

Licensing commitments in standard setting organizations

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November 14, 2007

Abstract

This paper compares three possible procedures for the licensing of patents reading on a technology standard. In the first scenario the licensor fixes its royalties once manufacturers have entered the market for standard compliant products. In two alternative scenarios the licensor commits on a royalty level or on a royalty cap before manufacturers enter that market. The licensor's choice between the three procedures depends on a trade-off between the uncertainty it faces on the expected demand for standard compliant products, and a hold-up effect that deters the entry of manufacturers when royalties are set ex post. We show that the first scenario is always dominated by the royalty cap and can be dominated by the commitment on a royalty level. We derive several policy implications for standard setting policies and their antitrust treatment.

CERNA Working paper 11/2007

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1 Introduction

Standard setting organizations aim at defining common technology norms at the industry level. The standards developed within these organizations may embody numerous patented technologies, which must then be licensed to users of the standard by their respective owners. During the last two decades, the number of patents reading on standards has increased dramatically, which has raised new issues concerning their licensing conditions. Recent antitrust cases suggest in particular that the current licensing practices may deter potential users from adopting a standard. In absence of clear commitments on the licensing conditions, users may indeed fear to be held up by patent holders if the licensing terms are announced after they have already adopted the standard¹. We address this problem in this paper by analyzing various ways in which patent owners could commit on licensing terms at early stages of the standard setting process.

For this purpose, we develop a model in which a unique patent owner licenses its essential patents to manufacturers of differentiated standard compliant products. This simple setting allows to capture different problems related to the timing of royalty announcement. On the one hand, the patent owner initially faces uncertainty on the size of the future market. This creates an incentive for him to fix his royalty at the end of the standard setting process, once manufacturers have entered the market and uncertainty is dissipated. On the other hand, manufacturers must incur fixed cost of entry during the standard setting process in order to master the technology standard. They may thus be reluctant to invest for fear to be held up if royalties are set once these costs are sunk. In this context, the choice of patent owners between fixing royalties before or after the entry of manufacturers depends on a trade off between uncertainty on the size of the market for standard compliant products, and the need to attract manufacturers towards those markets.

We use this model to compare three procedures for royalty setting, namely ex post royalty setting, ex ante royalty announcement, and the ex ante announcement of a royalty cap. As far as consumers are concerned, the best option is always ex ante royalty announcement. The best option for the patent owner depends on the levels of the fixed costs, of uncertainty and on the degree of product differentiation. We find that ex ante announcement can be more profitable than ex post royalty setting, while a royalty cap is always preferable to ex post royalty setting. As a consequence, both consumers and patent owners can benefit from implementing an ex ante scheme. This is an important finding for it means that whenever standard setting organizations choose to make binding ex ante commitments on royalties, both patent owners and the buyers of standard compliant products will be better off.

¹Once a standard has been adopted, opportunistic hold-up may consist in disclosing an essential patent that had been hidden so far and ask royalties for it, or in upgrading the royalties that had been announced to future licensees. These two scenarios can be illustrated respectively by the Rambus and Qualcomm cases, both of which are discussed in Section 1 of this paper.

The paper is divided into seven parts. Section 2 briefly surveys the literature on patent hold-up in standard-setting processes, the rules standard-setting organizations enact to mitigate hold-up, and the recent antitrust complaints and rulings. Section 3 presents our model. The scenarios without commitment and with a commitment on a royalty level are analyzed and compared in Section 4. A third scenario in which patent owners commit on a royalty cap is introduced in Section 5 and compared with the two other ones. Section 6 derives policy implications. Section 7 concludes.

2 Review of the literature

The number of patents worldwide has increased enormously in the past 20 years (Lévêque and Ménière, 2003). A similar inflation has taken place in technology standards, in which patents have become an inevitable component. The MPEG-2 video and audio compression standard, for example, incorporates 425 patents with 28 different owners. This phenomenon raises two issues that have been in-depth studied in economic literature.

2.1 Multi-marginalization and patent pools

Firstly, the multiplicity of patent owners and their complementarity induce a multi-marginalization conundrum. Each patent that is essential for the standard enjoys a monopoly and the stacking of monopoly margins results in an inefficient global royalty. Some form of coordination between patent owners is necessary to reduce the global royalty and this would increase both patent owners' and licensees' surpluses. Patent pools that grant a single license for patents belonging to different owners provide such a mechanism. Of course, coordination between patent owners can also raise anticompetitive effects. It therefore deserves antitrust authorities' scrutiny. Gilbert (2003) has studied the evolution of antitrust enforcement vis-vis patent pools. Lerner and Tirole (2004, 2005) have identified the conditions for patent pools being procompetitive.

2.2 Patent hold-up

Secondly, patent owners can be tempted to hold-up standard users. Once users are locked in a standard, the owners of patents reading on the standard can leverage their exclusive rights to extract more money from licensees. In addition to the monopoly profit they deserve for their innovation included into the standard, they gain an extra-profit that is equal to the costs of users to switch to an alternative technology and standard. This transfer of surplus between the gun-holder and the ransomed does matter because it also entails a welfare loss: knowing ex ante that they can be held up, users reduce their investments and choose technologies with lower performances². Patent ambush is a good

²Williamson 1985's hold-up theory was applied to intellectual property reading on standards by C. Shapiro (2001).

example of hold-up strategy. During the standard-setting process, participants are usually asked to disclose the patents that cover technologies that might be included in the future standard. The ambush consists for a firm in deliberately hiding it owns essential patent until the standard has been set and adopted. The US Federal Trade Commission recently held Rambus, a Californian firm, liable under antitrust law for such a behavior. Rambus' behavior is also under scrutiny of the European antitrust authorities. In a Statement of Objections sent to Rambus in July 2007, the Commission of European Communities has suspected that it engaged in intentional deceptive conduct and abused its dominant position by subsequently claiming unreasonable royalties for the use of its patents.

