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Licensing commitments in standard setting organizations.

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Licensing commitments in standard setting organizations

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Abstract

Because ICT standard frequently incorporate patented inventions, standard setting organizations have designed intellectual property policies whereby the owners of such "standard essential patents" must commit ex ante to license them on fair reasonable and non-discriminatory terms to manufacturers of standard-compliant products. However, these commitments are vague and may not be sufficient to prevent patent hold-up in practice. In this paper, we develop a simple framework to analyze the consequence of ineffective FRAND commitments, and compare them with legally binding commitments on a royalty level or a royalty cap. We show that the cap is systematically preferred by the licensor, while it has ambiguous effects on consumers depending on the licensor's preferred alternative strategy.

1 Introduction

Interoperability standards in ICT are usually complex technology platforms that include a large number of patented inventions. The perspective of owning such standard essential patents (or SEPs) and licensing them on an industry-wide scale plays a key role in companies' incentives to invest in R&D for standard setting purposes (Rysman & Simcoe, 2008). However, the exclusive rights conferred by patents on inventors may contradict the objective to make standards available to all for public use. To address this tension, most standard setting organisations (or SSOs) have defined intellectual property rights (IPR) policies whereby SSO members must commit ex ante to license their SEPs on Fair Reasonable and Non-Discriminatory (FRAND) terms. Legally these commitments are held as binding contracts. However, they remain vague and hardly enforceable in practice, because SSOs define neither what is a FRAND level of royalty, nor how it should be calculated.

In past years, a number of major legal disputes have raised controversy on the meaning of these licensing commitments. Standard implementers especially complain that FRAND commitments are too loose to prevent the risk of hold-up by SEP holders. Indeed, SEPs are usually licensed after implementers have sunk specific investment in the standard (e.g. in R&D and/or manufacturing equipment). SEP holders may therefore be able to abuse a dominant position acquired as a result of the standard setting process to charge higher royalty rates than their inventions would have been worth ex ante, when competing with other alternatives (Lemley & Shapiro, 2007).

This controversy has led some SSOs and licensors to envisage other types of commitments for licensing SEPs. In particular, two important SSOs (VITA and IEEE[1]) have recently revised their IPR policies to allow their members to commit on explicit royalty caps. In 2008, a number of companies also publicly disclosed the maximum royalty rates their were planning to charge for their essential patents on the LTE wireless communication standard [2]. These moves have drawn strong criticism among SEP holders, but also close attention from antitrust authorities (Masoudi, 2007; Lerner & Tirole, 2014). Whether they can effectively enhance the efficiency of SEP licensing thus remains an open issue.

In this paper, we develop a theoretical model of SEP licensing to compare these different types of commitments and their respective effects on SEP holders and consumers. We consider a single R&D firm that licences a SEP to a set of (symmetric) product manufacturers that compete à la Cournot. The model has

[1]VITA is the acronym of the VMEbus International Trade Association, a SSO that promotes architectures based on the VMEbus computer technology. In January 2007, VITA approved a new patent policy that requires, inter alia, its members to disclose the maximum royalty rate they will demand for their potentially essential patents. The commitment is irrevocable, but the patent owners are free to submit subsequent declarations with lower rates. Unlike in VITA's policy, declaring a royalty cap is just an option amongst others possibilities in the recently reformed policy of the standard association of the Institute of Electrical and Electronics Engineers (IEEE).

[2]See E. Stasik "Royalty Rates and Licensing Strategies for Essential Patents on LTE (4G) telecommunication standards" Les Nouvelles, September 2010, pp115-116.

three stages: first, the SEP holder may commit on its future licensing terms; second, manufacturers enter the product market, and finally, the SEP owner sets the actual royalty level charged to manufacturers. In order to account for the uncertainty faced by the licensor when making ex ante commitments, we posit that the level of demand is a random parameter for the SEP holder until manufacturers enter the market for standard compliant products. Manufacturers know the exact value of this parameter, and make their entry decision accordingly.

This simple framework makes it possible to analyze hold-up as a general coordination failure stemming from ex post royalty setting. We show that in the absence of a binding ex ante commitment[3], the patent holder tends to charge a high royalty ex post. This royalty results from a simple trade-off between the level of the per unit royalty and the number of products sold by each manufacturer. However, it does not internalize the deterring effect of a high ex post royalty on the entry of manufacturers at the previous stage. By contrast, we show that a legally binding commitment on a precise FRAND royalty level induces more entry on expectation, and can actually generate more expected profits for the SEP holder when the entry cost of manufacturers is high and/or the variance of the demand parameter is low.

We consider as a second step a binding commitment on a royalty cap as an alternative policy option. We show that, for the SEP holders, such a commitment always dominates a non-binding FRAND commitment, and it weakly dominates a binding FRAND commitment. However, its effect on consumers is not always positive. Indeed the binding cap induces lower expected prices when the licensor's best alternative is a broken FRAND royalty strategy, but it can trigger higher prices when the best alternative is a binding FRAND.

