Standard-Setting, Innovation Specialists, and Competition Policy

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ABSTRACT

Using a simple model of patent licensing followed by product-market competition, this paper investigates several competition policy questions related to standard-setting organizations (SSOs). It concludes that competition policy should not favor patent-holders who practice their patents against innovation specialists who do not, that SSOs should not be required to conduct auctions among patent-holders before standards are set in order to determine post-standard royalty rates (though less formal ex ante competition should be encouraged), and that antitrust policy should not allow or encourage collective negotiation of patent royalty rates. Some recent policy developments in this area are discussed.

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I. INTRODUCTION

This essay is concerned with several competition policy questions related to standard-setting organizations (SSOs), in which industry participants, perhaps with some customer representation, voluntarily come together and attempt to produce consensus standards. SSOs have a long history. The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA), for instance, grew out of standard-setting activity that began in 1890.[1] SSOs have played an increasingly important role in the advance of the information technology and telecommunications sectors. Chiao et al [2007] have identified 59 SSOs operating in that arena, and they do not claim to have found them all. As of 2001, the IEEE-SA alone had 866 active standards and 526 projects in hand, with over 450 technical working groups and committees.[2]

Antitrust authorities generally approve of voluntary standard-setting, particularly when compatibility standards are involved,[3] despite the authorities' general hostility toward collaboration among competitors. Section II illustrates one effect that rationalizes this stance, using a simple model that is employed in later sections. To the extent that adopting a compatibility standard reduces differentiation, it tends to intensify price competition. If it also expands the market enough so that it is nonetheless profitable for producers, then all else (including royalty rates) equal, it makes consumers better off in this model even though they value product diversity.

At some level it is surprising that voluntary standard-setting works at all.[4] Standard-setting processes often involve diverse interests, including innovation specialists that only provide intellectual property, manufacturing specialists that do not innovate, and integrated firms that both innovate and manufacture. Decisions made by SSOs can have significant and divergent implications for the value of intellectual property and other assets held by SSO participants. Moreover, modern standards are often quite complex and cannot be used without licenses to large numbers of patents held by many firms. The MPEG-2 standard, for instance, involves 425 patents with 28 owners.[5] Not only do most standard-setting processes nonetheless seem to produce socially valuable standards, some evidence suggests that they tend to select particularly promising technologies and thereby to enhance their impact.[6] A few recent, high-profile antitrust proceedings in the US and EU have involved standard-setting, but their number seems small relative to the total volume of standard-setting activity.[7]

Two reasons are frequently given for this performance. First, the large integrated firms that have traditionally dominated standard-setting processes typically have large patent portfolios that could potentially be used in mutually destructive infringement litigation. To avoid this outcome, it is argued, integrated firms typically engage in mutual forbearance and charge low royalty rates to each other.[8] Second, in technology-based industries the same firms tend to interact with each other repeatedly over time. This means that 'bad' behavior by any firm in any one standard-setting process can be punished by others in subsequent processes; see DeLacey et al [2006].

Nonetheless, it seems to be widely believed that standard-setting has become more difficult and more contentious in recent years. Many observers have argued that the US Patent Office has been awarding patents too easily and that US courts have been too willing to uphold the validity of dubious patents.[9] To the extent that patent policy inflates the number of patents that must be licensed in order to practice a standard, it contributes to what has been called a 'patent thicket' through which standard-setting must pass. This clearly complicates standard-setting and may make standards less socially valuable.[10] As my concern here is with antitrust policy, however, I will treat patent policy as given.

A second complicating development, and the one with which this essay is primarily concerned, is the rise of innovation specialists, firms that license intellectual property but do not produce tangible products.[11] The growth of such firms has been one of the most important developments since around 1990 in industries in which intellectual property is important.[12] Separation of innovation from manufacturing permits individual firms to focus on what they do best and is thus potentially efficiency-enhancing. Moreover, vertical disintegration is normally more likely to alleviate competition policy concerns than to raise them. The potentially disruptive complication is that innovation specialists are much less vulnerable to infringement suits than manufacturers and thus have less incentive to engage in the sort of mutual forbearance described above. It is thus not surprising that innovation specialists have been the defendants in a number of recent high-profile SSO-related proceedings.[13]

It is similarly unsurprising there has emerged significant hostility toward innovation specialists within at least parts of the policy community. In 2006, for instance, four Justices of the US Supreme Court signed an opinion stating

> An industry has developed in which firms use patents not for producing and selling goods but, instead, primarily for obtaining licensing fees. For these firms, an injunction … can be employed as a bargaining tool to charge exorbitant fees to companies that seek to buy licenses to practice the patent.[14]

Of course, firms that *do* produce and sell goods could also use injunctions for this purpose, as well as for other socially undesirable purposes.

Innovation specialists have been accused of three forms of behavior that adversely affect social welfare. Perhaps the most common accusation is that they behave as *patent trolls*. Just as trolls in folk tales hide under bridges and emerge suddenly to demand tolls from unsuspecting travelers, so patent trolls hide their intellectual property until an opportune time and then emerge to extract royalties.[15] In the standard-setting context, the opportune time is typically after their intellectual property has been embodied in a standard and, perhaps, after additional standard-specific costs have been sunk. This term has sometimes been applied to all innovation specialists, but it seems best to reserve it for those – specialists or not – that engage in troll-like deceptive behavior.

