Moving Beyond Simple Examples: Assessing the Incremental Value Rule within Standards*

Anne Layne-Farrar  
*Compass Lexecon*

Gerard Llobet  
*CEMFI*

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Abstract

This paper presents a model of patent licensing in a standard setting context when patented technologies must be evaluated on multiple dimensions of value or quality. The model allows us to assess a policy proposal put forth in the literature: that an incremental value pricing rule should define Fair, Reasonable, and Non-Discriminatory (FRAND) patent licensing within standard setting organizations. We find that when patented technologies must be weighed on numerous factors, and not simply one-dimensional cost-savings, there is unlikely to be a single incremental value that can be agreed upon by all relevant parties. As a result, an incremental value pricing rule does not offer a precise benchmark for FRAND, although it can inform individual ex post assessments of standard essential patent licensing.

JEL codes: L15, L24, O31, O34.


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1 Introduction

Standard Setting Organizations (SSOs) are crucial in industries where products sold by different firms have come to rely on standards. Their role is to coordinate the activities of a large variety of firms so that interoperable products can be marketed. From pure technology providers to final good producers to integrated players, firms that participate in an SSO have very different interests. Thus, one of the roles of SSOs is to determine standards that firms can implement and the underlying technologies that might support them. At the time the standard is drafted, firms that own the selected technologies typically commit to license them to potential users under Fair, Reasonable, and Non-Discriminatory (FRAND) terms.

Recent competition policy cases have brought attention to these licensing contracts. In the continuing search to bring greater clarity and specificity to the concept of FRAND licensing within standard setting contexts, economists have proposed - and policymakers have readily latched onto - the theory of incremental value pricing; a innovator’s technology should command a price premium equal to its advantage over the next best alternative. Thus far, however, the literature on the application of incremental value theory to patent licensing within standards has been based on very simple setups that are unlikely to characterize the behavior of heterogeneous firms in SSOs.

One early proposal to extend the theory of incremental value pricing to patent licensing is found in the influential paper by Swanson and Baumol (2005). The focus in their paper is on how best to define FRAND licensing in light of the potential that an SSO member whose patents are “essential” for the practice of a standard (standard essential patents, or SEPs) could gain market power through the standardization process, which by definition eliminates alternatives. Swanson and Baumol observe that the standard development process often involves competition over technologies vying to be included in
a standard and thus argue that such competition could be harnessed to define a fair and reasonable royalty rate for the patented technologies that “win” the competition and are included in the standard. That is, they argue that the licensing price a patent holder charges after its patent is included in the standard should be commensurate with the price it could have obtained during the standard setting process, if there had been an auction among competing technologies.\(^1\)

Farrell et al. (2007) supports the Swanson and Baumol (2005) logic, proposing that a patent’s “incremental value” provides an upper bound (a cap) on the licensing fees that patent owners participating in SSOs can obtain. Mariniello (2011) also takes the incremental value concept as a key element in his proposed test for determining whether actual licensing rates assessed after the standard is set meet patent holders’ FRAND commitments, although he proposes that a patent’s “incremental value” provides a benchmark for ex post analysis and not a strict cap on allowable licensing rates.\(^2\)

Neither Farrell et al. (2007) nor Mariniello (2011) provide a precise definition of “incremental value” in relation to patented technology, but instead both rely more generally on the notion of aggregate value added (such as cost savings in Farrell et al.). While Swanson and Baumol (2005) provides a discussion of many of the implications of extending incremental value theory to patent licensing within standard setting, their model is meant as an illustration only and is thus quite simple: one upstream firm has one patent which, if licensed, would lower the manufacturing costs of one downstream firm. Unfortunately, in the context of SSOs the interpretation of quality differentials as different cost reductions is unlikely to provide a framework rich enough to analyze how an “incremental value” rule should be implemented since the same technology might mean different things

\(^1\)They also argue that this price should incorporate costs like those associated with licensing or the ongoing costs of R&D.

\(^2\)Epstein et al. (2012) provide a qualitative discussion of a number of practical difficulties with an incremental value cap, including the likelihood that different buyers will have different valuations for different technologies, rendering the notion of a single incremental value over the next best alternative unachievable.
to different potential licensees.

The goal of this paper is to understand how the heterogeneity in the technologies that innovators may provide and the different valuation that their users may have may affect the equilibrium licensing agreements. Our model departs from the typical framework in two dimensions. First, we consider situations in which different technologies imply different trade-offs among their characteristics. Second, we recognize that neither SSO members nor the ultimate downstream consumers purchasing products that implement standards is a monolithic group. Instead, different parties are likely to place different “incremental values” on the same technology.

The two sources of heterogeneity we describe in our model are typical of most SSOs. Interoperability standards cover complex products (computers, the internet, mobile phones) whose contributing technologies typically cannot be evaluated solely on a one-dimensional cost-savings basis. Instead, these technologies are more likely to compete on multiple dimensions, like transmission speed versus accuracy, software complexity versus hardware cost, and so forth. Furthermore, the final users of the products created by firms that make use of these technologies have heterogeneous preferences for the trade-offs that these technologies entail.

Our model considers a setup in which innovators compete to sell their technology to downstream firms that use it to provide a good in the final market. Downstream producers face heterogeneous consumers that may choose between their products. Different technologies provide different value to the final product but may also help in making the product appealing to a wider or narrower set of consumers. In other words, technologies might be more or less versatile.

We find that if we allow for the value of a technology to be determined by several dimensions the notion of incremental value becomes considerably more complicated. Abstracting from downstream competition we provide examples in which firms face different
trade-offs depending on the characteristics of the market they serve, making the incremental value firm-specific.