The breach of RAND commitment is another type of hold-up. Members of standard setting organizations commonly commit they will license their patents according to Reasonable And Non-Discriminatory terms if the technology it covers is eventually included in the standard. Once the standard is adopted, the patent owner sets a royalty level that is much higher than what was expected by licensees. Qualcomm, a US mobile phone chipset company, is alleged by competitors and customers to have undertaken such a strategy. They lodged a complaint at the Commission of the European Communities in 2006 for competition law infringement³. In the US, Broadcom has accused Qualcomm for the same misconduct. It alleged Qualcomm violated section 2 of Sherman Act by licensing its technology on non RAND terms although it agreed to do it before its technology was chosen as a standard. The claim was dismissed by a lower court reasoning that Qualcomm enjoys a legal monopoly in its patented technology and that its deceptive conduct did not matter under antitrust law because the adoption of a standard would inevitably result in the absence of competition. However, the Third Circuit reversed the District court's ruling in appeal. Circuit judges recognized that a firm's deceptive RAND commitment may constitute actionable anticompetitive conduct.

2.3 Reasonable royalties

The critical question is what does mean "reasonable terms" of licensing, and especially what is a reasonable level of royalty. For several authors (Swanson and Baumol, 2005; Shapiro, 2006), a reasonable royalty should reflect the outcome of ex ante competition between technologies for being selected in the standard. Swanson and Baumol (2005) conceptualize it as the result of an auction mechanism in which each patent owner states the royalty it intends to ask if his technology is chosen. The reasonable royalty R can therefore be written as follows:

$$R = c + V_1 - V_2 \tag{1}$$

³In September 2007, the European Commission decided not to dismiss the complaint and initiated formal proceedings against Qualcomm.

where c denotes the incremental cost of licensing, that is the licensing costs incurred by the patent owner for negotiation, royalty collection and any related services (e.g., training for the licensee), and $V_1 - V_2$ measures the gain for users of choosing the best technology over the second-best. As defined, this royalty amount enables the owner of the superior technology to reap the entire gain of its innovation for users. This point is essential because it means that RAND licensing does not block or erode the exercise of intellectual property rights (thereafter, IPRs).

The reference of reasonable royalties to ex ante competition has raised two main critics. Firstly, the concept of reasonable royalty is vague (Patterson, 2002) and standard-setting organizations have made little efforts to define it (Lemley, 2002). As a consequence, different interpretations can be given to the meaning of RAND terms. For Geradin and Rato (2006), for instance, a RAND commitment only entails the promise of the patent owner to engage in good faith negotiations with companies asking for a license to implement the standard. It does not impose obligations on the licensor on the actual level of royalties. Moreover, they wonder whether hold-up in standard-setting processes is a significant phenomenon for robust empirical evidence is lacking. They suspect hold-up theory in antitrust complaints for breach of RAND commitment is used as a smoke screen: manufacturers that make products complying with the standards only want to pay lower royalties. Secondly, practical obstacles may render difficult the organizing of ex ante competition. Participants involved in SSOs' meetings are usually engineers or scientists. Unlike sellers and lawyers they are not familiar with patent valuation and the setting of licensing conditions. They often even do not know which patents of their company protect the technology that may be incorporated in the standard. According to Wiser (2007), decisions on standards can no longer be made on purely technical grounds and SSOs must adapt their operating to the new reality.

3 The model

We develop a licensing model to study how various ex ante commitments affect patent owners, manufacturers of standard compliant products and consumers. We consider the licensing of a technology standard to firms in a downstream industry of n manufacturers with differentiated products. For simplicity we assume that all the patents reading on the standard are owned by a single licensor. The manufacturers pay a per unit royalty R for this bundle of patents. Before studying how the level of global royalty is determined, we study as a first step the downstream market in order to derive the demand for licenses.

The inverse demand function to manufacturer i writes

$$P_i = x - q_i - \alpha \sum_{j \neq i} q_j$$

where $\alpha \in]0, 1]$ denotes the degree of homogeneity between products, with perfect homogeneity at $\alpha = 1$.

The unit production costs of manufacturers are noted c ; they are symmetric and constant. Moreover manufacturers pay the per unit royalty R for using the technology standard. The program of a manufacturer, given that n firms compete on the downstream market, writes:

$$\max_{q_i} \left(x - q_i - \alpha \sum_{j \neq i} q_j - c - R \right)$$

At symmetric equilibrium, the individual production q and profit π_M of a manufacturer are respectively

$$\begin{aligned} q(R) &= \frac{x - c - R}{2 + \alpha(n - 1)} \\ \pi_M(R) &= q(R)^2 \end{aligned} \tag{2}$$

We consider monopolistic competition. There is a fixed cost I of entry into the downstream market. This cost corresponds especially to the cost of implementing the standard. Given a royalty level R , firms enter into the market until the entry profit is zero, e.g. $\pi(n) = I$. At free entry equilibrium, the number of manufacturers is thus given by

$$n(R) = 1 + \frac{x - c - R - 2\sqrt{I}}{\alpha\sqrt{I}}$$

Observe that at free entry equilibrium the individual production is $q = \sqrt{I}$ whatever the level of royalty R . From n and q we can derive the total production Q and the price P of goods on the downstream market:

$$\begin{aligned} Q(R) &= n(R)q(R) = \sqrt{I} + \frac{x - c - R - 2\sqrt{I}}{\alpha} \\ P(R) &= c + \sqrt{I} + R \end{aligned} \tag{3}$$

In the next Sections, we study successively three possible timings of royalty setting. In the first case manufacturers enter the downstream market before the licensor fixes the royalty level R . In the second case the licensor fixes R before manufacturers enter the market. In the third case, the licensor announces a royalty cap ex ante, and keeps the option to downgrade the royalty after manufacturers have entered the market.