The paper is related to a large strand of literature on the licensing of standard essential patents. While a large part of this literature focuses on the double-marginalization and patent pooling as consequences of the fragmentation of SEP ownership (Shapiro, 2001; Lerner & Tirole, 2004; Lerner et al., 2007; Ménière & Parlane, 2010), there are fewer theoretical papers that address the timing of SEP licensing and the resulting hold-up problem. Llanes and Poblete (2014) consider the articulation of patent pool formation and standard setting. In another paper (Lévêque & Ménière, 2011), we study the problem of early stage patent pool formation as a means to foster entry in the product market when manufacturers are exposed to hold-up. In a recent paper, Lerner and Tirole (2014) develop a general model of standard setting and SEP licensing, and conclude that ex ante commitments should be implemented as a single policy to prevent hold-up and royalty stacking. However, although their framework is richer than ours in various respect, it accounts neither for the entry cost in the product market that underpins hold-up in our model, nor for the uncertainy

[3] In practice, there may be cases where ex ante commitment are only partially binding. Although this possibility would be interesting to analyze, we simply focus on fully binding versus non-binding commitments in this article. We can yet expect that our results for non-binding commitments would still be present in a milder form if ex ante commitments were only partially binding.

on demand that SEP holders face during the standard setting process. In this respect, our model provides original and complementary results that lead to similar policy conclusions. We show in particular that implementing a royalty cap licensing policy is always benefical to SEP owners, but may come at a cost for consumers in comparison with a binding FRAND commitment.

The remainder of this article is organized in three sections. We present our theoretical framework in section 2, and use it to compare legally binding versus non-binding FRAND commitments on a royalty level. We study the case of an ex ante commitment on a royalty cap in section 3, and compare it with the binding and non-binding FRAND commitments. Section 4 concludes.

2 A simple model for FRAND licensing

Our model is based on a simple setting, wherein a patent owner licenses an essential patent to a set of manufacturers who produce and sell a standard-compliant product. Considering a single patent owner is sufficient here because the problem of holdup can arise whatever the number of patent holders and patents. This simplification also presents the advantage of leaving aside the multi-marginalization problem.

We consider that n symmetric manufacturers compete in the market for standard-compliant goods. Assuming that their products are perfect substitutes, the inverse demand function is

$$P = x - \sum_{i=1}^{n} q_i$$

where P and x denote respectively the market price and the valuation of the product by the consumers. The parameter q_i reflects the production of manufacturer $i = 1, ...n$, and $\sum_{i=1}^{n} q_i$ thus reflects the total production of all manufacturers.

We assume that the demand intercept x is known by the manufacturers when they enter the market, but not by the patent owner. More precisely, x is a random parameter for the patent owner, with distribution $F(x)$ on $[\underline{x}, \overline{x}]$ [4]. This assumption reflects the uncertainty surrounding the future success of the standard that is being developed, especially if it is competing with alternative standards (Besen & Farrell, 1994). The entry of manufacturers reveals the actual value of x to the patent owner, who can then better adjust the level of royalty.

Without loss of generality, we assume the unit production costs of manufacturers is zero. Manufacturers pay the per unit royalty R for using the technology standard. Given that $n-1$ other firms compete on the downstream market, manufacturer i chooses its production q_i so as to maximize its profit::

[4] We assume that F has the standard monotone hazard rate property: $f/[1-F]$ is increasing.

$$q_i\left[P-R\right]=q_i\left[x-q_i-\sum_{j\neq i}q_j-R\right]$$

Since all manufacturers behave the same way, each of them has the same individual production q and profit π_M at equilibrium. This profit can be expressed as follows:

$$\pi_M=\left[\frac{x-R}{n+1}\right]^2 \tag{1}$$

As expected, it increases with the demand parameter x, and decreases with the royalty cost R and the number of competitors n.

There is a fixed cost I of entry into the downstream market. This corresponds to the cost of implementing the standard, and determines the number of competitors that can be simultaneously in the market. More precisely, the free entry equilibrium is defined by $\pi_M=I$. Using this condition and equation (1), we can derive the total production Q and the price P of goods in the downstream market:

$$Q=nq=x-R-\sqrt{I} \tag{2}$$

$$P=\sqrt{I}+R \tag{3}$$

Proof. See Appendix . ■

We can see from (3) that the price charged to consumers reflects the entry cost I, plus the per unit royalty R. Hence the total production in (2) is decreasing in both I and R. In the sequel, we will assume that $I<\underline{x}^2$ so that at least one manufacturer can enter the market if $R=0$.

In the next sections, we study successively two different scenarios of royalty setting. The first one features an effective FRAND commitment: The licensor announces in advance the royalty that it will charge to manufacturers upon their market entry; his commitment is legally binding and manufacturers know precisely what level of royalty to expect. In the second scenario, the FRAND commitment is not credible and has therefore no effect on the manufacturers' entry decision. This scenario is equivalent to a situation where the patent owner does not make any announcement on the future royalty he will charge. Note moreover that we assume in all the paper that the non-discrimination requirement of FRAND is satisified for all the licensing strategies that we consider.

2.1 Effective FRAND

As said above, we assume that the level of demand x is a random parameter for the patent owner (with distribution $F(x)$ on $[\underline{x},\overline{x}]$) whereas the manufacturers are not subject to this uncertainty. The timing of the game is therefore:

1. The licensor announces the reasonable royalty R^a it will charge to downstream manufacturers. It does not know the exact level of demand at this moment.