Once we introduce competition, our results show that if the stand-alone value of a technology is sufficiently high compared to the alternative, its inventor will be able to capture all the market. The royalty rate the innovator might obtain, however, will depend not only on the difference in value, as the simple version of the incremental value rule would suggest, but also on the versatility of these technologies. We also characterize situations in which the difference in the value of these technologies is small and we find that absent a standardization process both of them may be used in equilibrium. Interestingly, we show that the use of both technologies might occur even when one of them has higher value and more versatility than the other. The reason is that more versatile technologies imply more competition in the final market, reducing the willingness to pay of downstream producers.\(^3\)

Less directly than to the three patent incremental value papers discussed above, our work is also related to the long literature on patent licensing. Earlier models, summarized in Kamien (1992), study the optimal contract that a monopolist may offer to various downstream competitors. More recent papers such as Muto (1993) and Hernández-Murillo and Llobet (2006) discussed the effect of the heterogeneity in the use that downstream firms can make of the innovation over the optimal contract that the innovator offers. Schmidt (2009) and Rey and Salant (2012) also allow for downstream heterogeneity and study the effect of the licensing of complementary patents on the number of producers and competition in the final good market.

Although this paper does not model SSOs directly, it is also related to the debate

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\(^3\)The “excess of inertia” concept for the adoption of \textit{de facto} standards, introduced in the literature by Farrell and Saloner (1985) has similar implications. In that case users do not switch to a superior technology due to a lack of coordination. Here, however, firms may not adopt a better technology because they are afraid of the fiercer competition it might entail. In both cases, however, social welfare is reduced as a result.
over the strategic behavior of firms in these organizations (Lerner and Tirole, 2006) and how firms that contribute technology should be compensated in order to avoid potential hold-up problems (Ganglmair et al., 2011).

The remainder of this paper procedes as follows. In Section 2 and 3, we develop a model which explicitly accounts for heterogeneity in the uses of the technology. Different firms face consumers with heterogeneous preferences for multiple dimensions of the product. Section 4 introduces competition in the final market. Section 5 discusses some policy implications implied by our analysis and section 6 concludes.

2 The Basic Model

Consider a market where there are two upstream and two downstream firms. We denote the upstream firms as 1 and 2, and the downstream firms as A and B. Downstream firms are competitors in a linear city of length one. Firm A is located at 0 and firm B is located at 1. The downstream firms can sell products that differ in two dimensions: the valuation that consumers assign for the good, \( v \), and the transportation cost of delivering the product to the consumer, \( \alpha \). As a result, a consumer located at point \( x \) on the line facing prices \( p_A \) and \( p_B \) would obtain utility as follows:

\[
U(x) = \begin{cases} 
  v_A - \alpha_A x - p_A & \text{if buying from A,} \\
  v_B - \alpha_B (1 - x) - p_B & \text{if buying from B.}
\end{cases}
\]

We interpret \( v \) as the quality of the product and \( \alpha \) as its “specificity”. We refer to technologies with a lower value of \( \alpha \) as being more versatile, since this attribute is related to how broad the market for the product is. We assume that consumers are distributed according to the distribution function \( \Phi(x) \). In most of the paper this distribution will be assumed to be uniform between 0 and 1.

Upstream firms possess an innovation that downstream producers can embed in their final products. For simplicity, we assume that the quality of the final good is deter-
mined exclusively by this innovation, so that if upstream producer \( i = \{1, 2\} \) has an innovation with attributes \((v_i, \alpha_i)\), this will also be the quality of the product that the downstream producer will offer. We normalize the consumer valuation of a product when the downstream firm does not adopt any of the innovations to 0.

Upstream innovators offer their technology at a per-unit royalty \( r_i \) for \( i = 1, 2 \). Again for simplicity, we assume that downstream producers have no marginal cost of production aside from the royalty paid to the upstream innovator.

The timing of the model is as follows. In the first stage upstream innovators simultaneously choose the royalties that they offer to downstream producers. Downstream firms then choose the innovation that maximizes their profits, anticipating the outcome that will arise in the last stage of the game when they set their final prices, which is also done simultaneously.

In order to analyze this model we will proceed in two steps. In the next section we analyze the case in which there is only one downstream firm. This assumption allows us to analyze how the choice of technologies changes with the level of heterogeneity among consumers. In the following section we then discuss the equilibrium with multiple competing downstream firms.

### 3 Downstream Monopolistic Producer

Consider the situation in which only firm \( A \) is present in the final market. In that case, consumers will buy if their utility is positive. Let’s assume that the consumer location \( x \) is distributed according to \( \Phi(x) = x^\gamma \). The parameter \( \gamma \in [0, 1] \) can be interpreted as a measure of how important heterogeneity among consumers is. In particular, if \( \gamma = 0 \) all consumers are homogeneous and their utility is \( v - p \). As \( \gamma \) grows this heterogeneity becomes more important. When \( \gamma = 1 \) consumers are uniformly distributed along the unit line. The structure of the model is described in Figure 1.
In the second stage, if firm $A$ obtains the technology from innovator $i$, demand will correspond to

$$D_A(p_A) = \Phi\left(\frac{v_i - p_A}{\alpha_i}\right) = \left(\frac{v_i - p_A}{\alpha_i}\right)^\gamma.$$  

The previous demand is decreasing in the price and increasing in the valuation and versatility of the technology. This downstream producer will maximize profits according to

$$\max_{p_A} (p_A - r_i) \left(\frac{v_i - p_A}{\alpha_i}\right)^\gamma.$$  

This expression leads to a monopoly price

$$p_A^* = p^M = \frac{v_i + \gamma r_i}{\gamma + 1},$$  

Profits from licensing the technology of firm $i$ can, in turn, be written as

$$\Pi^M_A(i) = \left(\frac{\gamma}{\alpha_i}\right)^\gamma \left(\frac{v_i - r_i}{1 + \gamma}\right)^{1+\gamma}.$$  

As expected, profits for the downstream monopolist will be increasing in the versatility of the technology (a low $\alpha_i$) and the stand-alone value $v_i$.