4 Ex post versus ex ante royalty setting

We assume from now on that the level of demand x is a random parameter for the patent owners, with distribution $F(x)$ on $[\underline{x}, \bar{x}]$. The manufacturers

are not subject to this uncertainty. Hence the patent owners can solve for the uncertainty is they wait for the manufacturers to enter before setting their royalty.

4.1 Ex post licensing

We study now the scenario in which the licensor sets a global royalty level after manufacturers have adopted the standard. In that case the licensor sets the global royalty that maximizes the global royalty revenue. The timing of the game is now the following:

1. Nature decides the level of demand
2. Manufacturers enter the market
3. The licensor sets a global royalty R^p

We solve the game backwards and therefore study first the licensor's licensing strategy when the number n of manufacturers is given. The licensor maximizes its total royalty revenue:

$$\max_R \pi_L^p(R) \equiv nRq(R)$$

The optimal royalty resulting from this program is

$$\begin{aligned} nRq(R) &= nR \frac{x - c - R}{2 + \alpha(n - 1)} \\ R^p &= \frac{x - c}{2} \end{aligned} \tag{4}$$

This royalty level is anticipated by manufacturers when they make their entry decision. It is easy to derive the number of firms n^p , the total production Q^p and individual prices P^p at free entry equilibrium.

$$\begin{aligned} n^p &= \frac{x - c - 2(2 - \alpha)\sqrt{I}}{2\alpha\sqrt{I}} \\ Q^p &= \sqrt{I} + \frac{x - c - 4\sqrt{I}}{2\alpha} \\ P^p &= \frac{x + c}{2} + \sqrt{I} \end{aligned}$$

We can now derive the licensor's royalty revenue π_L at subgame perfect Nash equilibrium:

$$\pi_L^p(R^p) = \frac{x - c}{4\alpha} [x - c - 2(2 - \alpha)\sqrt{I}]$$

When they choose whether to set the royalty ex ante or ex post, patent owners do not know the exact level of demand. Hence their ex ante expected profit writes:

$$\tilde{\pi}_L^p(R^p) = \frac{1}{4\alpha} \int_{\underline{x}}^{\bar{x}} (x - c) \left[x - c - 2(2 - \alpha)\sqrt{I} \right] f(x) dx \quad (5)$$

4.2 Ex ante commitment on the royalty

We study now the scenario where the licensor announces the global royalty before manufacturers adopt the standard and enter the market. We assume for this that the royalty announcement is a binding commitment. The timing of this game is:

1. The licensor announces the global royalty R^a it will charge to downstream manufacturers
2. Nature decides the level of demand
3. Manufacturers enter the market

Since entry takes place at the second stage, the manufacturer now anticipates the effect of the royalty on the number of firms at free entry equilibrium. The licensor thus solves

$$\max_R \tilde{\pi}_L^a(R) \equiv R \int_{\underline{x}}^{\bar{x}} Q(R) f(x) dx$$

where

$$Q(R) = \frac{x - c - R - (2 - \alpha)\sqrt{I}}{\alpha}$$

The optimal royalty resulting from this program is

$$R^a = \frac{E(x) - c - (2 - \alpha)\sqrt{I}}{2} \quad (6)$$

And after some calculation (see Appendix), the licensing profits can be expressed as:

$$\tilde{\pi}_L^a(R^a) = \frac{1}{4\alpha} \left[E(x) - c - (2 - \alpha)\sqrt{I} \right]^2 \quad (7)$$

4.3 Comparison

We can now compare the licensing profits in both cases. After some calculation (see Appendix), $\tilde{\pi}_L^a(R^a) - \tilde{\pi}_L^p(R^p)$ writes

$$\tilde{\pi}_L^a(R^a) - \tilde{\pi}_L^p(R^p) = \frac{1}{4\alpha} \left[(2 - \alpha)^2 I - V(x) \right]$$

It follows that:

$$\tilde{\pi}_L^a(R^a) > \tilde{\pi}_L^p(R^p) \quad \Leftrightarrow \quad (2 - \alpha)^2 I > Var(x)$$

The right hand expression clearly captures the degree of uncertainty on the expected demand for standard compliant products. The left hand expression reflects the profit loss induced for patent owners by a reduction of the number of manufacturers; it depends on the entry cost and on the degree of product differentiation. The higher the fixed costs, and the stronger the differentiation, the higher the profit loss due ex post royalty setting.

Proposition 1 *The licensor will prefer ex post royalty setting if the uncertainty on demand is strong and the opportunity cost of entry is low.*

Proof. See Appendix. ■

We must also make the comparison for consumers welfare. For this we must consider both the prices charged to consumers and the variety of products supplied to consumers. We have:

$$E(P^a) = \int_{\underline{x}}^{\bar{x}} \left[c + \sqrt{I} + R^a \right] f(x) dx = \frac{c}{2} + \alpha \frac{\sqrt{I}}{2} + \frac{E(x)}{2}$$

$$E(P^p) = \int_{\underline{x}}^{\bar{x}} \left[c + \sqrt{I} + R^p(x) \right] f(x) dx = \frac{c}{2} + \sqrt{I} + E(x)$$

We thus have always lower expected prices when the royalty is fixed ex ante. Turning now to products variety we have:

$$E(n^a) = \int_{\underline{x}}^{\bar{x}} \frac{x - c - R^a - (2 - \alpha)\sqrt{I}}{\alpha\sqrt{I}} f(x) dx$$

$$= \frac{E(x) - c - (2 - \alpha)\sqrt{I}}{2\alpha\sqrt{I}}$$

$$E(n^p) = \int_{\underline{x}}^{\bar{x}} \frac{x - c - R^p(x) - (2 - \alpha)\sqrt{I}}{\alpha\sqrt{I}} f(x) dx$$

$$= \frac{E(x) - c - 2(2 - \alpha)\sqrt{I}}{2\alpha\sqrt{I}} = E(n^a) - \frac{2 - \alpha}{\alpha}$$

It can be checked easily that $E(n^a) > E(n^p)$ is always true, such that ex ante royalty setting also enhances a larger consumer welfare in terms of product variety. Interestingly, the difference is only function of the differentiation parameter α . When products are perfectly homogenous ($\alpha = 1$), the difference in the number of firms is equal to one firm. It increases then as products get more differentiated.

