3.1. Then, the equilibrium probability of imitation that results from the first-order condition of the following optimisation problem:

$$\max_{y \geq 0} \quad y\pi_2^i + (1 - y)\pi_2^d - \frac{1}{2}\alpha y^2, \qquad (3.19)$$

is $\frac{1}{\alpha}(\pi_2^i - \pi_2^d)$. This result implies that in the first stage of the game, Firm 2 can always choose an optimal imitation effort, which induces Firm 1 to pursue no litigation in the second stage.

Finally, it suggests that litigation (*Litigate*) characterises the Nash equilibrium of

subgame B in Figure 3.1 and thus the dispute goes to trial. Then, Firm 2 solves the following problem:

$$\max_{y \geq 0} \quad y\pi_2^{NS}(l_2^*) + (1-y)\pi_2^d - \frac{1}{2}\alpha y^2, \tag{3.20}$$

which gives an optimal imitation effort equal to $\frac{1}{\alpha}[\pi_2^{NS}(l_2^*) - \pi_2^d]$. This means that Firm 2 is better off by pursuing imitation at the optimal effort, even when the lawsuit goes to trial; thus, the profit allocation depends on the court's verdict.

Let us now summarise the results derived above and determine firms' expected profits in equilibrium. If licensing in the second stage of the game (*Ex-post License*) characterises the Nash equilibrium of the game, the expected profits of Firms 1 and 2 are as follows:

$$\begin{aligned}
\pi_1^{PL}(y^*, F^*) &= y^*(\pi^d + F^*) + (1-y^*)\pi_1^d, \\
\pi_2^{PL}(y^*, F^*) &= y^*(\pi^d - F^*) + (1-y^*)\pi_2^d - \frac{1}{2}\alpha(y^*)^2.
\end{aligned} \tag{3.21}$$

However, if no litigation (*No Litigate*) dominates instead, then the allocation of the expected profits in equilibrium is:

$$\begin{aligned}
\pi_1^{NL}(y^*) &= y^*\pi_1^i + (1-y^*)\pi_1^d, \\
\pi_2^{NL}(y^*) &= y^*\pi_2^i + (1-y^*)\pi_2^d - \frac{1}{2}\alpha(y^*)^2.
\end{aligned} \tag{3.22}$$

Finally, if the dispute goes to trial in equilibrium, then firms' expected profits are as follows:

$$\begin{aligned}
\pi_1^{NS}(l_1^*, y^*) &= y^*(\pi_1^i + \theta_1^*[\pi_1^d - \pi_1^i + D] - l_1^*) + (1-y^*)\pi_1^d, \\
\pi_2^{NS}(l_2^*, y^*) &= y^*(\pi_2^i - \theta_2^*[\pi_2^i - \pi_2^d + D] - l_2^*) + (1-y^*)\pi_2^d - \frac{1}{2}\alpha(y^*)^2,
\end{aligned} \tag{3.23}$$

where

$$y^* = \begin{cases} \frac{1}{\alpha}(\pi^d - \pi_2^d - F^*) & \text{when part A in Theorem 2 holds,} \\ \frac{1}{\alpha}(\pi_2^i - \pi_2^d) & \text{when part B in Theorem 2 holds,} \\ \frac{1}{\alpha}[\pi_2^{NS}(l_2^*) - \pi_2^d] & \text{otherwise.} \end{cases} \tag{3.24}$$