In the first stage, given royalties $r_1$ and $r_2$ the downstream firm will choose the technology that leads to the highest profits. The following proposition characterizes the
equilibrium royalty rates that emerge as a result of the competition among innovators.

**Proposition 1.** Suppose that \( \frac{v_i}{\alpha_i^{1+\gamma}} \geq \frac{v_j}{\alpha_j^{1+\gamma}} \). Then technology \( i \) will be adopted. The equilibrium royalties will be \( r^*_j = 0 \) and

\[
r^*_i = v_i - \left( \frac{\alpha_i}{\alpha_j} \right)^{\frac{\gamma}{1+\gamma}} v_j.
\]

The previous result emphasizes the fact that whether a technology is superior to the other or not depends on its combination of quality and versatility – both dimensions play a role. Of course, if both technologies have the same versatility the one with the highest value will be adopted. The resulting royalty for the “winning” firm will be \( r_i = v_i - v_j \). In other words, as the standard interpretation of the incremental value theory indicates, if innovations differ only in the stand-alone value in equilibrium its creator will charge a royalty equal to the technology’s incremental value over the next best alternative.

Once we introduce differences in the second dimension, the results vary. If a technology is superior in both dimensions (i.e. a higher \( v \) and a lower \( \alpha \)) that technology will “win” the competition and be chosen by any downstream monopolist. In many realistic situations, however, we expect each technology to involve a trade-off between the two dimensions; one will have a higher quality and the other will be more versatile. Proposition 1 suggests that if all buyers had the same preferences for both dimensions it would be enough to redefine the measure of quality as \( \frac{v_i}{\alpha_i^{1+\gamma}} \) in order to determine which innovation should command a positive royalty.

This redefined expression for “quality”, however, is endogenous to the characteristics of the downstream buyer, through the parameter \( \gamma \). An immediate consequence is that if we consider different downstream monopolists that operate in different markets and face different demands they will have a different valuation for each technology. These differences might be such that one manufacturer prefers technology 1 while the other prefers technology 2. The reason is that different values of \( \gamma \) imply different valuations
for the trade-off between the two technologies. In particular, if $\gamma$ is high the versatility becomes more important since consumers are more heterogeneous in their tastes. Thus, the downstream firm that faces a higher value of $\gamma$ will tend to choose the more versatile technology.

4 Downstream Competition

With the foundation laid in the simple downstream monopoly case, we now turn to the case in which two downstream producers, $A$ and $B$, located at the two extremes of a linear city compete in the final market. As in the previous case we will assume that innovator $i = \{1, 2\}$ has a technology with components $(v_i, \alpha_i)$. To simplify the algebra, we assume that consumers are uniformly distributed; that is, in the specification of the previous section we set $\gamma = 1$.\footnote{If $\gamma = 0$ all consumers are homogeneous. In that case, downstream the versatility of the technology will not play a role and the winning technology will be determined only according to the stand-alone value. If $v_i > v_j$ the equilibrium royalty will correspond to the quality premium, $r_i = v_i - v_j$.} This structure is described in Figure 2.

As usual, we solve the game by backwards induction, starting with the final pricing stage. We compute the optimal decisions of downstream firms as a function of their initial licensing decisions. We denote as $(\tilde{v}_j, \tilde{\alpha}_j)$ the characteristic of the technology that firm $j = \{A, B\}$ has licensed. If downstream firm $j$ licenses from innovator $i = \{1, 2\}$ it will use the technology $(\tilde{v}_j, \tilde{\alpha}_j) = (v_i, \alpha_i)$ and pay a royalty rate $\tilde{r}_j = r_i$.

Given prices $p_A$ and $p_B$ and assuming that all consumers buy (that is, the market is covered), the consumer indifferent between buying from either of the firms, $x^*$, will be defined by

$$\tilde{v}_A - \tilde{\alpha}_A x^* - p_A = \tilde{v}_B - \tilde{\alpha}_B (1 - x^*) - p_B.$$ 

Downstream firms simultaneously choose prices to maximize profits. Standard calcu-
lations lead to equilibrium prices
\[ p_A^* = \frac{\tilde{v}_A - \tilde{v}_B + 2\tilde{\alpha}_A + \tilde{\alpha}_A + 2\tilde{r}_A + \tilde{r}_B}{3}, \]
\[ p_B^* = \frac{\tilde{v}_B - \tilde{v}_A + 2\tilde{\alpha}_B + \tilde{\alpha}_B + 2\tilde{r}_B + \tilde{r}_A}{3}, \]
and the indifferent consumer, in equilibrium, will therefore be located at
\[ x^* = \frac{\tilde{v}_A - \tilde{v}_B + 2\tilde{\alpha}_B + \tilde{\alpha}_A + \tilde{r}_B - \tilde{r}_A}{3(\tilde{\alpha}_A + \tilde{\alpha}_B)}. \]

Equilibrium profits are obtained as
\[ \Pi_A^* = (p_A^* - \tilde{r}_A)x^* = \frac{(\tilde{v}_A - \tilde{v}_B + 2\tilde{\alpha}_B + \tilde{\alpha}_A + \tilde{r}_A - \tilde{r}_B)^2}{9(\tilde{\alpha}_A + \tilde{\alpha}_B)}, \quad (1) \]
\[ \Pi_B^* = (p_B^* - \tilde{r}_B)(1 - x^*) = \frac{(\tilde{v}_B - \tilde{v}_A + 2\tilde{\alpha}_A + \tilde{\alpha}_B + \tilde{r}_A - \tilde{r}_B)^2}{9(\tilde{\alpha}_B + \tilde{\alpha}_A)}. \quad (2) \]

We can now turn to the first stage, where innovators compete to have their innovation adopted by one or more downstream competitors. We will restrict ourselves to the case in which an innovator offers the same royalty to the two downstream firms. Furthermore, in order to reduce the number of cases that may emerge we assume that the second firm produces a *generic* technology. That is, we assume that the technology firm 2 owns technology that generates the same value to all final consumers regardless of \( x \), which implies that \( \alpha_2 = 0 \).
As a result, when at least one downstream firm adopts the technology of firm 2 the market will be covered, as postulated above.