We summarize these findings in the Table below, which displays the difference in licensor's profit, product prices and number of products.

Table 1: comparison between ex ante and ex post royalty

Licensor's profit	$\tilde{\pi}_L^a(R^a) - \tilde{\pi}_L^p(R^p)$	$= \frac{1}{4\alpha} \left[(2 - \alpha)^2 I - V(x) \right]$	> 0
Product prices	$E(P^a) - E(P^p)$	$= -\frac{1}{2} \left[E(x) + (2 - \alpha) \sqrt{I} \right]$	< 0
Product variety	$E(n^a) - E(n^p)$	$= \frac{2-\alpha}{\alpha}$	≥ 1

We can see that the difference in the licensor's profit and price charged to consumers are larger when the entry cost I is high and when products are more differentiated. By contrast the difference in the number of product varieties does not depend on the entry cost, but only on product differentiation. The more differentiated the products, the larger the difference in number of products, and therefore the larger the loss in variety for consumers.

Proposition 2 *Ex ante royalty setting always dominates ex post royalty setting in terms of consumer welfare.*

5 Ex ante commitment on a royalty cap

We study finally the scenario where the licensor announces a royalty cap. The timing of this game is now:

1. The licensor announces a royalty cap R^c
2. Nature decides the level of demand
3. Manufacturers enter the market
4. The licensor eventually revises the royalty downwards

The demand level below which the licensor will revise the royalty downwards can be found by comparing the ex post royalty with the royalty cap. It corresponds to the demand level at which the licensor is indifferent between

revising the royalty or not. This demand level, denoted $\hat{x}(R^c)$, is thus defined by $R^p(\hat{x}) = R^c$, that is:

$$\frac{\hat{x} - c}{2} = R^c \Leftrightarrow \hat{x}(R^c) = c + 2R^c \quad (8)$$

For any $x < \hat{x}(R^c)$, the licensor will prefer to revise the royalty, while it will stick to R^c when $x \geq \hat{x}(R^c)$. The licensor maximizes its expected profit:

$$\max_R \tilde{\pi}_L^c(R) \equiv \int_{\underline{x}}^{\hat{x}(R)} \pi_L^p(R^p(x)) f(x) dx + \int_{\hat{x}(R)}^{\bar{x}} \pi_L^a(R) f(x) dx \quad (9)$$

The licensor maximizes this profit with respect to R^c . After some calculation, the first order condition of this program writes (see Proof of equation (10) in the appendix):

$$R^c = \frac{1}{2} \left[\frac{E(x|x \geq \hat{x}(R^c))}{1 - F(\hat{x}(R^c))} - c - (2 - \alpha) \sqrt{I} \right] \quad (10)$$

Using the expression of R^c in (8) this rewrites into:

$$L(\hat{x}(R^c)) = (2 - \alpha) \sqrt{I} \quad (11)$$

where

$$L(\hat{x}) \equiv \frac{E(x|x \geq \hat{x}(R^c))}{1 - F(\hat{x}(R^c))} - \hat{x}$$

From this condition we obtain the following result:

Proposition 3 *There exists is a unique threshold $T \in [E(x) - \underline{x}; \bar{x} - \underline{x}]$ such that the licensor will define a royalty cap ex ante if $(2 - \alpha) \sqrt{I} < T$, while it will set a pure ex ante royalty if $(2 - \alpha) \sqrt{I} > T$.*

Proof. See Appendix. ■

When the problem admits an interior solution, we can see from (11) and (8) that the equilibrium demand threshold $\hat{x}(R^c)$ and royalty cap R^c are decreasing with the opportunity cost of entry. Therefore large entry costs and strong differentiation entail a lower royalty cap.

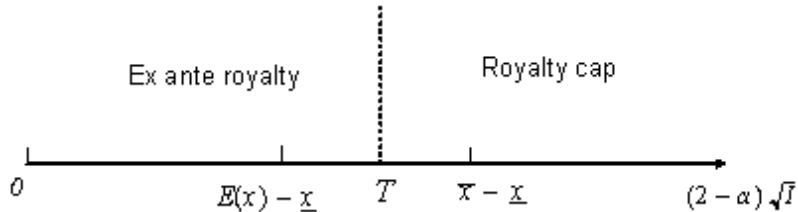


Figure 1: decision of the licensor

We can now study the effects of the royalty cap on the consumers' welfare. Comparing the expected price and number of firms resulting from the ex ante setting of a royalty cap with the outcomes of the ex post and pure ex ante royalties yields the following results.

Proposition 4 *In expectation, there are more manufacturers and lower prices (i) with a commitment on a royalty than with a commitment on a royalty cap and (ii) with a commitment on a royalty cap than with an ex post royalty.*

Proof. See Appendix. ■

The commitment on a royalty cap increases the expected number of products with respect to the ex post royalty, while it decreases this number when compared with the commitment on a royalty level. This result reflects the fact that the royalty cap is a mix of ex ante and ex post royalty setting. The larger number of manufacturers in turn induces lower prices due to enhanced competition. Therefore expected prices are higher with an ex post royalty than with a commitment on a royalty cap, and with a royalty cap than with a commitment on a royalty level. Both results imply that concerning consumers welfare the commitment on a royalty is a first best, the commitment on a royalty cap is the second best, and the ex post royalty is the least desirable solution.