It seems generally agreed in the US and the EU that deception on the part of a patent-holder that alters the choice of technology within a standard-setting process so as to increase the patent-holder's ex post market power significantly is an antitrust violation. The recent *Rambus* case in the US, however, suggests that it may generally be difficult to prove that a different standard would have been adopted but for particular deceptive acts.[16] SSOs commonly attempt to prevent troll-like behavior by various rules requiring participants to disclose their intellectual property, but such rules cannot eliminate such behavior.[17]

The other two accusations, with which this essay is primarily concerned, involve charges of excessive or abusive royalties. The behaviors involved are sometimes lumped together, but they are analytically quite distinct. The first is *patent hold-up*. When technology covered by a patent is included in a standard, the ex ante value of that patent may be increased substantially ex post. It seems broadly consistent with most of the literature to say that patent hold-up occurs when a patent-holder demands royalties ex post that are above the reasonable ex ante expectations of potential licensees, expectations that presumably reflect the patent's ex ante value rather than its ex post value. Thus defined, patent hold-up does not necessarily involve hiding the existence of intellectual property, but it generally does involve at least some deception (perhaps only misleading silence) regarding licensing terms and conditions. If ex post royalties are in line with ex ante expectations, it seems reasonable to say that there is no hold-up.[18]

Over the years, many SSOs have required participants to commit ex ante to charge royalty rates that are reasonable and non-discriminatory (RAND) or, particularly in Europe, fair, reasonable, and non-discriminatory (FRAND).[19] These commitments at least oblige patent-holders to negotiate non-exclusive licenses in good faith; some have argued that they carry with them additional obligations as regards licensing terms and conditions.[20] Despite this ambiguity, FRAND commitments seem to have worked reasonably well to make essential patents generally available at acceptable royalty rates. The IEEE-SA [2002], for instance, testified that '[w]ith very few exceptions, this approach has worked very successfully for at least the past twenty years.'

Finally, innovation specialists are sometimes also accused of *royalty-stacking*. In a classic analysis, Cournot [1838] showed that in a one-period model, two unaffiliated monopolists selling complementary products would set higher prices than a single monopolist selling both products. In the standard-setting context this analysis implies that if the patents essential to a standard are in multiple hands, total royalty rates will be higher than if all essential patents had a single owner. Because Cournot's model assumes away important aspects of reality, especially repeated interactions among participants in SSOs, the importance of this effect in general or in any particular standardization process must be an empirical question, which has yet to receive a definitive answer.[21]

Section III contrasts royalty rate determination by innovation specialists and by integrated firms in the absence of hold-up. Royalty-stacking emerges in both cases. And, while upstream innovation specialists face a more severe double marginalization problem than integrated firms would, the latter have the incentive to diminish competition by raising rivals' costs. This analysis provides no basis for a general policy tilt against innovation specialists.

Sections IV and V consider two proposed responses to hold-up and royalty-stacking. In an influential paper, Swanson and Baumol [2005, esp. pp. 16-18] advocated the use of formal ex ante competition, which they suggested might be implemented via an auction, to determine royalty rates in SSOs. If an auction or other similarly transparent, arms-length ex ante process were a workable mechanism for royalty determination, antitrust authorities might either require or actively encourage SSOs to employ it. However, Section IV shows that formal ex ante competition is unlikely to be workable in practice, importantly because there is generally no formulaic way to compare competing bids by innovation specialists and integrated firms.

Section V considers the alternative of allowing potential licensees operating in SSOs to engage in collective negotiation of royalty terms ex ante, before a standard has been set. Though a clear departure from antitrust's general hostility toward cartels, this approach has been favorably discussed by policy-makers in both the US and the EU. Section V shows that the different strategic incentives of innovation specialists and integrated firms may distort technology choice under collective negotiation and argues that licensee collusion may unduly reduce incentives to innovate and thereby slow technical progress.

Section VI concludes with a brief discussion of the implications of the analysis of preceding sections for competition policy responses to the difficulties that seem to beset contemporary standard-setting organizations and processes.

II. AN ILLUSTRATIVE MODEL

This section introduces an illustrative two-stage oligopoly model that is employed in Sections III-V and uses it to illustrate a simple point about the benefits of voluntary standardization. Consider a simple economy with the following representative consumer utility function:

(1) $$U = X_0 + \alpha \sum_{i=1}^{N} X_i - \frac{1}{2} \sum_{i=1}^{N} X_i \left(X_i + \gamma \sum_{j \neq i} X_j \right)$$

Here X_0 is consumption of the numeraire good, produced competitively at constant unit cost and price of 1, $\alpha > 0$ and $\gamma \in [0,1]$ are constants, and $X_1 \ldots X_N$ are the outputs of N Cournot oligopolists, each with constant unit cost C. When $\gamma = 0$, goods 1 through N are independent in demand, while when $\gamma = 1$ they are perfect substitutes.