2. Manufacturers enter the market taking into account the exact level of demand and the announced reasonable royalty.

Since entry takes place at the second stage, the manufacturers can anticipate the effect of the reasonable royalty and make their entry and production decisions accordingly. The total production is thus a function of R as given by (2), and the licensor solves

$$\max_R \widetilde{\pi}_L^a(R) \equiv R \int_{\underline{x}}^{\overline{x}} Q(R) f(x)\,dx$$

$$\text{where} \quad Q(R) = x - R - \sqrt{I}$$

The optimal royalty resulting from this program is

$$R^a = \frac{E(x) - \sqrt{I}}{2} \tag{4}$$

The reasonable royalty announced by the licensor depends on the expected level of demand $E(x)$, minus a term reflecting the entry cost I of manufacturers. If entry costs are high, the patent owner would rather commit on a lower royalty in order to benefit of a larger number of entrants, and hence a higher level of production and sales. With free entry, the market price of standard compliant products is $P^a = R^a + \sqrt{I}$. The actual level of demand x does not affect this price, but given R^a, it determines the actual number n^a of manufacturers who can enter the market:

$$n^a = \frac{x + [x - E(x)] - \sqrt{I}}{2\sqrt{I}} \tag{5}$$

Consequently, it determines the total production of standard compliant goods $Q^a = \sqrt{I}n^a$. From equation (5) we can see that the number of manufacturers in the market depends not only on the actual, but also on the discrepancy between the actual and expected levels of demand. There is more entry if expected demand happens to be lower than the actual one, for then the licensor charges a lower royalty than what it would have done with full information.

2.2 Broken FRAND

Let us study now the scenario wherein the patent owner sets his royalty after manufacturers entered into the market for standard-compliant products. This scenario is interpreted as what happens when the FRAND promise is not credible. The timing of the game is now the following:

1. Manufacturers observe the actual level of demand and enter the market.
2. The licensor observes the actual level of demand and number of manufacturers, and sets a 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:

$$\begin{aligned} \max_R \pi_L^p(R) &\equiv nRq(R,n) \\ &\text{where} \\ q(R,n) &= \frac{x-R}{n+1} \end{aligned}$$

The optimal royalty resulting from this program is

$$R^p(x) = \frac{x}{2} \tag{6}$$

This ex post royalty does not depend anymore on the expected level of demand $E(x)$, but on the actual level x. Moreover, the licensor does not take into account the entry cost of manufacturers, as was the case in (4). Manufacturers are rational and can therefore anticipate this level of royalty when they enter the market. Given a demand level x and the corresponding royalty $R^p(x)$, there is room for n^p manufacturers on the market, where

$$n^p = \frac{x - 2\sqrt{I}}{2\sqrt{I}},$$

and the product price charged to consumers at free entry equilibrium is $P^p = R^p + \sqrt{I}$. Note that we have $P^p > P^a$ (and $n^p < n^a$) if the following condition is verified:

$$R^p > R^a \Leftrightarrow \sqrt{I} > E(x) - x \tag{7}$$

Assuming that the actual level of demand meets the expectation (e.g., $x = E(x)$), it is clear that the broken FRAND scenario would entail a higher royalty than in the case of the effective the FRAND scenario: $R^p > R^a$. The reason is that by setting the royalty ex post, the patent owner neglects the fact that a higher royalty would deter the entry of manufacturers. In fact, $R^p < R^a$ is possible only in the particular case where the actual level of demand x happens to be much lower than expected (so that the FRAND royalty was overshot) while the entry cost I is relative low (so that entry is not substantially affected by the royalty level). This result can be generalized. Considering both scenarios from an ex ante standpoint (e.g., while the level of demand is still uncertain), we can show easily that $E(R^p) > R^a$ always holds, such that in turn $E(P^p) > P^a$ and $E(n^p) < E(n^a)$. In other terms, a broken FRAND scenario entails on average a higher royalty, and thus less entry and higher prices charged to consumers for standard-compliant products.

Proposition 1 *On average, effective FRAND dominates broken FRAND in terms of consumer welfare.*

2.3 Effective FRAND can be beneficial to the patent owner

Let us consider now the patent owner's profits in the broken and effective FRAND scenarios. We consider first the licensing profits for a given value of x, before comparing the expected profits from an ex ante standpoint, that is, when the value of x is still uncertain. Computing the licensing profit of the patent owner for a given x yields the following results, respectively in the effective and broken FRAND scenarios:

$$\begin{aligned} \pi_L^a\left(R^a, x\right) &= \frac{1}{4}\left[E\left(x\right)-\sqrt{I}\right]\left[2x-E\left(x\right)-\sqrt{I}\right] \\ \pi_L^p\left(x\right) &= \frac{x}{4}\left[x-2\sqrt{I}\right] \end{aligned}$$

It can be shown easily that $\pi_L^a > \pi_L^p$ if:

$$I > \left[x-E\left(x\right)\right]^2 \tag{8}$$

Hence the effective FRAND scenario entails higher ex post profits if, given the entry cost I, the actual level of demand x is not too far from its expected level $E\left(x\right)$. In other words, the effective FRAND scenario generates larger profits provided the ex ante commitment does not induce an excessive over–or undershooting of the royalty R^a. Note, moreover, that $\pi_L^a > \pi_L^p$ holds only if the loss associated with a wrong anticipation of x exceeds a threshold depending on the entry cost I. The dominance of the FRAND scenario is thus all the more likely as entry is costly–and thus sensitive to the royalty level. Note also that depending on whether $x > E\left(x\right)$ or $x < E\left(x\right)$, a wrong anticipation by the licensor will either benefit or be detrimental to consumers.