6 Policy implications

Table 1 recapitulates the effects of the different royalty announcements on the welfare of consumers and on the profit of the patent owner (or patent owners if they are several but collectively act as a single owner). It does not mention the effect on manufacturers for their profit is always zero. By construction of the model, manufacturers stop to enter into the market of standard compliant products when expected revenue becomes lower than fixed costs. At the entry equilibrium the profit is nil. As far as consumer surplus is concerned (see proposition 4 above), we observe that the first best arrangement occurs when the future level of royalty is announced ex ante and the worst one when royalty is announced ex post. Consumers suffer from the latter because the number of entrants is lower, thus the total investment is reduced, and in turn consumers' choice between differentiated standard compliant products is more constrained and price higher. Ex ante royalty cap ensures an intermediary level of investments and then is better for consumers than ex post royalty announcement, but worse than ex ante announcement of the precise level of royalty.

Table 1: welfare effects of royalty setting scenarios

	$(2 - \alpha)^2 I \leq Var(x)$	$Var(x) < (2 - \alpha)^2 I \leq T$	$T < (2 - \alpha)^2 I$
Licensors	RC \succ EP \succeq EA	RC \succeq EA \succ EP	EA \succ RC \succ EP
Consumers	EA \succ RC \succ EP		

Two interesting points from Table 1 deserve a discussion. Firstly, the preference order for the different royalty announcements can be the same for patent owners and consumers. When manufacturers investment is high relatively to demand uncertainty, consumers and patent owners are better off if royalties are announced ex ante. Moreover, this circumstance is the unique setting for which ex ante royalty is the patent owners' first best. As a consequence, the initiative of patent owners to announce the level of royalty ex ante signals that consumers will also be better off. A key policy recommendation follows from this finding: antitrust authorities have to abandon the per se approach prohibiting the negotiation of licensing terms between patent owners during the standard setting-process. A rule of reason balancing the pro-competitive and anti-competitive effects (e.g., the inclusion of non essential patents in the standard) must be adopted. It is important to notice that this recommendation does not derive here from usual considerations on multi-marginalization and ex ante competition. As reminded in section 1, coordination between patents owners is necessary to reduce the global royalty. It eliminates the Cournot problem of multiple monopoly margins. This coordination can take place before or after the standard is adopted. In fact, patent pools usually form ex post (Gilbert, 2004). In our model, there is no room for multi-marginalization. We have assumed that the owners of patents reading on the standard collectively behave as a single owner. The other commonly reason advanced to abandon the per se rule is that announcing licensing terms during the standard setting process may increase competition⁴. It is true the organizing of an ex ante auction where holders of patents protecting competing technologies shout the royalties they will ask if their technology is chosen reduces the level of the global royalty, and thus increases the surplus of consumers. However, our recommendation holds even in absence of competition: for a standard based on unique technologies (i.e., no substitutes for each technology included into the standard) the patent holders' collective initiative to ex ante announce their royalties is pro-competitive.

Secondly, ex ante announcement of royalty cap is always better both for consumers and patent owners than ex post announcement. This finding is important for the design of intellectual property policy of SSOs. The setting of a royalty cap has only been recently implemented by organizations such as VITA. VITA stands for VMEbus International Trade Association; it creates standards for certain computer bus architecture. Its policy includes a special provision that requires its members to disclose maximum royalty rates they will demand for their essential patents. The commitment is irrevocable; however, the patent owners are free to submit subsequent declarations with lower rates. If a patent owner fails to disclose an essential patent or does not comply with his royalty commitment, he is forced to license his intellectual property right on a royalty-free basis. Our paper provides an economic rationale for this innova-

⁴See for instance the US DoJ and FTC report (2007) stating that “[I]n the Agencies’ view, a per se approach fails to recognize that negotiating licensing terms during the standard-setting process may increase competition technologies that are being considered for inclusion in a standard. In light of these potential procompetitive benefits, the Agencies would generally expect to apply the rule of reason to evaluate conduct such as multilateral ex ante licencing.”

tive arrangement. It shows that besides its lower cost of implementation, the royalty cap provides patent owners a benefit in terms of uncertainty mitigation relatively to the ex ante announcement of the exact level of the future royalty. This risk has not been taken into account so far in literature on ex post versus ex ante royalty setting. Moreover, royalty cap has a decisive advantage when uncertainty is high (relatively to investment). In this circumstance, the interests of patent owners and consumers for ex post and ex ante announcement of the royalty are opposed. The former will delay its announcement. By contrast, if the SSO allows the setting of a royalty cap, both patent owners and consumers will be better off. In a nutshell, the integration of the royalty cap into patent policy of SSOs is recommended and should not be discouraged by antitrust authorities.

Lastly, our paper casts light on the current controversy on patent ambush and breach of RAND. This statement can be striking for the reader because such practices are generally viewed as a key example of patent hold-up whereas hold-up seems never to occur in our model! It is true that in our setting the profit of manufacturers is never negative. They always recoup the fixed costs they incur in investing. Unlike standard users harmed by patent ambush or breach of RAND, they are not expropriated from sunk investments. However, hold-up is a two-sided phenomenon. It also has an invisible side: knowing that they could be held up ex post, economic agents reduce their investments ex ante. This invisible part of the iceberg is merely what our model captures. It shows that there is always a form of ex ante announcement of royalty (i.e., the exact or the cap level) that is better for both consumer and patent holder's welfare. The reason is that ex post announcement reduces the total investment of manufacturers. So as a negative print, the paper illustrates the welfare loss patent policy of SSOs entails when it does not address hold-up by specific rules (e.g., patent disclosure obligation, royalty cap). Note that, as always, the lack of enforcement results in the same effects than the absence of the rules. An ex ante announcement that is not credible is similar to an ex post announcement regarding patent owner's and consumer's surplus: manufacturers reduce their investments. The paper therefore shows how making commitments of patent owners binding is critical for SSOs.