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Case III $\{\epsilon \geq \mathbf{a} - \mathbf{c}\}$: In this specific interval of ϵ, which corresponds to a drastic invention, taking no action (*No Imitate*) drives Firm 2 out of the market ($\pi_2^d = 0$). As a result, choosing not to imitate cannot occur in equilibrium. Likewise, licensing in the first stage of the game (*Ex-ante License*) cannot be part of a Nash equilibrium, because Firm 1 earns more by becoming a monopolist (π^m). Hence, imitation (*Imitate*) is the only remaining action that can be chosen by Firm 2. Consequently, the Nash equilibrium of subgame B in Figure 3.1, which is defined in Theorem 2, is also a Nash equilibrium for the complete game. Let us now derive the expected profits in equilibrium. If licensing ex-post imitation (*Ex-post License*) dominates in equilibrium, then the expected profits of Firms 1 and 2 are as follows:

$$
\begin{aligned}
\pi_1^{PL}(y^*, F^*) &= y^*(\pi^d + F^*) + (1 - y^*)\pi^m, \\
\pi_2^{PL}(y^*, F^*) &= y^*(\pi^d - F^*) - \frac{1}{2}\alpha(y^*)^2.
\end{aligned}
\tag{3.25}
$$

However, if no litigation (*No Litigate*) occurs in equilibrium, then firms' expected profits are as follows:

$$
\begin{aligned}
\pi_1^{NL}(y^*) &= y^*\pi_1^i + (1 - y^*)\pi^m, \\
\pi_2^{NL}(y^*) &= y^*\pi_2^i - \frac{1}{2}\alpha(y^*)^2.
\end{aligned}
\tag{3.26}
$$

Finally, if the litigants fail to settle in equilibrium (*No Settle*), then the allocation of the expected profit is as follows:

$$
\begin{aligned}
\pi_1^{NS}(l_1^*, y^*) &= y^*(\pi_1^i + \theta_1^*[\pi^m - \pi_1^i + D] - l_1^*) + (1 - y^*)\pi^m, \\
\pi_2^{NS}(l_2^*, y^*) &= y^*(\pi_2^i - \theta_2^*[\pi_2^i + D] - l_2^*) - \frac{1}{2}\alpha(y^*)^2,
\end{aligned}
\tag{3.27}
$$

where

$$
y^* = \begin{cases}
\frac{1}{\alpha}(\pi^d - F^*) & \text{when part A in Theorem 2 holds,} \\
\frac{1}{\alpha}\pi_2^i & \text{when part B in Theorem 2 holds,} \\
\frac{1}{\alpha}\pi_2^{NS}(l_2^*) & \text{otherwise.}
\end{cases}
\tag{3.28}
$$

Summing up the analysis described above, we establish the following result:

Theorem 3 *The Nash equilibrium of the game in Figure 3.1 is characterised as follows.*

A. Firms 1 and 2 reach a licensing agreement ex-ante imitation (Ex-ante License) if

and only if conditions (1), (3), and (6) are satisfied.

B. *Firms 1 and 2 reach a licensing agreement ex-post imitation (Ex-post License) if and only if conditions (2), (3), and (6) are satisfied.*

C. *Firm 1 takes no action against infringement (No Litigate) if and only if conditions (2), (3), and (5) are satisfied.*

D. *Firm 1 litigates (Litigate) if and only if condition (4) is satisfied.*

Conditions (1) to (6) are defined as follows:

(1) $0 < \epsilon < \frac{2}{3}(a - c)$,

(2) $\epsilon \geq \frac{2}{3}(a - c)$,

(3) $\{\theta < \hat{\theta} \ and \ D < \hat{D}\}$, or
$\{\theta \geq \hat{\theta} \ and \ D > \hat{D}\}$,

(4) $\{\theta < \hat{\theta} \ and \ D > \hat{D}\}$, or
$\{\theta \geq \hat{\theta} \ and \ D < \hat{D}\}$,

(5) $\epsilon' < \frac{3}{5}\epsilon - \frac{2}{5}(a - c)$,

(6) $\epsilon' \geq \frac{3}{5}\epsilon - \frac{2}{5}(a - c)$, or
$\epsilon' = \epsilon$.