If P_i is the price of good *i*, equation (1) implies the following inverse demand functions:

(2) $$P_i = \alpha - X_i - \gamma \sum_{j \neq i} X_j, \qquad i = 1, \ldots, N.$$

Substituting the budget constraint with total income *I* into (1) and using (2) then yields

(3) $$U = I + \frac{1}{2} \sum_{i=1}^{N} X_i \left(X_i + \gamma \sum_{j \neq i} X_j \right).$$

We simplify—and follow most of the literature—by assuming all royalties are linear in output.[22] Let there be K upstream innovation specialists, each with patents that are essential for production of the final product according to some standard, and let S_k be the royalty charged per unit of final output by specialist k to each downstream manufacturing firm. Similarly, let R_i be the per-unit royalty charged by manufacturing firm i for its essential patents to each *other* manufacturing firm. (If firm *j* is a manufacturing specialist, with no essential intellectual patents, $R_j = 0$.) Let *S* be the sum of the S_k, and *R* be the sum of the R_i. Then firm i's profits are given by

(4) $$\Pi_i = X_i\left[\left(\alpha - X_i - \gamma\sum_{j\neq i} X_j\right) - \left(R - R_i\right) - S - C\right] + R_i\sum_{j\neq i} X_j, \quad \text{i = 1, …, N.}$$

Sections III – V consider two stage games in which royalty rates are selected in the first stage and outputs are selected in the second, taking royalty rates as given.[23]

To solve the second stage, differentiate (4) with respect to X_i and add across *i*:

(5) $$\sum_{i=1}^{N} X_i = \frac{N\left(\alpha - S - C\right) - (N-1)R}{2 + \gamma\left(N-1\right)},$$

Substitution into (4) then yields

(6) $$X_i = \frac{\left(\alpha - S - C\right)\left(2-\gamma\right) + \gamma\left(N-1\right)R_i - 2\sum_{j\neq i} R_j}{\left(2-\gamma\right)\left[2 + \gamma\left(N-1\right)\right]}, \qquad \text{i = 1, …, N.}$$

In this simple world with one-component products, no network effects, and a host of other real-world complications absent, the most natural way to model standardization is as an agreement by firms 1, …, N to increase γ. Since such an agreement would reduce differentiation and thus intensify price competition in this model, firms 1, …, N would accept it only if it also expanded their markets by also increasing α. To illustrate the implications of such an agreement most simply, let us assume $R_i = R_j$ for all *i* and *j*, and let β denote the total royalties paid per unit of output by each manufacturing firm,

(7) $$\beta \equiv S + (N\text{-}1)R/N.$$

Then substituting (6) into (4) produces

(8) $$\sum_{i=1}^{N} \Pi_i = N\left\{\left[\frac{\alpha - C - \beta}{2 + \gamma(N-1)}\right]^2 + \beta\left[\frac{\alpha - C - \beta}{2 + \gamma(N-1)}\right]\right\},$$

and substitution of (6) into (3) and simplifying yields

(9) $$U = I + \frac{\left[1 + \gamma\left(N-1\right)\right]}{2}\left[\frac{\alpha - C - \beta}{2 + \gamma(N-1)}\right]^2.$$

In this symmetric case, $\partial U/\partial\gamma < 0$: consumers' preference for variety in this model is strong enough that standardization that does not increase α makes them worse off even though it intensifies competition among manufacturing firms.

With β fixed, examination of the derivatives of (8) and (9) with respect to both α and γ serves to demonstrate that small increases in γ and α that together increase total profit must increase consumer utility and thus total economic welfare. The converse is not true: there are always ($\Delta\gamma$, $\Delta\alpha$) combinations that increase utility but not profit and would thus not be voluntarily adopted.[24] If standardization also involves a change in β, however, no such general results are available. While an increase in β always reduces U by decreasing output, it may thereby increase or decrease total profit.

III. STRATEGIC ROYALTY-SETTING

Using the model just introduced, and assuming away complications related to hold-up and the ex ante/ex post distinction (on which the following two sections focus), this section compares royalty-setting behavior by innovation specialists and integrated firms.

We first show that royalty-stacking arises with both integrated firms and innovation specialists. Suppose initially that the intellectual property that is essential for some standard is divided among K upstream innovation specialists. From (5), the stage 1 objective of the k^{th} such firm is

$$\Pi_k = S_k \frac{N\left(\alpha - \sum_{j=1}^{K} S_j - C\right)}{2+\gamma(N-1)}, \qquad k = 1, \ldots, K, \tag{10}$$

The corresponding one-shot Nash equilibrium royalty rates are given by

$$S = KS_k = \frac{K(\alpha - C)}{K+1}, \qquad k = 1, \ldots, K. \tag{11}$$

The total per-unit royalty paid by each downstream firm, S, is increasing in K and tends to $(\alpha - C)$ in the limit as K increases. In this limit, total downstream output is zero.

Suppose now that there are N manufacturing firms, as above, and firms 1, …, K, where $K \leq N$, have essential intellectual property. Substituting (5) and (6) into (4) to obtain the stage 1 objective function of a typical integrated firm yields

$$\begin{aligned}\Pi_i &= \left\{\frac{(2-\gamma)(\alpha-C)+\gamma(N-1)R_i - 2\sum_{j\neq i} R_j}{(2-\gamma)(2+\gamma(N-1))}\right\}^2 \\ &+ R_i \frac{(N-1)(2-\gamma)(\alpha-C) - 2(N-1)R_i + (4+\gamma N - 2N - \gamma)\sum_{j\neq i} R_j}{(2-\gamma)\left[2+\gamma(N-1)\right]}, i = 1, \ldots, K.\end{aligned} \tag{12}$$

The first term on the right here is the firm's operating profit; the second is its royalty revenue.