This perspective provides new insights on RAND terms for licensing. The declaration by a patent owner he will license his patent at a reasonable rate (if his technology is included into the standard) is formally an ex ante announcement of royalty. However, in so far as 'reasonable' is interpreted as a vague term by manufacturers, or is not perceived as a binding commitment, RAND in its very nature is just another version of ex post announcement. Being at risk to be held up, manufacturers reduce or delay their investments. Note that considerations of reputation may replace legally binding commitments when the same firms participate in the different setting processes, for instance for successive generations of a particular standard. If the sense of 'reasonable' is similarly understood by all parties and the SSO, a cheater may fear to be excluded from other standard setting processes or to deter the adoption of future standard. RAND can then play the role of an ex ante royalty announcement. It seems to

us, however, that the recent litigations for alleged breach of RAND announce a new era wherein SSOs are no longer technological clubs and wherein clearer and more enforceable rules on royalties, such as in VITA patent policy, are needed. Antitrust authorities through competition advocacy, and more controversially through competition law enforcement, may help to ensure this transition.

Observe finally that ex ante commitments may be more complicated when, unlike in our model, there are several owners of essential patent. The problem here is how individual royalties should be defined. The principle of ex ante competition advocated by Swanson & Baumol (2005) implies that individual royalties should be calculated firsthand. Indeed the royalty charged on each patent should be calculated separately as the difference between the value $V1$ of the standard when the said patent is selected, and the value $V2$ of the standard when the best available alternative is selected instead. In practice, the values $V1$ and $V2$ however depend on the expected demand and on the total amount of royalties. Moreover there is no guarantee that the sum of individual royalties calculated in this way matches the level that maximizes the total profit from licensing. Our analysis suggests that the total amount of royalties charged to manufacturers must rather be defined as a first step, and then split as a second step between the patent owners. This procedure is not incompatible with the ex ante competition principle. It just requires that ex ante competition for selection in the standard be applied to calculate only the royalty share of individual patent owners, not the total amount of royalties⁵.

7 Conclusion

We have developed a model in which the owner of a patent reading on standard grants licences to manufacturers of standard compliant products. We have used this model to study three different procedures for setting the licensing terms. In the first one, the licensor fixes its royalties once manufacturers have entered the market for standard compliant products. In the two other procedures the licensor commits on a royalty level or on a royalty cap before manufacturers enter that market. The procedure chosen by the licensor depends on a trade-off between the uncertainty it faces on the expected demand for standard compliant products, and a hold-up effect that deters the entry of manufacturers when royalties are set ex post.

We have firstly found that the stronger the ex ante commitments, the more entry in the product market and the better off consumers are. The licensor may prefer an ex ante commitment on the royalty level to an ex post royalty setting when manufacturers incur high entry costs while uncertainty is mild.

⁵This method can easily be applied in our simple model. Assuming that competing patented technologies affect the level of demand x or the unit production cost c of standard compliant products, it is easy to calculate the incremental licensing profit generated by the selection of the best of these technologies for a particular royalty setting procedure. The sum of incremental profits will then exceed the total licensing profit, but the share of each patent owner can be calculated easily by defining the incremental profit attributed to his technology by the sum of incremental profits for all selected technologies.

Interestingly, it also always prefers an ex ante commitment on a royalty cap to an ex post royalty setting scenario.

These results have important policy implications on the way standard setting organizations can organize their intellectual property policy to address the patent hold-up problem, and on the attitude antitrust authorities may adopt vis-a-vis such policies. In particular, the RAND licensing commitments that are often required from patent owners may not be effective enough, and may be replaced or complemented with early commitments on royalty caps. From this perspective it is very important that standard setting organizations make sure that early commitments be really binding in order to be effective.

The work carried out in this paper has several limitations that allow further analysis. Introducing more than one patent owner would introduce additional coordination issues, thereby making the analysis of commitments more complicated. A particularly interesting extension would consist in studying separated commitments on royalties or on royalty caps by individual patent owners.

8 References

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Appendix

Proof of Proposition 1

We demonstrate here how we obtain inequation (??). Replacing expected profits with their expressions in (7) and (5), the inequality $\tilde{\pi}_L^a(R^a) > \tilde{\pi}_L^p(R^p)$ rewrites:

$$\int_{\underline{x}}^{\bar{x}} (x - c) \left[x - c - 2(2 - \alpha) \sqrt{I} \right] f(x) dx > \left[E(x) - c - (2 - \alpha) \sqrt{I} \right]^2 \quad (12)$$

The expression on the left hand side can rewrite into:

$$\int_{\underline{x}}^{\bar{x}} x^2 f(x) dx - 2 \left[c + (2 - \alpha) \sqrt{I} \right] E(x) + c \left[c + 2(2 - \alpha) \sqrt{I} \right] \quad (13)$$

And the expression on the right hand side can rewrite into:

$$\left[E(x) \right]^2 + \left[c + (2 - \alpha) \sqrt{I} \right]^2 - 2 \left[c + (2 - \alpha) \sqrt{I} \right] E(x) \quad (14)$$

The second term of (13) and the last term of (14) simplify in inequation (12), thus giving:

$$\begin{aligned} \int_{\underline{x}}^{\bar{x}} x^2 f(x) dx + c \left[c + 2(2 - \alpha) \sqrt{I} \right] &> \left[E(x) \right]^2 + \left[c + (2 - \alpha) \sqrt{I} \right]^2 \\ &\Leftrightarrow \\ \int_{\underline{x}}^{\bar{x}} x^2 f(x) dx - \left[E(x) \right]^2 &> \left[c + (2 - \alpha) \sqrt{I} \right]^2 - c \left[c + 2(2 - \alpha) \sqrt{I} \right] \end{aligned}$$