We now turn to the second step in comparing profits. Denoting, respectively, $\widetilde{\pi}_L^a$ and $\widetilde{\pi}_L^p$, the expected profits of the licensor in the effective and broken FRAND scenarios, where:

$$\widetilde{\pi}_L^\gamma = \int_{\underline{x}}^{\overline{x}} \pi_L^\gamma\left(x\right) f\left(x\right) dx \qquad ,\gamma = a, p \tag{9}$$

Again, it is difficult to interpret these expressions directly. Yet comparing them quickly shows that $\widetilde{\pi}_L^a\left(R^a\right) > \widetilde{\pi}_L^p$ if

$$I > Var\left(x\right)$$

We can thus derive the following Proposition, which generalizes the comparison of profits. It shows that when the cost of entry is high the effective FRAND scenario is the most profitable situation for the licensor, for providing manufacturers with a guarantee on royalties then ensures a maximal entry into the product market. The downside is, however, the risk taken by the licensor in anticipating the level of demand. The licensor would always benefit from the effective FRAND scenario if the demand were not uncertain (e.g., $Var(x) = 0$). By contrast, uncertain demand generates a risk of overshooting or undershooting when committing on a royalty, thereby inducing a loss (by stiffling entry with a too high royalty in the first case, or missing easy profits by charging a too low royalty in the second case) for the licensor.

Proposition 2 *The licensor benefits from an effective FRAND scenario if the cost of entry is high and/or the uncertainty on demand is low.*

It is important to notive that the licensor's incentive to opt for a binding FRAND commitment rather than ex post royalty setting crucially hinges on the assuption of free entry with a positive entry cost. On one hand, Proposition 2 clearly establishes than the licensor would not opt for a binding FRAND commitment if entry cost are low (and in the extreme case if they are nil), since in that case there is little (or no) entry deterrence effect of hold-up. On the other hand, the FRAND commitment would also be useless for the licensor if the downstream industry were a closed group of identified incumbent manufacturers, with no possibility of entry by new competitors. Indeed, there would again be no incentive for the licensor to use a commitment to foster entry in that case.

3 Testing new SSOs IP policies

In this section we assume that the patent owner's FRAND commitment is not binding and thus not credible for manufacturers. As demonstrated in the previous section, this situation can be detrimental to the patent owner, who may therefore have an interest in designing new IP policies. We therefore analyze as a first step the effect of a royaly cap policy adopted by the two SSOs VITA and IEEE. We then study as a second step the patent owner's incentive to choose between different strategies, namely giving no assurance, announcing the exact royalty, or announcing a royalty cap.

3.1 A new policy option: royalty cap

In the case of a royalty cap, the patent owner can adjust his royalty after the entry of manufacturers, in function of the actual value of the market, x. His commitment simply requires that the ex post royalties be not fixed above the ex ante announced cap, but the owner remains free to fix any royalty below the cap if appropriate. Transposed in our analytical setting, the timing of this new policy is the following:

1. The licensor credibly commits on a royalty cap R^c while demand for the standard is still uncertain.

2. Manufacturers observe the actual level of demand and, given the announced cap, enter the market.

3. Given the actual level of demand and number of manufacturers, the licensor sets a royalty equal to, or lower than, the announced cap.

As in the previous section, we solve this game backwards. Observe first that in absence of commitment the licensor would set an ex post royalty R^p in function of the observed demand x, as in the no-assurance strategy. Given the cap R^c announced at stage 1, the licensor would thus rather revise the royalty downwards if the ex post royalty $R^p < R^c$. If $R^p > R^c$, the licensor would rather charge an ex post royalty above the cap, but he cannot because he is bound by his commitment. Recall also that the ex post royalty cap is increasing in the observed level of demand x. Hence we can expect the licensor to price below the cap if x happens to be lower than expected, and to be bound by the cap otherwise.