Setting the derivative of (11) with respect to R_i equal to zero and solving yields a quite complex expression even when symmetry is imposed. The special case of perfect downstream substitutes ($\gamma = 1$) serves to illustrate the main point, however. In this case,

(13) $$R_i = \frac{(\alpha - C)(N+3)(N-1)}{(K-1)(N^2+2N-7)+(N-1)(2N+6)}, \qquad i = 1, \ldots, K$$

Integrated firms pay total per-unit royalties equal to (K-1) times this quantity, while firms K+1, …, N pay K times this quantity. It is easy to show that both these total royalty rates rise with K. If K = N, so that all manufacturing firms are integrated, each pays

(14) $$(N-1)R_i = (\alpha - C)\frac{(N-1)(N+3)}{N^2+4N-1}, \qquad i = 1, \ldots, N.$$

The right-hand side of (14) is increasing in N and in the limit approaches *(α – C)*, the aggregate royalty rate that drives downstream output to zero, exactly as when all essential intellectual property is held by innovation specialists. Thus royalty-stacking arises when essential (and thus complementary) intellectual property is divided among multiple owners, whether or not those owners are also engaged in manufacturing.

In models of this sort, royalty-setting by integrated firms and by innovation specialists is affected by a number of strategic considerations.[25] First, if all firms involved are integrated, they can use cooperatively set royalty rates to raise marginal costs just enough to induce monopoly output in stage 2.[26] Second, because downstream competition is imperfect, upstream innovation specialists' ability to extract profit via royalty income is limited by vertical double marginalization: downstream manufacturers add markups to the royalty costs they pay, thus tending to raise final prices too high for maximization of total profit. Each integrated firm avoids this problem with respect to its own output, but its competitors mark up the royalties it charges them. Finally, the payoff to each integrated firm individually from raising its rivals' costs, thus reducing their output and increasing the first term on the right of (4), leads to aggressive royalty-setting in the absence of collusion. In fact in this model the raising-rivals'-cost effect is so strong when $\gamma = 1$ that it is easily shown that collusive royalty-setting among N integrated firms yields higher output than non-cooperative royalty-setting.

Two further examples are illuminating. First, when $\gamma = 1$we can use (11) with N replacing K and (14) to compare the case in which N innovation specialists set royalties for N manufacturing firms with the case in which N integrated firms non-cooperatively set royalties for each other. This comparison demonstrates that, as Schmidt [2008] has previously shown, the equilibrium royalty charged by each integrated firm, R_i, is higher than the rate charged by each innovation specialist, S_k. Schmidt [2008] has also shown, however, that the reverse holds when demand for the final product is log-linear.

In this first example, when royalties are set upstream each producing firm pays NS_k, while if they are set by integrated firms (which don't pay royalties to themselves) each producing firm pays $(N-1)R_i$. It is easy to show that the former quantity exceeds the latter under the linear demand assumption made here, and it follows from the Schmidt [2008] result cited just above that it also does with log-linear demand. Accordingly, in this two-stage model with linear or constant-elasticity demand for the final product and $\gamma = 1$, output and consumer welfare are higher when N integrated firms charge royalties to each other than when N manufacturing specialists are charged royalties by N innovation specialists.[27]

A second example, which is explored further in Sections IV and V, involves comparing the case in which all essential intellectual property is owned by a single innovation specialist with the case in which all such property is owned by a single integrated firm, firm 1, say. From (11), an innovation specialist would charge all N downstream firms $S_1 = 0.5(\alpha - C)$. Differentiating (12) for $i = 1$ with respect to R_1 and setting $R_j = 0$ for $j \neq 1$ yields

$$R_1 = (\alpha - C)(2-\gamma)\frac{4-2\gamma+2\gamma N+\gamma^2-\gamma^2 N}{16-16\gamma+8\gamma N+6\gamma^2-6\gamma^2 N}. \tag{15}$$

This quantity equals S_I for $\gamma = 0$ and $\gamma = 1$. For intermediate values of γ and for $2 \leq N \leq 30$, numerical evaluation reveals $0.45(\alpha - C) < R_I < S_I$.

When $\gamma = 0$, the integrated firm 1 is effectively an upstream supplier of intellectual property to all other manufacturers, and it charges the same royalty rate as would an innovation specialist, S_I. For $\gamma > 0$, firm 1 faces competition from firms 2, …, N, and its incentive to increase their costs rises with γ. The equilibrium ratio of X_I to X_j for $j \neq 1$ is 2 when $\gamma = 0$ because of double marginalization: its competitors mark up R_I, but firm 1 does not. This ratio rises with γ, and, as Kim [2004] has shown, when $\gamma = 1$, firm 1's optimal royalty rate is so high that all other firms produce zero.

Straightforward computation reveals that because an integrated firm always faces a smaller double marginalization problem in this example, for $0 \leq \gamma \leq 1$ and $2 \leq N \leq 30$, total output and consumer utility are higher if it owns the essential intellectual property than if that property is owned by an innovation specialist. On the other hand, if royalties are charged by an integrated firms, the mix of final products is distorted except when $\gamma = 1$ (there is only one product), and this affects profit except when $\gamma = 0$ (the products aren't substitutes). Total industry profit may be higher or lower than when an innovation specialist owns the essential intellectual property for $0 < \gamma < 1$. Total profit is higher with an innovation specialist, for instance, when $\gamma = 0.7$ and N > 2. (Larger values of N always reduce the double marginalization problem.)