An important difference between this case and the one we discussed in the previous section is that the willingness to pay of a downstream producer now does not depend only on the technology that it licenses but also on the technology licensed by the competitor in the final market. In particular, we need to consider three cases depending on the technology that each firm licenses. Specifically, both firms could license the (generic) technology from innovator 2, both firms could license a (specific) technology from innovator 1 or, finally, each firm could license a different technology. In this last case, without loss of generality, we assume that firm \( B \) licenses the (generic) technology of firm 2.

### 4.1 Both Downstream Firms License from innovator 2

If both firms license the technology from innovator 2 they will both produce a good that consumers regard as homogeneous due to the zero transportation cost \( \alpha_2 = 0 \). Thus, equilibrium prices of the final good converge to marginal cost \( p_A = p_B = r_2 \) and, consequently, downstream producers make zero profits, \( \Pi_A^* = \Pi_B^* = 0 \).

Given royalties \( r_1 \) and \( r_2 \), if instead one firm, say firm \( A \), decides to license from innovator 1, it will obtain profits (using equation (1) above) of

\[
\hat{\Pi}_A(r_1, r_2) = \frac{(v_1 - v_2 + \alpha_1 + r_2 - r_1)^2}{9\alpha_1}.
\]

Thus, a deviation from the strategy of licensing from innovator 2 will be profitable if \( r_1 \leq v_1 - v_2 + \alpha_1 + r_2 \). In that case, because innovator 1 anticipates these profits it will have an incentive to choose such a royalty. Therefore, for both firms to license from innovator 2 in equilibrium we require that even if \( r_1 = 0 \) no downstream firm wants to deviate and license from innovator 1. A necessary condition for this equilibrium to emerge is that \( v_2 - v_1 \geq \alpha_1 \).

The next lemma summarizes the previous arguments.
Lemma 2. A necessary condition for an equilibrium in which both downstream firms license from innovator 2 is that \( v_2 - v_1 > \alpha_1 \). In that equilibrium \( r_1^* = 0 \) and \( r_2^* = v_2 - v_1 - \alpha_1 \).

Notice that, as opposed to the case of a downstream monopolist, this equilibrium may not be possible even if technology 2 is better than technology 1 in both dimensions. If the quality difference is small, \( v_1 < v_2 < v_1 + \alpha_1 \), downstream competitors will not be willing to switch to the technology offered by firm 2 even if it is offered at a royalty of 0. The reason is that the use of the generic technology implies fiercer competition with the other downstream producer, which leads to lower prices for the final product. This is the reason why the royalty that innovator 2 charges in equilibrium is increasing in the versatility of technology 1 (i.e., decreasing in \( \alpha_1 \)); the more versatile is technology 1 the less sheltered downstream firms are from competition if they switch to this technology.

The previous discussion emphasizes another important limitation of the usual interpretation of the incremental value rule. When innovations can affect aspects other than the level of the demand for the product, a downstream firm’s willingness to pay will depend on the expected response of competitors to its adoption of that technology. It also emphasizes that when an innovator must decide which technologies to develop, the effect on market competition could bias its decision towards more specific, less versatile technologies, even if these specific technologies are potentially inferior.

4.2 Both downstream firms license from innovator 1

If both downstream producers license the technology of firm 1 their profits, according to (1) and (2), correspond to

\[
\Pi_A^* = \Pi_B^* = \frac{\alpha_1}{2}.
\]

A firm could deviate, say firm \( A \), and license the technology from innovator 2 to obtain
profits, using (1) again, of
\[ \hat{\Pi}_A(r_1, r_2) = \frac{(v_2 - v_1 + 2\alpha_1 + r_1 - r_2)^2}{9\alpha_1}. \]
This deviation will be profitable (that is, it will imply \( \hat{\Pi}_A(r_1, r_2) \geq \Pi^*_A \)) if
\[ r_1 \geq \hat{r}_1 \equiv v_1 - v_2 + \left[ \frac{3}{\sqrt{2}} - 2 \right] \alpha_1 + r_2. \]  
(3)
Thus, for an equilibrium to involve both firms licensing technology 1 it must be that even if \( r_2 \) equals 0 firm A's profits decrease when licensing from 2. As a result, upstream innovator 1 will maximize profits by choosing
\[ r_1^* = v_1 - v_2 + \left[ \frac{3}{\sqrt{2}} - 2 \right] \alpha_1. \]
In this case we also need to guarantee that all consumers would buy the downstream product. In particular, the indifferent consumer, which in the symmetric equilibrium equals \( x^* = \frac{1}{2} \), must obtain a positive utility:
\[ U(x^*) = v_1 - \frac{\alpha_1}{2} - p^* \geq 0, \]
where under competition \( p^* = \alpha_1 + r_1^* \). Replacing the royalty from (3) we obtain that a sufficient condition for the market to be covered is \( \alpha_1 \leq \frac{2v_2}{3\sqrt{2} - 1} \).

The next lemma summarizes the previous arguments.