Let $\widehat{x}\left(R^c\right)$ denote the demand level at which the licensor is indifferent between revising the royalty or not. This demand level is defined by $R^p\left(\widehat{x}\right) = R^c$, that is:

$$\frac{\widehat{x}}{2} = R^c \;\Leftrightarrow\; \widehat{x}\left(R^c\right) = 2R^c \tag{10}$$

For any $x < \widehat{x}\left(R^c\right)$, the licensor will revise the royalty, while he will stick to R^c when $x \geq \widehat{x}\left(R^c\right)$. Observe that setting $R^c \leq \underline{x}/2$ (such that $\widehat{x}\left(R^c\right) = \underline{x}$) amounts to a pure ex ante commitment (no ex post revision). Conversely, setting $R^c \geq \overline{x}/2$ (such that $\widehat{x}\left(R^c\right) = \overline{x}$) is equivalent to a broken FRAND policy where royalties are always defined ex post. The licensor's expected profit at stage 1 can thus be expressed as follows:

$$\widetilde{\pi}_L^c\left(R^c\right) = \begin{cases} \widetilde{\pi}_L^p & \text{if } R^c \in \left[0, \frac{\underline{x}}{2}\right] \\ \int\limits_{\underline{x}}^{2R^c} \pi_L^p\left(R^p\left(x\right)\right) f\left(x\right) dx + \int\limits_{2R^c}^{\overline{x}} \pi_L^a\left(R^c\right) f\left(x\right) dx & \text{if } R^c \in \left(\frac{\underline{x}}{2}, \frac{\overline{x}}{2}\right) \\ \widetilde{\pi}_L^a\left(R^c\right) & \text{if } R^c \in \left[\frac{\overline{x}}{2}, \overline{x}\right] \end{cases} \tag{11}$$

When $R^c \in \left(\frac{\underline{x}}{2}, \frac{\overline{x}}{2}\right)$, the royalty cap R^c is effective and commands the manufacturers' entry decision at stage 2. If manufacturers observe that $x > \widehat{x}\left(R^c\right)$, they anticipate a royalty R^c and make their entry decision accordingly. The cap thus works as an ex ante commitment on a precise royalty R^c. If, on the other hand, $x < \widehat{x}\left(R^c\right)$, manufacturers anticipate that the royalty will be fixed ex post, similar to a no assurance strategy, and make their entry decision accordingly.

Maximizing the licensor's program with respect to R^c yields the following results:

Lemma 3 *The licensor's decision in the royalty cap strategy is the following:*

- *If $\sqrt{I} < E(x) - \underline{x}$, the licensor sets a royalty cap R^c which preserves the option to adjust royalties ex post for some value of x. The cap is defined by $R^{c*} = \left[E(x \mid x \geq 2R^{c*}) - \sqrt{I}\right]/2$ and it is decreasing with the entry cost I from $R^{c*} = \overline{x}/2$ for $\sqrt{I} = E(x) - \underline{x}$ to $R^{c*} = \underline{x}/2$ for $I = 0$*
- *If $\sqrt{I} \geq E(x) - \underline{x}$, the licensor replicates the FRAND policy by setting a cap $R^{c*} = R^a$ and never revising the royalty ex post. The royalty cap is then decreasing with the entry cost I.*

Proof. See Appendix. ■

The licensor will use the cap as a flexibility to combine the advantages of ex ante commitment and ex post royalty adjustment when the entry cost I is not too large. He will then set a constraining ap for any positive I, and reduce this cap as the I increases in order to promote entry in the downstream market. However, beyond a threshold $I = [E(x) - \underline{x}]^2$ of the entry cost, the cap becomes too low to enable any ex post adjustment of royalties. It is then perfectly equivalent to a binding FRAND commitment.

Note finally that the licensor can always replicate a broken FRAND policy by setting a large cap $R^c \geq \overline{x}/2$. By revealed preference, we can thus conclude that the cap strategy is more profitable for the licensor than a broken FRAND strategy whenever $I > 0$. By contrast, the licensor's ability to replicate an effective FRAND policy is limited to small royalty levels $R^c \in \left[0, \frac{\underline{x}}{2}\right]$, due to the possibility to adjust royalties ex post when $R^c \geq \underline{x}/2$.

3.2 Commitment on a royalty cap versus FRAND commitment

We can now compare the effect of the FRAND and cap strategies from the standpoint of the licensor and of total welfare. Let us take first the perspective of the licensor. We already established that he always prefers the cap strategy to the broken FRAND, while he prefers FRAND to broken FRAND if $I > Var(x)$. A first direct implication is thus that the licensors will opt for a royalty cap rather than broken FRAND whenever the latter dominates FRAND, that is, when $I < Var(x)$. When $I \geq Var(x)$, we have shown that the FRAND and royalty cap strategies are equivalent for a large enough entry cost $I \geq [E(x) - \underline{x}]^2$. However, we still need to compare the profitability of these two strategies when the licensor can use the cap as a real flexibility mechanism, that is when $Var(x) \leq I < [E(x) - \underline{x}]$.

Proposition 4 *The licensor will always opt for a royalty cap rather than FRAND or broken FRAND, and it will use it as a FRAND commitment when $I \geq [E(x) - \underline{x}]^2$.*

Proof. See Appendix. ■

This results implies that the potential ex post adjustment of royalties under a royalty cap system never prevents the licensor from the potential benefit of a fully binding commitment on a precise FRAND royalty level. In other words, the benefit of adjusting royalties ex post always offsets the costs in terms of entry deterrence when the cap strategy does not make it possible to replicate a FRAND commitment. This in turn implies that a single cap policy is sufficient for an SSO, as it yields teh same outcome as an optional choice between the cap, FRAND commitment and broken FRAND strategies.

It remains however to be checked whether the licensor's incentives are aligned with public interest, which we do in Proposition 5 below by comparing expected product prices under the three royalty strategies.