Competition policy is based on the presumption that market forces should generally be allowed to determine firms' boundaries and activity mixes. The analysis of strategic royalty-setting in this section does not support departing from that presumption and biasing public policy either for or against innovation specialists.

IV. FORMAL EX ANTE COMPETITION

This section evaluates the potential of formal ex ante competition to mitigate royalty-stacking and hold-up when standards involve multiple patents. We first exhibit conditions under which a formal, transparent royalty-rate bidding process that could be carried out by a third party completely solves these problems. [28]

Suppose that in order for a standard to be viable, it needs one technology, assumed for convenience to be covered by patents held by a single firm, for each of M components. Let us also assume, again mainly for convenience, that there are unique best and second-best technologies for each component, defined in terms of incremental contribution to the value of the standard, regardless of which technologies are used for the other components.[29] (It will be clear that only the first- and second-best technologies can matter in equilibrium.)

Four additional substantive assumptions ensure that formal ex ante competition works well in this model. The consequences of relaxing each are discussed below.

(1) All potential standards would yield a new product of exactly the same quality, so they differ only in the unit cost of production they would imply.

(2) All manufacturers are concerned with only the total unit cost (production cost plus royalty cost) implied by each possible standard; they do not care who owns the underlying intellectual property.

(3) The unit cost of producing the final product using any potential standard is known and is the same for all manufacturers. Let that cost be given by the function

$$C(d_1, d_2, \ldots, d_N),$$

where $d_i = 1$ if the best technology is used for component i, and $d_i = 2$ if the second-best technology is used.

(4) Total sales of the final product will be some fixed number of units as long as total production plus royalty cost is less than or equal to C_T and zero otherwise.

Let $a_i \geq 0$ be the per-unit royalty charged for the best technology for component i, and let $b_i \geq 0$ be the rate charged for the second-best technology. Licensing costs are neglected throughout for simplicity.

Suppose first that M = 1 and that the owners of the two technologies simultaneously announce their royalties. The conditions for the first-best technology to be selected as the standard and for that standard to be used are, respectively,

(16a) $$a_1 \leq b_1 + [C(2) - C(1)], \text{ and}$$

(16b) $$a_1 \leq C_T - C(1).$$

The quantity in brackets on the right of (16a) is non-negative by the definition of first- and second-best technologies. If a_1 is less than or equal to that quantity, the first-best technology will be selected regardless of the value of b_1. In this simple case, then, the obvious competitive outcome is $a_1 = \text{Min}\{C_T - C(1), C(2) - C(1)\}$ and $b_1 = 0$.

Next, consider the case M = 2. In the sort of Bertrand regime we are considering here, ex ante competition is provided by the willingness of the owners of the second-best technologies to license them at any non-negative rates. Setting $b_1 = b_2 = 0$ accordingly, the inequalities corresponding to (16) that must be satisfied in order for the standard with the lowest production cost to be selected and to be used are the following:

(17a) $$a_1 \leq C(2,1) - C(1,1) \equiv \Delta_1$$

(17b) $$a_2 \leq C(1,2) - C(1,1) \equiv \Delta_2$$

(17c) $$a_1 + a_2 \leq C(2,2) - C(1,1) \equiv \Delta_{12}$$

(17d) $$a_1 + a_2 \leq C_T - C(1,1) \equiv \Delta_{11}$$

By the definition of first- and second-best technologies, all the right-hand sides of these inequalities are non-negative.

Suppose the owners of the first-best technologies for components 1 and 2 submit bids a_1 and a_2 simultaneously. If all of inequalities (17) are satisfied, the firm bidding a_i receives that royalty rate times the (fixed) number of units sold, $i = 1,2$. If not, all firms receive zero.

This game clearly has at least one Nash equilibrium. Because the right-hand sides of (17) are all non-negative, all these inequalities are satisfied by $a_1 = a_2 = 0$. An equilibrium is a pair of non-negative a's such that neither can be increased without violating one or more of these inequalities. If at the point $a_1 = a_2 = 0$ neither royalty rate can be increased, that point is the unique equilibrium. Otherwise, one or more equilibria can be found by increasing one or both of the a_i until one of inequalities (17) holds with equality.

It follows from the analysis of Layne-Farrar et al [2007] that there may be many equilibria of this game and that if one first-best technology has a good substitute and the other does not, the latter will generally command higher royalties in equilibrium. In particular, if the first- and second-best technologies for component 1, say, are equivalent, so $\Delta_1 = 0$, then $a_1 = 0$ in equilibrium. At the other extreme, if there is only one plausible technology for component 2, so that C(1,2) and C(2,2) are very large, then (17b) and (17c) are irrelevant, and a_2 is only constrained by (17d). If $\Delta_1 = 0$ also, so $a_1 = 0$ in equilibrium, then $a_2 = C_T - C(1,1)$, and firm 2 captures all the rent associated with the standard. Alternatively, if technology 1 has only an imperfect substitute, so $\Delta_1 > 0$, then there is a continuum of equilibria.