**Lemma 3.** Assume that \( \alpha_1 \leq \frac{2v_2}{3\sqrt{2} - 1} \). A necessary condition for an equilibrium in which both downstream firms license the technology from innovator 1 exists if \( v_1 - v_2 > -\left[ \frac{3}{\sqrt{2}} - 2 \right] \alpha_1 \). In that equilibrium \( r_2^* = 0 \) and
\[ r_1^* = v_1 - v_2 + \left[ \frac{3}{\sqrt{2}} - 2 \right] \alpha_1. \]
This result is the counterpart of the previous lemma in the sense that firm 1 can charge a royalty higher than its incremental value (defined in the narrow sense described in the introduction) even in situations where its technology has lower quality than the technology of the other firm. Analogous to the previous case, this premium is based on the mitigated competition that its technology provides.
4.3 Downstream Firms License Different Technologies

The third and last case is the equilibrium in which downstream producer $A$ licenses from innovator 1 and producer $B$ licenses from innovator 2. From (1) and (2) we can write the profits of downstream firms as

$$
\Pi_A^* = \frac{(v_1 - v_2 + \alpha_1 + r_2 - r_1)^2}{9\alpha_1},
$$

$$
\Pi_B^* = \frac{(v_2 - v_1 + 2\alpha_1 + r_1 - r_2)^2}{9\alpha_1}.
$$

The previous expression requires firm demands to be well-defined,

$$
x^* = \frac{v_1 - v_2 + \alpha_1 + r_2 + r_1}{3\alpha_1} \in [0, 1],
$$

implying that

$$
v_1 - v_2 + \alpha_1 \geq r_1 - r_2 \geq v_1 - v_2 - 2\alpha_1.
$$

(4)

In the first stage upstream innovators choose royalties that maximize their profits subject to the previous conditions. Innovator 1 chooses the royalty rate $r_1$ that maximizes

$$
\max_{r_1} r_1 x^*,
$$

(5)

and innovator 2 chooses $r_2$ to maximize

$$
\max_{r_2} r_2 (1 - x^*).
$$

(6)

The royalties that result from (5) and (6), however, may not characterize the equilibrium for this case. Together with equation (4), we also need to verify that firms do not have incentives to deviate from the equilibrium. In this case deviation means that one upstream innovator might be interested in undercutting the competitor in order to sell to both downstream firms. This is not a concern for firm 2, because firm $A$ would obtain 0 profits if it were to license the technology from this firm (both downstream firms would sell a homogeneous product). Firm 1, however, might be interested in luring $B$ through
a lower license and obtain, as a result, profits of \( \alpha_1 \). The calculations in the previous case imply that for firm B to be willing to license from 1 (when firm A also licenses the technology from this firm) it must be that

\[
r_1 \leq \hat{r}_1 \equiv v_1 - v_2 + \left[ \frac{3}{\sqrt{2}} - 2 \right] \alpha_1 + r_2.
\]

Notice that this condition is weaker than the second part of (4). This deviation will occur in equilibrium only if firm 1 obtains higher profits by covering the whole market.

The next lemma characterizes the equilibrium royalty.

**Lemma 4.** If in equilibrium downstream firm A licenses from innovator 1 and downstream firm B licenses from innovator 2 the resulting royalties are defined as

\[
r_1^* = \frac{v_1 - v_2 + 4\alpha_1}{3},
\]

\[
r_2^* = \frac{v_2 - v_1 + 5\alpha_1}{3},
\]

if \(-5\alpha_1 \leq v_1 - v_2 \leq -\left( \frac{9}{2\sqrt{7}} - 5 \right) \alpha_1 \). Otherwise,

\[
r_1^* = 3 \left( 1 - 2^{-\frac{4}{4}} \right) \alpha_1,
\]

\[
r_2^* = v_2 - v_1 + (5 - 3 \times 2^\frac{3}{4})\alpha_1,
\]

if \(-\left( \frac{9}{2\sqrt{7}} - 5 \right) \alpha_1 \leq v_1 - v_2 < (5 - 3 \times 2^\frac{3}{4})\alpha_1 \).

This lemma shows that the two technologies can be used in equilibrium in two different forms. First, if the stand-alone value of technology 2 is sufficiently high, compared to technology 1, both upstream producers will choose the royalty that results from the maximizations in (5) and (6). No firm will benefit from undercutting its competitor.

If \(v_1 - v_2\) is sufficiently high, however, innovator 1 might be interested in undercutting innovator 2 in order to attract downstream firm B and as a result serve the whole market. This undercutting would take the form described in equation (7). The profitability of this strategy depends on the royalty \(r_2\). For this reason, innovator 2 can prevent innovator
1 from undercutting by choosing a lower value of $r_2$. The second part of the previous lemma describes the equilibrium in which firm 2 chooses the highest value that $r_2$ can take which does not trigger a royalty by firm 1 that steals all the market. The royalty $r_1$ is obtained as the best response resulting from (5).

Notice that innovator 2 will never find it optimal to undercut innovator 1 in order to lure downstream producer $A$. The reason is that, as pointed out before, this producer anticipates that if both downstream firms use the same (homogeneous) technology profits will be 0.

### 4.4 Equilibrium Royalties

In the previous section we have characterized necessary conditions for the three possible equilibria of the model. The next proposition states the values of the parameters for which each of these equilibria may emerge. We restrict to situations in which the market is always covered in equilibrium.

**Proposition 5.** Assume that $\alpha_1 \leq \frac{2v_2}{3\sqrt{2} - 1}$ so that the market is always covered. Four possible equilibria may exist depending on the difference $v_1 - v_2$.