Proposition 5 *In expectation, the royalties and product prices are higher under broken FRAND than under royalty cap, and weakly higher under royalty cap than under FRAND. The effect of the cap is thus beneficial to consumers when it replaces a broken FRAND strategy, neutral if it replicates a FRAND strategy ($I \geq [E(x) - \underline{x}]$), and detrimental for them if it replaces a FRAND strategy ($Var(x) \leq I < [E(x) - \underline{x}]$).*

Proposition 5 first establishes that the royalty cap induces lower expected product prices than the broken FRAND strategy, which is not surprising since the royalty cap precisely aim at capping the level of ex port royalties for high levels of demand. The Proposition also shows that the licensor's preference for the cap rather than FRAND comes at a cost for consumers, since expected prices are always higher with the cap. One should however note that introducing a cap would benefit consumers whenever the licensor would prefer broken FRAND to FRAND; be neutral when the cap is equivalent to FRAND; and harm them only in the intermediate case (defined by $Var(x) \leq I < [E(x) - \underline{x}]$) where the licensor would opt for a flexible cap rather than a pure FRAND commitment.

4 Conclusion

In this paper, we first highlighted the negative impact of loose FRAND commitments on licensors and consumers, and then discussed the advantages of requiring more precise commitments. In addition to a contractually binding ex ante commitment on the exact royalty, we analyzed and compared the effects of two new IP policies currently experimented in some SSO: a commitment on a royalty cap, and allowing patent owners to choose between a cap and an exact royalty.

Our simple licensing model shows that licensing commitments made before the entry of manufacturers induce lower prices for standard compliant products. Therefore, it may be even in the interest of the licensor to induce more entry by committing on charging low royalties to manufacturers. Making such ex ante commitments is yet risky, for licensors have to commit on a royalty while the commercial success of the standard is still uncertain. Eventually, whether patent owners are willing to commit thus depends on the balance between uncertainty and entry promotion.

Building on these premises, we have explored the interest of requiring contractually binding commitments from patent owners. Our analysis implies that restoring the FRAND regime would actually be welcomed by patent owners only if manufacturers incur high entry costs, while ex ante uncertainty on the standard's commercial success is mild. The possibility to commit on a royalty cap is a more attractive option: it guarantees manufacturers against prohibitive ex post royalties, while preserving the option for the licensor to adjust royalty downwards when the commercial success of the standard is lower than expected. Compared with a FRAND or no-assurance policy, a royalty cap policy is thus systematically beneficial to licensors. This comes however at a cost for consumers when the second best option of the licensor would be to commit on a binding FRAND royalty.

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Appendix

Proof of Lemma 3

Recall that the expected profit of the licensor writes:

$$\widetilde{\pi}_L^c(R^c) = \begin{cases} \widetilde{\pi}_L^p & \text{if } R^c \in \left[0, \frac{\underline{x}}{2}\right] \\ \int\limits_{\underline{x}}^{2R^c} \pi_L^p(R^p(x)) f(x)\, dx + \int\limits_{2R^c}^{\overline{x}} \pi_L^a(R^c) f(x)\, dx & \text{if } R^c \in \left(\frac{\underline{x}}{2}, \frac{\overline{x}}{2}\right) \\ \widetilde{\pi}_L^a(R^c) & \text{if } R^c \in \left[\frac{\overline{x}}{2}, \overline{x}\right] \end{cases}$$

We consider in turn the sign of $\frac{\partial \widetilde{\pi}_L^c}{\partial R^c}$ for the three ranges of R^c.

Step 1: $R^c \in \left[0, \frac{\underline{x}}{2}\right]$ In that case it comes easily that $\partial \widetilde{\pi}_L^c / \partial R^c = E(x) - \sqrt{I} - 2R^c > 0$ for $R^c < \left[E(x) - \sqrt{I}\right]/2$.

Hence we have $\partial \widetilde{\pi}_L^c / \partial R^c > 0$ for any $R^c \in \left[0, \frac{\underline{x}}{2}\right]$ if $\underline{x}/2 \leq \left[E(x) - \sqrt{I}\right]/2 \Leftrightarrow \sqrt{I} \leq E(x) - \underline{x}$. As a result, $\widetilde{\pi}_L^c(R^c)$ has a unique corner solution $R^c = \underline{x}/2$ on $\left[0, \frac{\underline{x}}{2}\right]$ when $\sqrt{I} \leq E(x) - \underline{x}$.

Observe now $\partial \widetilde{\pi}_L^c / \partial R^c < 0$ for $R^c = \underline{x}/2$ if $\sqrt{I} > E(x) - \underline{x}$. Moreover, we always have $\partial \widetilde{\pi}_L^c / \partial R^c = E(x) - \sqrt{I} > 0$ for $R^c = 0$. Hence $\widetilde{\pi}_L^c(R^c)$ admits a unique interior solution on $\left[0, \frac{\underline{x}}{2}\right]$ when $\sqrt{I} > E(x) - \underline{x}$. This solution corresponds to the optimal ex ante royalty R^a that is set in a FRAND scenario when $\sqrt{I} > E(x) - \underline{x}$.