4 Conclusion

The premise of this paper is to study patent licensing and litigation while acknowledging that the enforcement of IPRs is imperfect, and thus, patent protection is not absolute. These imperfections make imitation an inevitable event, which in turn might cause infringement of patent rights and lead to litigation. Imitation is, in fact, a strategic choice that can initiate a legal suit. If the lawsuit is lost in the court, it could prove costlier than a technology transfer fee, and might even result in serious consequences. The factors that determine the resolution of the lawsuit do also have a significant impact on the conduct of firms. For instance, consider how the costs spent in litigation affect the verdict of a trial, as well as the strategic use of IPRs by firms. These considerations highlight the importance of understanding the use of IPRs and the role of legal enforcement as a policy instrument on the strategic behaviour of innovating firms. In this section, we summarise

and discuss the most important results and insights gained from the analysis described above.

In this paper, we examine the factors that determine the strategic use of IPRs by focusing on the patent rights of a cost-reducing technology. Specifically, we study the aggregate effect of the strength of the judicial system, the size of the innovation, and the efficacy of the imitation process on the strategic interaction between a patent owner and a potential infringer. Based on a set of assumptions and conditions, we characterise the Nash equilibrium of a three-stage litigation game. In particular, we find that, in equilibrium, when both parties expect to settle the dispute out of court and when the innovation is sufficiently small, a technology transfer occurs before imitation (*Ex-ante License*). Moreover, when the firms again expect a private settlement of the dispute but when the innovation is sufficiently large, there are two potential outcomes that can occur in equilibrium depending on the efficacy of the imitation process. If imitation is sufficiently efficient, i.e. $\epsilon' \to \epsilon$, then a technology transfer occurs after imitation (*Ex-post License*). If the efficiency of imitation is sufficiently low, i.e. $\epsilon' \to 0$, then taking no action against imitation (*No Litigate*) characterises the equilibrium. The results also suggest that the decision to resort to trial to resolve the dispute does not directly depend on the magnitude of innovation, but rather on the expected damage award and the extent that the disputants, by increasing the amount spent in litigation, can actually influence the court's verdict. Finally, changes in policy instruments, such as the damage award D, have an effect on the licence terms and the allocation of the expected profits in equilibrium.

Another purpose of the paper is also to come closer to approximating real-world infringement disputes. For example, we allow each firm to choose among a bundle of alternative actions characterised by a set of parameters and variables that capture observed features of lawsuits. In addition, we assume that the strategic conduct of each firm is defined not only by its own perception of the court's judgement, even when a trial is not reached, but also by the perception of the opposite party. However, we do not consider the impact of a verdict on the reputation of the litigants. For instance, an infringement verdict in favour of a patent owner strengthens his position against new entry and his bargaining power for a technology transfer in the future, which therefore discourages subsequent imitative conduct. Second, we do not incorporate the concept of time into our model, although we aim to determine conditions that favour a technology transfer and that thus prevent a costly legal dispute. Including the time factor in the analysis could engender to an interesting discussion about the effect of a lengthy legal procedure on the decision-making of the firms. Finally, we do not analyse alternative

strategic reasons to postpone settlement, such as litigating now in order to gain better licensing terms in the future. Our model can also be applied to analyse patent hold-out (see, for example, Heiden and Petit, 2017). Future research is needed to address these considerations.

Appendix

Proof of Lemma 1. First, solve the following optimisation problems:

$$\max_{l_1 \geq 0} \quad \pi_1^i + \theta_1(\pi_1^d - \pi_1^i + D) - l_1 \quad \text{and}$$
$$\max_{l_2 \geq 0} \quad \pi_2^i - \theta_2(\pi_2^i - \pi_2^d + D) - l_2, \tag{A.1}$$

where $\theta_1 = \theta_{01} + \theta[l_1/(l_1 + l_2)]$ and $\theta_2 = \theta_{02} + \theta[l_1/(l_1 + l_2)]$. Then, from the following first-order conditions:

$$l_1 = \sqrt{\theta(\pi_1^d - \pi_1^i + D)l_2} - l_2 \quad \text{and}$$
$$l_2 = \sqrt{\theta(\pi_2^i - \pi_2^d + D)l_1} - l_1, \tag{A.2}$$

solve for the optimal legal costs. The lemma follows from simple calculations.