1. If $v_1 - v_2 \leq -4\alpha_1$, only upstream producer 2 licenses its technology. The equilibrium royalties correspond to

   $$r_1^* = 0,$$
   $$r_2^* = v_2 - v_1 - \alpha_1.$$

2. If $-4\alpha_1 \leq v_1 - v_2 \leq -\left(\frac{9}{2\sqrt{2}} - 5\right)\alpha_1$ each innovator sells to only one downstream firm and sets royalties

   $$r_1^* = \frac{v_1 - v_2 + 4\alpha_1}{3},$$
   $$r_2^* = \frac{v_2 - v_1 + 5\alpha_1}{3}.$$
3. If \( -\left(\frac{9}{2^7} - 5\right) \alpha_1 \leq v_1 - v_2 \leq (5 - 3 \times 2^\frac{3}{4}) \alpha_1 \) each innovator sells to only one downstream firm and sets royalties

\[
\begin{align*}
r_1^* &= 3 \left(1 - 2^{-\frac{3}{4}}\right) \alpha_1, \\
r_2^* &= v_2 - v_1 + (5 - 3 \times 2^\frac{3}{4}) \alpha_1,
\end{align*}
\]

4. If \( v_1 - v_2 > (5 - 3 \times 2^\frac{3}{4}) \alpha_1 \) only upstream producer 1 licenses its technology. The equilibrium royalties correspond to

\[
\begin{align*}
r_1^* &= v_1 - v_2 + \left[\frac{3}{\sqrt{2}} - 2\right] \alpha_1, \\
r_2^* &= 0.
\end{align*}
\]

The characterization of the equilibrium royalty in Proposition 5 can be better explained using Figure 3. This figure represents the royalty that both innovators charge as a function of the difference in the stand-alone quality of both innovations. As expected, the royalty that each innovator can charge is, for the most part, increasing in its quality advantage with respect to the competitor.

The proposition shows that when one of the technologies has a high stand-alone value only that technology will be used in equilibrium. This result arises from the fact that the large difference in stand-alone value translates into a large royalty that the innovator can charge and, for this reason, a large interest in covering the whole market. When both technologies are very similar, however, both upstream innovators can share the market unless a standard setting effort leads to only one being chosen through some majority voting rule.

We observe that the region under which an innovator finds it optimal to serve the whole market is substantially smaller than the region described in Lemmas 2 and 3. In other words, the conditions outlined in those lemmas are necessary but not sufficient. The fact that an innovator can price out the competitor from the market does not mean it is
Figure 3: Equilibrium royalty charged by innovator 1 and 2 as a function of $v_1 - v_2$. We have defined $\Delta v_a \equiv -4\alpha_1$, $\Delta v_b \equiv -\left(\frac{9}{2^{3/4}} - 5\right)\alpha_1$, and $\Delta v_c \equiv (5 - 3 \times 2^{1/4})\alpha_1$.

profitable to do so. The reason is that when the difference between the two technologies is not very large, even if the competitor charges a royalty of 0 the innovator might prefer to charge a higher royalty and focus only on part of the market. In particular, Lemma 2 shows that whenever $v_1 - v_2 < -\alpha_1$ innovator 2 can lure both downstream producers. The previous proposition, however, shows that only when $v_1 - v_2 < \Delta v_a$ will it decide to do so. Similarly, when $v_1 - v_2 > \Delta v_c$ innovator 1 will find it optimal to take all the market although, according to Lemma 3, it would be possible for $v_1 - v_2 \geq \left[\frac{3}{\sqrt{2}} - 2\right]\alpha_1$.

In the intermediate region both innovators can sell to one of the downstream producers. As Lemma 4 shows, the market can be shared under two different configurations. If $v_1 - v_2$ is relatively low (in the region $\Delta v_a$ to $\Delta v_b$) both innovators compete, when choosing their royalty rate, to obtain a large market share downstream, under the assumption that each innovator sells to one downstream firm. When $v_1 - v_2$ is between $\Delta v_a$ and $\Delta v_b$ the stand alone quality of firm 1 is sufficiently high that, under the previous royalty rate
undercutting would be profitable. For this reason, innovator 2 chooses a lower royalty. When \( v_1 - v_2 = \Delta v_c \), \( r_2 = 0 \) and innovator 1 chooses a lower \( r_1 \) in order to serve the whole market.

Interestingly, since \( \Delta v_c < 0 \) this implies that there might be situations in which even though innovator 1 produces a good that is inferior in both dimensions, a lower quality and a lower versatility, its technology will be adopted in equilibrium by both downstream producers. This is in contrast with the case in which there is no downstream competition. As we argued earlier, in that case, a technology that is superior in both dimensions would be adopted by any downstream producer.

5 Policy Implications

Relying on a simple horizontal product differentiation framework, in the prior section we analyzed the licensing rates that were likely to emerge when inventions are evaluated on two-dimensions: stand-alone quality and versatility. These two dimensions have very different implications in our setting, particularly when there is competition in the final market. The effect of \( v \) is homogeneous across final consumers, and thus, only quality differences matter. The versatility of the technology, however, affects competition. The parameter \( \alpha \) captures how much the innovator tailors the technology to a few specific consumers. A low value of \( \alpha \) has been interpreted as a very generic technology. Alternatively, it could measure how easy it is for the innovator to provide variations of the technology for different uses. To the extent that the (lack of) versatility of the technology may affect consumers differently it changes the incentives of downstream firms to compete with each other.

In this section, we draw lessons from the analysis and then translate the results into implications for standard setting policy.
5.1 Multiple Technology Dimensions Change Everything

In the first model, the downstream manufacturer is a monopolist. This assumption enables us to isolate the effects of having a multidimensional evaluation for technologies. The model emphasizes that the trade-offs that different technologies entail are going to be resolved differently depending on the characteristics of the demand that the final good producer faces. A firm serving a market with greater consumer heterogeneity will place a greater value on the versatility factor, while a firm serving a less diverse market will place greater value on the quality factor. Thus, even in this simplified setting, a pure incremental value rule is difficult to impose. Two very simple examples can illustrate the different preferences.