Step 2: $R^c \in \left[\frac{\overline{x}}{2}, \overline{x}\right]$ It is obvious that $\partial \widetilde{\pi}_L^c / \partial R^c = 0$ for this range of R^c, since any cap $R^c \in \left[\frac{\overline{x}}{2}, \overline{x}\right]$ corresponds to a broken FRAND policy.

Step 3: $R^c \in \left(\frac{\underline{x}}{2}, \frac{\overline{x}}{2}\right)$ In that case, it is useful to note $\widetilde{\pi}_L^c(R) = \Phi + \Psi$ where

$$\begin{cases} \Phi = \int\limits_{\underline{x}}^{2R} \pi_L^p(R^p(x)) f(x)\, dx \\ \Psi = \int\limits_{2R}^{\overline{x}} \pi_L^a(R) f(x)\, dx \end{cases}$$

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:

$$\Phi = \int_{\underline{x}}^{2R} \frac{x}{4} \left[x - 2\sqrt{I} \right] f(x)\, dx$$

Derivating with respect to R and rearranging, we obtain

$$\frac{d\Phi}{dR} = 2R \left[R - \sqrt{I} \right] f(2R) \tag{12}$$

Consider now Ψ. Its full expression is:

$$\begin{aligned} \Psi &= R \int_{2R}^{\overline{x}} \left(x - R - \sqrt{I} \right) f(x)\, dx \\ &= R \int_{2R}^{\overline{x}} x f(x)\, dx - R \left[R + \sqrt{I} \right] [1 - F(2R)] \end{aligned}$$

Derivating with respect to R and rearranging, we obtain:

$$\begin{aligned} \frac{d\Psi}{dR} &= \int_{2R}^{\overline{x}} x f(x)\, dx - 4R^2 f(2R) - \left[2R + \sqrt{I} \right] [1 - F(2R)] + 2R \left[R + \sqrt{I} \right] f(2R) \\ &= 2R \left[\sqrt{I} - R \right] f(2R) + [1 - F(2R)] \left[E(x \mid x \geq 2R) - \left(2R + \sqrt{I} \right) \right] \\ &= -\frac{d\Phi}{dR} + [1 - F(2R)] \left[E(x \mid x \geq 2R) - \left(2R + \sqrt{I} \right) \right] \end{aligned}$$

Summing (12) and (**??**),and noting that the terms in $f(2R)$ cancel; we obtain:

$$\begin{aligned} \frac{\partial \widetilde{\pi}_L^c}{\partial R} &= [1 - F(2R)] \left[E(x \mid x \geq 2R) - 2R - \sqrt{I} \right] \\ &= [1 - F(\widehat{x})] \left[E(x \mid x \geq \widehat{x}) - \widehat{x} - \sqrt{I} \right] \end{aligned} \tag{13}$$

Since $F(\widehat{x}(R)) \leq 1$, the sign of $\partial \widetilde{\pi}_L^c / \partial R$ depends on the second term in brackets. Let

$$L(y) \equiv E(x \mid x \geq y) - y, \qquad y \in [\underline{x}, \overline{x}] \tag{14}$$

It can be checked easily that $L(\overline{x}) = \overline{x} - \overline{x} = 0$ while $L(\underline{x}) = E(x) - \underline{x} > 0$. Assuming that F has the standard monotone hazard rate property, e.g., $f / [1 - F]$ is increasing, in turn implies that $E(x \mid x \geq y)$ grows with y at a rate lower than 1. It follows that $L(y)$ is strictly decreasing in y:

$$L'(y) = \frac{f(y)}{1-F(y)} L(y) - 1 < 0$$

Since $L(y)$ is strictly decreasing in y from $L(\underline{x}) = E(x) - \underline{x}$ to $L(\overline{x}) = \overline{x} - \overline{x} = 0$, it follows that the terms in arrows in (**??**) is decreasing in $\widehat{x}$. Given that

$$E(x \mid x \geq \overline{x}) - \overline{x} - \sqrt{I} = -\sqrt{I} < 0$$

there are two possibilities depending on $E(x) - \underline{x}$.

Case 1: $\sqrt{I} \leq E(x) - \underline{x}$ If $E(x) - \underline{x} - \sqrt{I} \geq 0$, then equation (14) has an interior solution $R^c \in (\underline{x}/2, \overline{x}/2)$:

$$R^c = \frac{1}{2}\left[E(x \mid x \geq \widehat{x}(R^c)) - \sqrt{I}\right] \tag{15}$$

Obviously, the cap $R^c = \widehat{x}/2$ is lower the higher the entry cost I. When $I = 0$, the highest royalty cap is $R^c = \overline{x}/2$, which is equivalent to ex post royalty setting. The lowest royalty cap $R^c = \underline{x}/2$ is in turn obtained for $\sqrt{I} = E(x) - \underline{x}$. Observe that in this case, there is no ex post revision and that the cap can also be expressed as:

$$R^c|_{E(x)-\underline{x}=\sqrt{I}} = \frac{\underline{x}}{2} = \frac{E(x) - \sqrt{I}}{2} = R^a$$

Hence for $E(x) - \underline{x} = \sqrt{I}$ the cap is exactly equivalent to an ex ante FRAND commitment.