Proof of Corollary 1. The proof for the first four properties is straightforward except one: $\partial l_i^* / \partial D > 0$ for $i = \{1, 2\}$. Let $i = 1$ and differentiate the optimal legal cost with respect to the damage award:

$$\frac{\partial l_1^*}{\partial D} = \theta \frac{\pi_1^d - \pi_1^i + D}{(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)^3} \left[(\pi_1^d - \pi_1^i + D)^2 + 2(\pi_2^i - \pi_2^d + D)^2 - (\pi_1^d - \pi_1^i + D)(\pi_2^i - \pi_2^d + D) \right]. \tag{A.3}$$

Clearly, the sign of the fraction is positive. Therefore, consider only the sign of the expression in square brackets. Simple algebra shows that the sign of the expression in brackets is also positive. The same basic analysis can be applied for $i = 2$. Consider now the last differentiation:

$$\frac{\partial \theta_i^*}{\partial D} = \frac{(\pi_2^i - \pi_2^d) - (\pi_1^d - \pi_1^i)}{(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)^2}.$$

Evidently, it is the nominator that determines the sign of the differentiation. Therefore, substitute for the duopoly Cournot equilibrium profits in the denominator and show that $(\pi_2^i - \pi_2^d) - (\pi_1^d - \pi_1^i) > 0$ if $\epsilon' > \frac{2}{5}(4\epsilon - [a - c])$; otherwise, the sign of the denominator is negative.

Proof of Corollary 2. Consider first that $D < (\pi_1^d - \pi_1^i) - 2(\pi_2^i - \pi_2^d)$. Then, the proof for the first two properties is straightforward:

$$
\begin{aligned}
\frac{\partial \theta^S}{\partial \theta_{01}} &= \frac{-(\pi_1^d - \pi_1^i + D)(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)}{(\pi_1^d - \pi_1^i + D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)} \quad < \quad 0, \\
\frac{\partial \theta^S}{\partial \theta_{02}} &= \frac{-(\pi_2^i - \pi_2^d + D)(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)}{(\pi_1^d - \pi_1^i + D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)} \quad > \quad 0.
\end{aligned}
\tag{A.4}
$$

The same basic analysis can be applied for the remaining case, $D > (\pi_1^d - \pi_1^i) - 2(\pi_2^i - \pi_2^d)$. Consider now the last differentiation:

$$
\begin{aligned}
\frac{\partial \theta^S}{\partial D} =& \frac{(-\theta_{01} + \theta_{02})(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)}{(\pi_1^d - \pi_1^i + D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)} \\
&+ \frac{2(2\pi^d - \pi_1^i - \pi_2^i - \theta_{01}[\pi_1^d - \pi_1^i + D] + \theta_{02}[\pi_2^i - \pi_2^d + D])}{(\pi_1^d - \pi_1^i + D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)} \\
&- \frac{(2\pi^d - \pi_1^i - \pi_2^i - \theta_{01}[\pi_1^d - \pi_1^i + D] + \theta_{02}[\pi_2^i - \pi_2^d + D])(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)}{(\pi_1^d - \pi_1^i + D)^2(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)} \\
&+ \frac{(2\pi^d - \pi_1^i - \pi_2^i - \theta_{01}[\pi_1^d - \pi_1^i + D] + \theta_{02}[\pi_2^i - \pi_2^d + D])(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)}{(\pi_1^d - \pi_1^i + D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)^2},
\end{aligned}
\tag{A.5}
$$