Consider first the case of navigation systems. Even though their market has developed considerably in recent years due to the integration of GPS chips in smart phones, in their early years they were sold primarily as specialized devices used in cars. This relatively homogeneous market suggests a high emphasis on features that were valued by the large majority of drivers (e.g. a better screen or better measurement of distances) rather than innovations intended to appeal to other users. In this setting, technologies with higher value and greater specificity would likely win any competition against more general, but lower quality technologies.

A very different example is the case of Radio-Frequency Identification tags (RFID) which are used by tracking systems for shipping, payments, identification, etc. RFID chips are used in a host of disparate products and services. It is no surprise, then, that among the promoters of this technology we find firms as diverse as 3M, Chrysler, France Telecom, HP, LG, Motorola, ThinkMagic, Wal-Mart, and Zebra Technologies. Rather than develop specific solutions for each of these uses – which might be expensive and lead to large coordination costs – downstream firms (chip makers) will highly value versatility,
so they can cater their chips to a wider market.

Thus, even when we have a downstream monopolist, and so can ignore differences across licensees as well as competition effects, end consumer heterogeneity and multi-dimension upstream technologies imply that there is no single incremental value (as Proposition 1 above makes clear). The tradeoff between the technology dimensions depends on the market the downstream firm expects to serve.

The only way to force a single incremental value is to add unrealistic assumptions to an already simplified model. For instance, we could define an index measure that accounts for both the quality and the specificity dimensions, as we did above, but for this to be workable (i.e., non-endogenous), the consumers that different firms serve must share the same characteristics. This assumption will generally not hold in the real world. Alternatively, we could assume that both upstream technologies have the same degree of specificity (or quality), so that the comparison will be on the incremental improvement of the remaining factor, but this is merely assuming away multiple dimensions.

5.2 Competition Affects Technology Choices

The fundamental contribution of the incremental value theory is that it brings aspects of competition to the licensing of standard-essential patents, providing a mechanism to keep licensing fees reasonable even when licenses are not negotiated until after the standard is set. But competition over technologies at the upstream level is not all that matters. As our model demonstrates, adding competition downstream can also alter upstream technology choices and licensing prices in dramatic ways as well.

In the duopoly model a downstream firm considers not only how a particular technology will affect its expected profitability, but it will also consider which technology its rival will choose. When a downstream producer licenses a specific technology from innovator 1, it receives a technology that is valued by a small segment of final users, making the firm
less aggressive in the market. This would occur for example in the computer market if innovators develop technologies (hardware or software) that could be optimized for certain uses or certain manufacturers (e.g. different versions of java for different environments), rather than developing interoperable technologies that work across the various flavors of a platform. When both firms license a specific technology, both focus on different niches within the downstream market. Thus, innovator 1 has room to charge a royalty higher than just the joint incremental quality difference because it knows that should any of the downstream firms move to generic technology 2, they would face stiffer competition from one another.

The opposite is true for innovator 2. Recall that when both downstream firms use the generic technology they cannot differentiate from each other and compete directly over the full set of consumers. Consequently, they make 0 profits. Thus, in order to keep both firms licensing its generic technology, innovator 2 must choose a lower royalty rate. This is reflected in Lemma 2. The royalty $r_2$ is less than $v_2 - v_1$ and lowered by $\alpha_1$, not increased by it, as would be the case if innovator 2 were not concerned about licensees defecting to technology 1.

5.3 Ex Ante Royalties Are Not Defined by Incremental Value

Despite the fact that our model adopts the key elements assumed in the proposed applications of the incremental value theory to patent licensing in standard setting - that is, upstream competition exists, upstream innovators have already invested in R&D and have their patents in hand, but downstream producers have not made any irreversible investments - we find that licenses are not defined by the incremental value of the technology in any of the cases we analyze.

The model shows that there are two circumstances in which the downstream firms can prefer different technologies, so that the downstream market is not standardized. The
first is a high $\alpha_1$ and a low $v_1$ compared to $v_2$. In that case, one downstream producer may choose technology 1 and cover a small part of the market. The other downstream firm might select the general technology 2 and cover the rest of the market. Because both technologies entail significant trade-offs, it is not worthwhile for any of the innovators to sell to both downstream firms. Each innovator anticipates that it would have to charge a very low royalty in order to compensate for the low stand-alone quality (innovator 1) or the high competition resulting from the versatility of its technology (innovator 2).

The second circumstance for the downstream firms to select different technologies is when the quality level of the two technologies is quite close. This latter circumstance is a key scenario that proponents of an incremental value licensing cap for standards point to: when the technology race is close, a one-dimensional incremental value rule would call for a very low royalty rate for the technology chosen, reflecting the stiff competition for inclusion in the standard. Thus, in this case an incremental value rule would impose a low and binding cap. With multiple dimensions for the technology competition, however, this result does not hold. Instead, as Lemma 4 reports, there is room for both technologies to be offered at positive royalty rates, both increasing in the specificity factor $\alpha_1$, during the technology competition for a standard component. Observe that this outcome does not involve any ex post hold up: the two innovators’ positive rates are determined after they have made their R&D investments, but before any standard has been set and thus before any implementation investments have been made.