Recall finally that when $\sqrt{I} \leq E(x) - \underline{x}$, we have $\partial \widetilde{\pi}_L^c / \partial R^c = 0$ for $R^c \in \left[\frac{\overline{x}}{2}, \overline{x}\right]$ and $\partial \widetilde{\pi}_L^c / \partial R^c > 0$ for $R^c \in \left[0, \frac{\underline{x}}{2}\right]$. Hence, when $\sqrt{I} \leq E(x) - \underline{x}$, there is a unique profit-maximizing royalty cap $R^{c*} \in \left[\frac{\underline{x}}{2}, \frac{\overline{x}}{2}\right]$ which is implicetly defined by (13).

Case 2: $\sqrt{I} > E(x) - \underline{x}$ If $E(x) - \underline{x} - \sqrt{I} < 0$**,** then $E(x \mid x \geq 2R) - 2R - \sqrt{I}$ is finite and strictly negative for all $R^c \in [\underline{x}/2, \overline{x}/2]$. Hence $\frac{\partial \widetilde{\pi}_L^c}{\partial R} < 0$ and $\frac{\partial \widetilde{\pi}_L^c}{\partial R} \underset{R^c \to \overline{x}/2}{\rightarrow} 0$.

Recall also that when $\sqrt{I} > E(x) - \underline{x}$, we have $\partial \widetilde{\pi}_L^c / \partial R^c = 0$ for $R^c \in \left[\frac{\overline{x}}{2}, \overline{x}\right]$, while $\widetilde{\pi}_L^c$ admits an optimal cap $R^{c*} = R^a \in \left[0, \frac{\overline{x}}{2}\right]$ such that $\partial \widetilde{\pi}_L^c / \partial R^c (R^{c*}) = 0$. Hence $R^{c*} = R^a \in \left[0, \frac{\overline{x}}{2}\right]$ is the optimal solution for the licensor when $\sqrt{I} > E(x) - \underline{x}$.

Proof of Propositon 4

We focus here on the case where $I - Var(x) > 0$, so that FRAND dominates broken FRAND for the liecnsor.

Note that for $\sqrt{I} \leq E(x) - \underline{x}$, we can express $\widetilde{\pi}_L^c(R^{c*})$ as

$$\widetilde{\pi}_L^c(R^{c*}) = \widetilde{\pi}_L^p + \Pi(\widehat{x}(R^{c*}))$$

where

$$\Pi(\widehat{x}(R^{c*})) = \frac{1 - F(\widehat{x}(R^{c*}))}{4}\left[I - Var(x \mid x \geq \widehat{x}(R^{c*}))\right]$$

It follows that

$$\widetilde{\pi}_L^a(R^c) - \widetilde{\pi}_L^c(R^{c*}) = \widetilde{\pi}_L^a(R^c) - \widetilde{\pi}_L^p - \Pi(R^{c*})$$

so that $\widetilde{\pi}_L^a(R^c) > \widetilde{\pi}_L^c(R^{c*})$ if

$$\widetilde{\pi}_L^a(R^c) - \widetilde{\pi}_L^p > \Pi(R^{c*})$$

or after developing the left hand side,

$$\frac{I - Var(x)}{4} > \Pi(\widehat{x}(R^{c*})) \tag{16}$$

Observe now that $\Pi(\underline{x}) = [I - Var(x)]/4 > 0$ and $\Pi(\overline{x}) = 0$.

Moreover, we have $\partial\Pi(\widehat{x}(R^c))/\partial R^c = \partial\widetilde{\pi}_L^c(R^c)/\partial R^c$. Hence (since $\sqrt{I} \leq E(x) - \underline{x}$), $\Pi(\widehat{x}(R^c))$ admits a maximum R^{c*} on $\left(\frac{\underline{x}}{2}, \frac{\overline{x}}{2}\right)$.

It follows that

$$\Pi(\widehat{x}(R^{c*})) > \Pi(\underline{x}) = \frac{I - Var(x)}{4}$$

Hence we always have $\widetilde{\pi}_L^a(R^c) < \widetilde{\pi}_L^c(R^{c*})$.

Proof of Propositon 5

It is obvious that expected prices and royalties are lower under the cap than under broken FRAND. We thus compare the expected prices of standard-compliant products under the cap and FRAND commitment. Since in any

case we have $p = \sqrt{I} + R$, it is sufficient to compare the expected royalty levels under each strategy.

$$
\begin{aligned}
E\left(R^{c*}\right)-E\left(R^{a}\right) &= \int\limits_{\underline{x}}^{\widehat{x}} R^{p}\left(x\right) f\left(x\right) dx+\int\limits_{\widehat{x}}^{\overline{x}} R^{c*} f\left(x\right)-R^{a} \\
&= \frac{1}{2}\left\{F\left(\widehat{x}\right) E(x \mid x<\widehat{x}(R^{c*}))+\left[1-F\left(\widehat{x}\right)\right]\left[E(x \mid x>\widehat{x}(R^{c*}))-\sqrt{I}\right]-\left[E(x)-\sqrt{I}\right]\right\} \\
&= \frac{F\left(\widehat{x}\right)\sqrt{I}}{2}>0
\end{aligned}
$$