or equivalently,

$$
\begin{aligned}
\frac{\partial \theta^S}{\partial D} =& \frac{-(\theta_{01} - \theta_{02})(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)(\pi_1^d - \pi_1^i + D)}{(\pi_1^d - \pi_1^i + D)^2(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)^2} \\
&+ \frac{2(2\pi^d - \pi_1^i - \pi_2^i - \theta_{01}[\pi_1^d - \pi_1^i + D] + \theta_{02}[\pi_2^i - \pi_2^d + D])(\pi_1^d + \pi_2^d - \pi_1^i - \pi_2^i)^2}{(\pi_1^d - \pi_1^i + D)^2(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)^2} \\
&+ \frac{2(2\pi^d - \pi_1^i - \pi_2^i - \theta_{01}[\pi_1^d - \pi_1^i + D] + \theta_{02}[\pi_2^i - \pi_2^d + D])(\pi_1^d - \pi_2^i + D)(\pi_2^i - \pi_2^d + D)}{(\pi_1^d - \pi_1^i + D)^2(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)^2}.
\end{aligned}
\tag{A.6}
$$

Clearly, the sign of the denominator is always positive. Therefore, consider only the sign of the numerator. In fact, the numerator can be positive and negative; thus, the sign of the differentiation is ambiguous. However, by rearranging the terms, it can be shown

that $\partial\theta^S/\partial D \gtreqless 0$ if:

$$
\frac{(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)}{2([\pi_1^d + \pi_2^d - \pi_1^i - \pi_2^i]^2 + [\pi_1^d - \pi_1^i + D][\pi_2^i - \pi_2^d + D])} \lesseqgtr
$$

$$
\frac{(2\pi^d - \pi_1^i - \pi_2^i - \theta_{01}[\pi_1^d - \pi_1^i + D] + \theta_{02}[\pi_2^i - \pi_2^d + D])}{(\theta_{01} - \theta_{02})(\pi_1^d - \pi_1^i + D)}.
$$

$$(A.7)$$

Proof of Corollary 3. The proof of the first two properties is straightforward:

$$
\begin{aligned}
\frac{\partial F^*}{\partial \theta_{01}} &= (1 - \beta)(\pi_1^d - \pi_1^i + D) > 0, \\[2mm]
\frac{\partial F^*}{\partial \theta_{02}} &= \beta(\pi_2^i - \pi_2^d + D) > 0.
\end{aligned}
$$

$$(A.8)$$

Applying the same analysis and using simple algebra, it can be shown that:

$$
\begin{aligned}
\frac{\partial F^*}{\partial \beta} =\ & (2\pi^d - \pi_1^i - \pi_2^i) - \theta_{01}(\pi_1^d - \pi_1^i + D) + \theta_{02}(\pi_2^i - \pi_2^d + D) \\[2mm]
& - \frac{\theta(\pi_1^d - \pi_1^i - 2[\pi_2^i - \pi_2^d] - D)(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)(\pi_1^d - \pi_1^i + D)}{(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)^2} > 0.
\end{aligned}
$$

$$(A.9)$$

Finally, differentiate the equilibrium licence fee with respect to the damage award and get:

$$
\begin{aligned}
\frac{\partial F^*}{\partial D} =\ & \theta_{01} - \beta(\theta_{01} - \theta_{02}) + \frac{2\theta\beta([\pi_1^d - \pi_1^i + D]^3 + [\pi_2^i - \pi_2^d + D]^3)}{(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)^3} \\[2mm]
& - \frac{(\pi_1^d - \pi_1^i + D)^2(\pi_1^d - \pi_1^i - 3[\pi_2^i - \pi_2^d] - 2D)}{(\pi_1^d - \pi_1^i + \pi_2^i - \pi_2^d + 2D)^3}.
\end{aligned}
$$

$$(A.10)$$

Show that the above expression is positive if the bargaining power of the plaintiff is higher than or equal to that of the defendant, i.e. $\beta \geq \frac{1}{2}$; otherwise, i.e. when $\beta < \frac{1}{2}$, the effect of a change in the damage award cannot be determined.

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