Under either of these circumstances, if a single standard is to be agreed upon by the members of the SSO, one downstream firm is going to be disappointed. In fact, the downstream firm that “loses” the standard selection vote will have a negative “ex-ante” incremental valuation for the patented technology chosen for inclusion in the standard (where “ex-ante” is defined as during the standard setting process, a time better labeled as “medio amne”).
6 Concluding Remarks

This paper presents a model of licensing when patented technologies have multiple value aspects. Our primary result is that shifting from a single (cost saving) value assessment to a multiple factor one has important implications for the use of an incremental value pricing rule for assessing FRAND licensing of standard essential patents. Our analysis suggests that when technology choices involve evaluating multiple dimensions and not just one-dimensional cost savings, an incremental value rule per se cannot work. Given the diversity amongst SSO members, the heterogeneity amongst consumers of products implementing the standard, and the multi-dimensional nature of many technology choices, there will be no single incremental value to provide a clean, precise benchmark for FRAND licensing.

The concept of incremental value is still a useful one, along the lines proposed in Mariniello (2011), but as a practical matter applying the incremental value concept to the licensing of standard essential patents is likely to require in-depth case-by-case analysis, with technical comparisons of the vying alternatives. This approach can be useful in court cases or specific competition agency inquiries, where the facts can be culled and complicated analysis can be done by experts. However, the incremental value theory is unlikely to yield any useful general policy prescriptions, such as the imposition of a standard-wide royalty cap.
References


A Proofs

In this section we include the proof of the results of this paper.

Proof of Proposition 1: The downstream firm chooses to license the technology that maximizes its profits. Naturally, the technology of upstream producer $i$ will be preferred to technology of $j$ if $\pi^M_A(i) \geq \pi^M_A(j)$. This condition is satisfied if

$$\frac{v_i}{\alpha_i^{1+\gamma}} - \frac{r_i}{\alpha_i^{1+\gamma}} \geq \frac{v_i}{\alpha_j^{1+\gamma}} - \frac{r_j}{\alpha_j^{1+\gamma}}$$

Bertrand competition among technology producers implies that in equilibrium one of the firms, say firm $j$, will set a royalty equal to 0. In that case firm $i$ will set a positive royalty if

$$\frac{v_i}{\alpha_i^{1+\gamma}} > \frac{v_j}{\alpha_j^{1+\gamma}}$$

Using the previous expressions and replacing $r_j = 0$ we obtain that the maximum royalty that firm $i$ can charge and, therefore, the optimal one as

$$r^*_i = v_i - \left(\frac{\alpha_i}{\alpha_j}\right)^{1+\gamma} v_j.$$

\[\Box\]

Proof of Lemma 2: In the text. \[\Box\]

Proof of Lemma 3: In the text. \[\Box\]

Proof of Lemma 4: The first order condition that determines the solution to the problem of both upstream producers in the text leads to reaction functions

$$r^R_1(r_2) = \frac{v_1 - v_2 + r_2 + \alpha_1}{2},$$
$$r^R_2(r_1) = \frac{v_2 - v_1 + r_1 + 2\alpha_1}{2}.$$

The intersection of both reaction functions determines the interior solution for the equilibrium royalty $r^*_1 = \frac{v_1 - v_2 + 4\alpha_1}{3}$ and $r^*_2 = \frac{v_2 - v_1 + 5\alpha_1}{3}$. Notice, however, that this result requires that $4\alpha_1 \geq v_2 - v_1 \geq -5\alpha_1$. These are the same conditions that guarantee that the indifferent consumer, $x^*$, lies between 0 and 1.

We now analyze the incentives for an innovator to undercut the competitor. In particular, consider a given $r_2$. Profits for innovator 1 when the market is shared correspond
to

$$\Pi^*_1(r_2) = \max_{r_1} r_1 x^* = \frac{(v_1 - v_2 + \alpha_1 + r_2)^2}{12\alpha_1},$$

whereas if it undercuts the innovator 2 by the lowest possible amount, as reflected in (7), profits become

$$\hat{\Pi}_1(r_2) = v_1 - v_2 + \left[\frac{3}{\sqrt{2}} - 2\right] \alpha_1 + r_2.$$

Under the previous equilibrium royalties undercutting will not occur if $$\Pi^*_1(r_2^*) \geq \hat{\Pi}_1(r_2^*).$$ That inequality will hold if $$v_1 - v_2 > \left(5 - \frac{9}{2\pi}\right) \alpha_1.$$ If the opposite is true, innovator 2 will find optimal to choose a royalty $$r_2 < r_2^*.$$ In particular, notice that

$$\frac{\partial}{\partial r_2} \left( \hat{\Pi}_1(r_2) - \Pi^*_1(r_2) \right) = 1 - \frac{v_1 - v_2 + \alpha_1 + r_2}{6\alpha_1} \geq 1 - \frac{v_1 - v_2 + \alpha_1 + r_2^*}{6\alpha_1} = \frac{5\alpha_1 - v_1 + v_2}{9\alpha_1} > 0,$$

since $$v_1 - v_2 \leq 5\alpha_1.$$ Thus, to prevent undercutting and maximize profits innovator 2 will choose the royalty $$\tilde{r}_2$$ that equates both profits, $$\Pi^*_1(\tilde{r}_2) = \hat{\Pi}_1(\tilde{r}_2),$$ or

$$\tilde{r}_2 = v_2 - v_1 + \left(5 - 3 \times 2^{\frac{1}{4}}\right) \alpha_1,$$

and the best response of innovator 1 corresponds to $$\tilde{r}_1^* = r_1^R(\tilde{r}_2) = 3 \left(1 - 2^{-\frac{1}{4}}\right) \alpha_1.$$

**Proof of Proposition 5:** From Lemma 2 we know that a sufficient condition for both downstream firms to buy from innovator 2 is that $$v_1 - v_2 < -\alpha_1.$$ Lemma 4, however, shows that only when $$v_1 - v_2 = -4\alpha_1$$ we have $$r_1^* = 0.$$ Thus, for $$-4\alpha_1 < v_1 - v_2 < -\alpha_1$$ sharing the market generates higher profits.

The remaining regions are immediate from Lemma 4 and 3.

$\square$