Developing the two parts of the expression on the right hand side and simplifying finally yields the inequation:

$$Var(x) > (2 - \alpha)^2 I$$

Proof of equation (10)

We demonstrate first how we obtain the first order condition (10). Recall that the expected profit of the licensor writes:

$$\tilde{\pi}_L^c(R) = \Phi + \Psi$$

where

$$\begin{cases} \Phi = \int_{\underline{x}}^{\hat{x}(R)} \pi_L^p(R^p(x)) f(x) dx \\ \Psi = \int_{\hat{x}(R)}^{\bar{x}} \pi_L^a(R) f(x) dx \end{cases}$$

The licensor maximizes this profit with respect to R . We express successively the derivative of the two terms of the expression on the right hand side. Consider the first Φ . Its full expression is:

$$\Phi = \int_{\underline{x}}^{\hat{x}(R)} \frac{x-c}{4\alpha} [x-c-2(2-\alpha)\sqrt{I}] f(x) dx$$

Using the expression of $\hat{x}(R) = c + 2R$ from (8) its derivative is:

$$\begin{aligned} \frac{d\Phi}{dR} &= \frac{\partial\Phi}{\partial\hat{x}} \frac{\partial\hat{x}}{\partial R} \\ &= \frac{\hat{x}-c}{2\alpha} [\hat{x}-c-2(2-\alpha)\sqrt{I}] f(\hat{x}) \end{aligned}$$

and finally

$$\frac{d\Phi}{dR} = \frac{2R}{\alpha} [R-(2-\alpha)\sqrt{I}] f(c+2R) \quad (15)$$

Consider now Ψ . Its full expression is:

$$\Psi = \int_{\hat{x}(R)}^{\bar{x}} R \left[\frac{x-c-R-(2-\alpha)\sqrt{I}}{\alpha} \right] f(x) dx$$

and it can be reformulated into

$$\Psi = -\frac{R}{\alpha} \int_{\bar{x}}^{\hat{x}(R)} x f(x) dx - \frac{R}{\alpha} [c+R+(2-\alpha)\sqrt{I}] [1-F(\hat{x}(R))]$$

Its derivative is:

$$\begin{aligned}
\frac{d\Psi}{dR} &= \frac{\partial\Psi}{\partial\hat{x}} \frac{\partial\hat{x}}{\partial R} + \frac{\partial\Psi}{\partial R} \\
&= \frac{2R}{\alpha} f(\hat{x}(R)) \left[-\hat{x}(R) + c + R + (2-\alpha)\sqrt{I} \right] \\
&\quad - \frac{1}{\alpha} \int_{\bar{x}}^{\hat{x}(R)} x f(x) dx - \frac{1}{\alpha} \left[c + 2R + (2-\alpha)\sqrt{I} \right] [1 - F(\hat{x}(R))]
\end{aligned}$$

Using the expression of $\hat{x}(R) = c + 2R$ from (8) we obtain:

$$\begin{aligned}
\frac{d\Psi}{dR} &= \frac{2R}{\alpha} \left[-R + (2-\alpha)\sqrt{I} \right] f(c+2R) \\
&\quad - \frac{1}{\alpha} \int_{\bar{x}}^{\hat{x}(c+2R)} x f(x) dx - \frac{1}{\alpha} \left[c + 2R + (2-\alpha)\sqrt{I} \right] [1 - F(c+2R)]
\end{aligned} \tag{16}$$

Summing (15) and (16) gives:

$$\begin{aligned}
\frac{\partial\tilde{\pi}_L^c}{\partial R} &= \frac{2R}{\alpha} \left[R - (2-\alpha)\sqrt{I} \right] f(c+2R) + \frac{2R}{\alpha} f(c+2R) \left[-R + (2-\alpha)\sqrt{I} \right] \\
&\quad - \frac{1}{\alpha} \int_{\bar{x}}^{\hat{x}(c+2R)} x f(x) dx - \frac{1}{\alpha} \left[c + 2R + (2-\alpha)\sqrt{I} \right] [1 - F(c+2R)]
\end{aligned}$$

The sum of the first two terms is zero. Hence the first order condition $\frac{\partial\tilde{\pi}_L^c}{\partial R} = 0$ rewrites into:

$$-\frac{\int_{\bar{x}}^{\hat{x}(c+2R^c)} x f(x) dx}{1 - F(c+2R^c)} = c + 2R^c + (2-\alpha)\sqrt{I}$$

Observing that

$$\frac{\int_{\bar{x}}^{\hat{x}(c+2R^c)} x f(x) dx}{1 - F(c+2R^c)} = \frac{E(x \mid x \geq \hat{x}(R^c))}{1 - F(\hat{x}(R^c))}$$

we can finally isolate the optimal royalty cap R^c to find equation (10):

$$R^c = \frac{1}{2} \left[\frac{E(x \mid x \geq \hat{x}(R^c))}{1 - F(\hat{x}(R^c))} - c - (2-\alpha)\sqrt{I} \right]$$

Proof of Proposition 3

The expected profits of the licensor admit extrema when the following equation is verified:

$$L(\hat{x}(R^c)) = (2 - \alpha) \sqrt{I} \quad (17)$$

where

$$L(\hat{x}) \equiv \frac{E(x \setminus x \geq \hat{x}(R^c))}{1 - F(\hat{x}(R^c))} - \hat{x} \quad (18)$$

It can be checked easily that $L(\bar{x}) = \bar{x} - \bar{x} = 0$ while $L(\underline{x}) = E(x) - \underline{x} > 0$. Studying the shape of $L(\hat{x})$ is more difficult for the sign of its derivative is not obvious. Indeed we have:

$$L'(\hat{x}) = \frac{f(\hat{x})}{1 - F(\hat{x})} L(\hat{x}) - 1$$

Assume now that $(2 - \alpha) \sqrt{I} \leq L(\underline{x})$. By the continuity of $L(\cdot)$ and given that $L(\bar{x}) = 0 < (2 - \alpha) \sqrt{I}$, there is necessarily at least one $\hat{x} \in [\underline{x}, \bar{x}]$ such that equation (17) is verified.