It is easy to describe hold-up in this model. Suppose that the production-cost-minimizing standard has been adopted without ex ante competition. If firms 1 and 2 then proceed ex post to set royalty rates, the only constraint binding them is (17d). If licensors' expectations were based on the assumption that all of inequalities (17) would be satisfied, hold-up may have occurred. There are an infinite number of equilibria of the game above with (17d) alone replacing (17). Because these ex post equilibria are not constrained by the presence of second-best technologies, they may involve higher rates charged by both firms. Of course, if neither firm's technology had a good substitute, the total royalty rate, a_1+a_2, would only be constrained by (17d) ex ante, so there could be no hold-up in terms of the total rate. More generally, the firms most likely to benefit from the absence of ex ante competition are those with close substitute technologies, since the tight competitive constraint provided by those technologies ex ante is eliminated once the standard is set. At the other extreme, if one firm has the only viable technology for some component, it is less likely to benefit from a shift from all of (17) to (17d) alone. Indeed, in the polar case discussed above in which one firm captures all the rents in ex ante competition, there will be a continuum of ex post equilibria in which its returns are lower. It would thus likely gain from ex ante competition.

With M components, there are 2^M potential standards in this model, and thus 2^M constraining inequalities corresponding to (17): $2^M - 1$ involving differences between costs under alternative standards and costs under the standard that minimizes production cost, and one comparing total costs to C_T. The right-hand sides of all these inequalities are non-negative, so all are satisfied by $a_i = 0$ for all i. If it is not possible to increase any a_i without violating any inequalities, $a_i = 0$ for all i is an equilibrium. In general, any point at which all a_i are non-negative and it is not possible to increase any a_i without violating a constraining inequality is an equilibrium.

As when M = 2, there may be an infinite number of equilibria of this game. Similarly, if the first-best technology for component i has a perfect substitute, the inequality on a_i alone (which corresponds to (17a) or (17b)) ensures that it cannot charge positive royalties in equilibrium. And if the first-best technology for component j has no substitutes, so that all standards that do not use it have prohibitively high production costs, then the only inequality that constrains a_j is the one that corresponds to (17d).

While the equilibria described above are delicate,[30] they have a number of desirable properties. There is no hold-up or royalty-stacking. The best standard is adopted,[31] and patents that are essential to that standard are rewarded on the basis of their incremental contributions to the value of the standard, which strikes most observers as fair.[32]

We now consider relaxing the four assumptions listed above. The most natural way to relax assumption (4), that market size is fixed as long as total cost is below C_T, when M = 2 would be to replace constraint (17d) with a function giving total sales of the final product as a declining function of production cost plus royalty cost. Thus if firm 1's royalty is otherwise unconstrained, raising it slightly would raise the cost of the final product slightly, reducing the number of units sold, and thus reducing the number of units on which it and firm 2 receive royalties. But, a la Cournot [1838], firm 1 would rationally ignore the impact of its royalty-setting on firm 2's royalties, and the incentive for royalty-stacking would emerge. But while even this rigorous ex ante competition doesn't eliminate the incentive for royalty-stacking, the ex ante presence of substitute technologies may substantially constrain licensors' ability to respond to that incentive. To take an extreme example, if when M =2 both first-best technologies have perfect substitutes, both will be constrained to charge zero royalties regardless of the demand function for the final product.

Assumption (1), that potential standards differ only in their implications for the cost of the final product, not in their implications for the attributes or overall quality of that product, implies that all decisions would be unanimous. But if it would cost more to implement some standard A than an alternative standard B and the former would produce higher quality products, firms that served different geographic markets or different market segments might well disagree on which was the better standard.[33] Firms with different production assets might even disagree about production cost. Bid evaluation under such conditions would not be simply a trivial matter of comparing total costs, and the identity of the bid evaluators and/or the details of the SSO's decision-making process could determine the outcome.

Assumption (2), that the cost implications of alternative standards is known ex ante, is critical because such knowledge is essential to evaluate patent-holders' bids. But it is also extremely unrealistic. In a standard of any complexity, writing down the counterparts of (17) would require knowing the cost implications of many potential standards, only one of which will ultimately be adopted. With only 20 components, for instance, the cost characteristics of over a million potential standards would have to be evaluated – even after all first- and second-best technologies have been identified. Moreover, standard-setting is a process that unfolds over time, during which information is exchanged and participants refine their understanding of the characteristics of alternative technologies and alternative potential standards. Indeed, as Miller [2007] and Hovenkamp [2008] have stressed, claims of pending patents can be altered during that process. Thus if competition takes place too early, it is likely to be based on poor information, while if it takes place too late, the standard may be largely determined and hold-up may be unavoidable.

Finally, assumption (3), that the value of any standard to all potential users depends only on the total unit cost of the final product that it implies and not on the ownership of the underlying intellectual property, may seem innocuous, but it is inconsistent with the increasingly common presence of both integrated firms and innovation specialists in standard-setting processes.

To illustrate this point, consider the model of the preceding section with M = 1. Suppose there are two bids on the table, one from integrated firm 1 and one from an upstream innovation specialist. Both would enable production at unit cost C, and both bidders would charge per-unit royalty r. The integrated firm would clearly vote for its own standard, as it would rather receive royalties than pay them, and charging its rivals royalties would give it a cost advantage over them.[34] The innovation specialist, if it had a seat at the table, would vote for its own standard, since if it does not receive royalties it has no income.