We can observe that $L(\hat{x}) \leq \bar{x} - \hat{x}$ is always true, such that $L(\hat{x})$ is bounded upwards by the decreasing function $g(\hat{x}) = \bar{x} - \hat{x}$. It follows that equation (17) is never verified if $(2 - \alpha) \sqrt{I} > \bar{x} - \underline{x}$.

The remaining case (where $E(x) - \underline{x} < (2 - \alpha) \sqrt{I} < \bar{x} - \underline{x}$) is ambiguous and depends on the shape of the distribution $f(\cdot)$. If $f(\cdot)$ is such that $L'(\hat{x}) < 0$ for all $\hat{x} \in [\underline{x}, \bar{x}]$, then equation (17) cannot be verified for $(2 - \alpha) \sqrt{I} > E(x) - \underline{x}$ and the licensor prefers a corner solution (see below). If $L(\hat{x})$ is not strictly decreasing, then it cannot be excluded that $\bar{L} \equiv \max_{\hat{x} \in [\underline{x}, \bar{x}]} L(\hat{x}) > E(x) - \underline{x}$. In

this latter case equation (17) is verified iff $(2 - \alpha) \sqrt{I} < \bar{L}$.

It follows from this that we can define a threshold

$$T \equiv \max \{E(x) - \underline{x}, \bar{L}\}$$

such that equation (17) has a solution if $(2 - \alpha) \sqrt{I} \leq T$ and no solution otherwise. Since $L(\hat{x}) \leq \bar{x} - \hat{x}$, $\forall \hat{x} \in [\underline{x}, \bar{x}]$ and (by definition) $\bar{L} \geq E(x) - \underline{x}$, we moreover have $T \in [E(x) - \underline{x}, \bar{x} - \hat{x}]$

If condition (17) is not verified (which corresponds to weak uncertainty and/or large entry costs), the licensor prefers a corner solution to the royalty cap strategy. When the corner and interior solutions are indifferent we have $\hat{x}(R^c) = \underline{x}$, which implies that the licensor never revises the royalty cap downwards. The corner solution therefore corresponds to a pure ex ante royalty, while the pure ex post royalty is entirely ruled out.

Proof of Proposition 4

We consider first the number of manufacturers and then the prices of their products.

The royalty cap replicates the ex post royalty $R^p(x) = (x - c)/2$ when $x < \hat{x}(R^c)$. If $x \geq \hat{x}(R^c)$, the royalty is constant and equal to R^c . Hence the expected number of manufacturers writes:

$$\begin{aligned} E(n^c) &= \int_{\underline{x}}^{\hat{x}(R)} n^p(R^p(x)) f(x) dx + \int_{\hat{x}(R)}^{\bar{x}} n^a(R^c) f(x) dx \\ &= E(n^p) + \frac{2 - \alpha}{2\alpha} [1 - F(\hat{x}(R))] \\ &= E(n^a) - \frac{2 - \alpha}{2\alpha} F(\hat{x}(R)) \end{aligned}$$

We can clearly see that the commitment on a royalty cap increases the expected number of products with respect to the ex post royalty, while it decreases this number when compared with the commitment on a royalty level.

The expected price charged to consumers when the licensor announces a royalty cap is:

$$E(P^c) = \int_{\underline{x}}^{\hat{x}(R)} [c + \sqrt{I} + R^p(x)] f(x) dx + [c + \sqrt{I} + R^c] [1 - F(\hat{x}(R))]$$

Let us firstly compare this expected price with the expected price under ex post royalty. Recall that the expected price under ex post royalty is

$$E(P^p) = \int_{\underline{x}}^{\bar{x}} [c + \sqrt{I} + R^p(x)] f(x) dx$$

Hence we have:

$$E(P^c) - E(P^p) = \int_{\hat{x}(R)}^{\bar{x}} [R^c - R^p(x)] f(x) dx < 0$$

The difference is clearly negative since by definition $R^p(x) > R^c$ for all $x > \hat{x}(R)$. Hence the setting of a royalty cap systematically implies lower expected prices charged to consumers. We turn now to the comparison with the pure ex ante royalty. Recall that the expected price under ex ante royalty is

$$E(P^a) = [c + \sqrt{I} + R^a] \int_{\underline{x}}^{\bar{x}} f(x) dx$$

Hence we have:

$$E(P^c) - E(P^a) = \int_{\underline{x}}^{\hat{x}(R^c)} [R^p(x) - R^a] f(x) dx + [R^c - R^a] [1 - F(\hat{x}(R^c))]$$

we can thus write:

$$\begin{aligned} E(P^c) &> E(P^a) \\ &\Leftrightarrow \\ R^c &> R^a - E(R^p(x) \setminus x < \hat{x}(R^c)) \end{aligned}$$

Using the expression of R^a , R^p and R^c in (6), (4) and (10) we can finally find the following equivalence:

$$E(P^c) > E(P^a) \quad (19)$$

\Leftrightarrow

$$[E(x \setminus x \geq \hat{x}(R^c)) - E(x)] + [E(x \setminus x < \hat{x}(R^c)) - c] > 0 \quad (20)$$

assuming that $\underline{x} > c$, the term on the left hand side is positive. Hence the expected price is higher with the royalty cap than with the pure ex and royalty.

We can see from this equivalence that the expected price is always lower with the price cap than with the ex ante royalty.