What about firms 2, …, N, which, by assumption, would license the patent underlying the standard selected and compete with firm 1? From (12), if the innovation specialist's bid were accepted, each such manufacturing specialist could look forward to profit of

(18a) $$\Pi_i^{IS} = \left\{ \frac{(2-\gamma)(\alpha - C - r)}{(2-\gamma)[2+\gamma(N-1)]} \right\}^2, \qquad i = 2, \ldots, N,$$

while if integrated firm1's bid were accepted, the typical manufacturing specialist would earn

(18b) $$\Pi_i^{IF} = \left\{ \frac{(2-\gamma)(\alpha - C) - 2r}{(2-\gamma)\left[2+\gamma(N-1)\right]} \right\}^2, \qquad i = 2, \ldots, N.$$

If $\gamma = 0$ there is no competition among manufacturing firms, and firms 2, …, N would be indifferent between the two bids. But for $\gamma > 0$, they would clearly prefer the standard offered by the innovation specialist. While their per-unit royalty payments would be the same under both standards, (18a) shows the results of competition in which all manufacturers pay r, while (18b) shows what happens when firms 2, …, N pay r but firm 1 does not. If royalty rates are equal, manufacturing specialists always prefer standards offered by innovation specialists.[35] The presence of integrated firms adds a strategic dimension to bid evaluation.

The analysis of this section has shown that the desirable properties of formal, transparent ex ante competition are unlikely to be realizable in practice. In Section VI we discuss whether more limited use of ex ante competition might nonetheless be desirable. [36]

V. COLLECTIVE EX ANTE NEGOTIATION

The US and the EU have recently moved in the direction of revising antitrust policy to allow collective negotiation of royalty terms before standards are set, echoing aspects of Galbraith's [1952] endorsement of an economy with widespread 'countervailing power' between upstream and downstream firms with market power.

In its Technology Transfer Guidelines, the European Commission [2004, ¶225] states

> Undertakings setting up a technology pool … , and any industry standard that it may support, are normally free to negotiate and fix royalties for the technology package and each share of the royalties either before or after the standard is set.

But for the slight ambiguity introduced by 'normally' and the question of whether this approval applies outside the context of patent pools, this would be a blanket endorsement of collective negotiation of royalty rates.

In their recent intellectual property report, the US Department of Justice and Federal Trade Commission [2007, p. 52] make a broader assertion:

> In most cases, it is likely that the Agencies would find that joint ex ante activity undertaken by an SSO or its members to establish licensing terms as part of the standard-setting process is likely to confer substantial procompetitive benefits…

Though the agencies go on to say that 'joint ex ante licensing negotiations may raise competition concerns in some settings,' they give only an extreme example (forcing down the royalty rate for the only acceptable technology), and they cite Majoras [2005] for the proposition that collective negotiation rarely poses a risk to innovation incentives.[37]

Some commentators would go even farther. Skitol [2005, p 729], for instance, argues that SSOs should have an antitrust duty to implement ex ante mechanisms to avoid hold-up and that such mechanisms could include 'collective negotiation of the license agreement.'[38]

Unlike formal ex ante competition, there is no reason to doubt the general workability of collective negotiation. On the other hand, there are at least two reasons why bargaining behind closed doors may not produce socially desirable results.[39] First, the different strategic positions of integrated firms and innovation specialists may lead to the selection of inferior standards. Second, collective negotiation risks inducing a sub-optimal pace of invention and technological process.

To illustrate the first problem, consider again a situation in which a single innovation specialist and a single integrated firm, firm 1, offer competing standards with identical unit production cost *C*. Suppose the innovation specialist offers a per-unit royalty of *s*, and the integrated firm offers a per-unit royalty of *r*. Let us suppose that voting in the standard-setting organization is such that manufacturing specialists, firms 2, …, *N*, will determine which standard is selected. It follows from equations (18) that the manufacturing specialists will be indifferent between these two offers if $s = 2r/(2-\gamma)$; as long as γ is positive, firm 1 must charge a lower royalty rate in order to offset the reluctance of manufacturing specialists to compete against it with a cost disadvantage.

Suppose first that side payments are not possible. Then the bargaining process amounts to Bertrand competition between the integrated firm and the innovation specialist for the votes of the manufacturing specialists. Since the specialists' profits are decreasing in the royalty rate, one would expect both royalty rates to be driven toward zero. As $s \rightarrow 0$, the profit of the innovation specialist goes to zero, since royalties are its only source of revenue. On the other hand, as $r \rightarrow 0$, firm 1's profit approaches a positive quantity: its earnings as a manufacturing specialist in a royalty-free *N*-firm industry. Thus if the innovation specialist has positive fixed costs of licensing or from any other source, the integrated firm can always offer an $\tilde{r} > 0$ low enough that if the innovation specialist were to offer $\tilde{s} \leq 2\tilde{r}/\left(2-\gamma\right)$, the specialist's royalty revenues would not cover its fixed costs. This asymmetry thus favors the integrated firm over the innovation specialist.[40]

Now suppose that side payments *are* possible. In this case, it is natural to assume that the standard that leads to higher total industry profit, rather than the one that maximizes the profits of the manufacturing specialists alone, would prevail in negotiation. If the innovation specialist's standard were adopted, total industry profits would be

$$\Pi_T^{IS} = sN\frac{\alpha - C - s}{2+\gamma(N-1)} + N\left[\frac{\alpha - C - s}{2+\gamma(N-1)}\right]^2 \tag{19}$$

The first term is the innovation specialist's royalty revenues, and the second is the total profit of the N manufacturing firms. It is easy to show that this quantity is maximized by

$$s^* = (\alpha - C)\frac{\gamma(N-1)}{2\left[1+\gamma(N-1)\right]}. \tag{20}$$

With this royalty rate, the manufacturing firms produce the monopoly/cartel output and share the resulting profits with the innovation specialist. Call this outcome regime IS.

If the integrated firm's standard were adopted instead, total industry profits would be

$$\begin{aligned}\Pi_T^{IF} &= \left\{\frac{(2-\gamma)(\alpha - C) + \gamma(N-1)r}{(2-\gamma)\left[2+\gamma(N-1)\right]}\right\}^2 + r(N-1)\frac{(2-\gamma)(\alpha - C) - 2r}{(2-\gamma)\left[2+\gamma(N-1)\right]} \\ &+ (N-1)\left\{\frac{(2-\gamma)(\alpha - C) - 2r}{(2-\gamma)\left[2+\gamma(N-1)\right]}\right\}^2,\end{aligned} \tag{21}$$

The terms on the right are the integrated firm's operating profit, its royalty revenue, and the total operating profit of the remaining (N-1) manufacturers, respectively. This quantity is maximized by[41]

$$r^* = (\alpha - C)\frac{\gamma(2-\gamma)^2(N-1)}{4+4\gamma(N-2)-3\gamma^2(N-1)}. \tag{22}$$

Call this outcome regime IF.

When $\gamma = 0$, total industry profits are maximized with zero royalties in both regimes. When $\gamma = 1$, firm 1 sets r just high enough to induce its rivals to produce zero, and it produces the entire monopoly/cartel output itself. In these extreme cases, the two regimes yield the same value of total profit. For $0 < \gamma < 1$, however, firm 1 produces more in regime IF than it would in regime IS, while firms 2, …, N produce less. This asymmetry in outputs in regime IF reduces maximum total industry profit below that in regime IS. For $\gamma = 1/2$, for instance, the ratio of maximized total industry profits is

$$(23) \qquad \frac{\Pi_T^{IF*}}{\Pi_T^{IS*}} = \frac{(N+1)(45N^2+22N-3)}{2N(5N+3)^2},$$

which is less than one for all $N \geq 2$.[42]

Thus if side payments are possible, the integrated firm is at a strategic disadvantage in collective negotiation with equivalent technologies because it cannot cartelize the industry, while, as we showed above, if side payments are not possible, the innovation specialist is disadvantaged if it has fixed costs. It follows by continuity that if the advantaged firm has a slightly inferior technology (slightly higher production costs) it can nonetheless prevail in negotiation. Of course, without a reliable general model of real-world collective negotiation, it is unclear which sort of firm would be advantaged by how much under what conditions.

The second basic reason to be concerned about collective negotiation of royalty rates is the possible retardation of the pace of innovation. Collective negotiation necessarily entails the exercise of the collective monopsony power of potential licensees. To the extent that this leads to lower royalty rates, the incentives to develop new intellectual property are reduced. In addition, when integrated firms are engaged in collective decision-making about royalty rates, there is some risk of collusion to reduce innovative efforts.

One might argue that the rate of innovation or at least of patenting is in fact too high in some sectors, particularly those in which the patent thicket problem is severe. A problem with this argument is that the returns to major innovations would be reduced by collective negotiation, not just the returns to the minor advances that contribute more to patent thickets than to real progress. Alternatively, one could contend that in many industries the probability that any given innovation will be involved in standard-setting is low enough that the general use of collective negotiation in standard-setting would not have a major impact on the expected returns to innovation. This argument does not seem persuasive in the IT/communications sector, however, where standard-setting is of central importance.

Those who favor collective negotiation generally stress the importance of bringing existing knowledge more efficiently to the marketplace; they typically either ignore or dismiss the possible adverse impact of collective negotiation on the generation of useful knowledge.[43] Some argue that antitrust authorities would be able to prevent 'monopsonistic behavior that leads to allocative inefficiencies by unreasonably suppressing prices for IP used in standards,'[44] but without standards for the reasonability of such prices, it is hard to predict how, if at all, antitrust supervision of collective negotiation would limit the exercise of monopsony power.

VI. CONCLUDING OBSERVATIONS

The analysis of preceding sections has not revealed a simple and comprehensive solution to royalty-stacking and hold-up in standard-setting. While innovation specialists have received much of the blame for standard-setting problems and controversies, Section III showed that the royalty-setting behavior of integrated firms is equally affected by strategic considerations, so that a strong policy bias against innovation specialists would be hard to justify. Section IV presented conditions under which formal ex ante competition among potential licensors could eliminate hold-up and mitigate royalty-stacking but argued that this approach is unlikely to be workable in practice. Section V contended that allowing potential licensees to act as a buyers' cartel to negotiate royalty rates would risk biasing standard-setting processes and slowing the pace of technical progress. The remainder of this section briefly considers some less comprehensive policy alternatives.

The U.S. Federal Trade Commission's recent *N-Data* settlement involves expanding the reach of antitrust policy to reduce troll-like behavior as well as hold-up. In that case, the Commission asserted that behavior by a patent-holder during standard-setting that led to higher royalties (charging a royalty higher than that promised by a prior owner of the patent) was an 'unfair method of competition' and thus a violation of Section 5 of the FTC Act, even though the Commission did not contend that the behavior in question gave rise to monopoly power or even market power.[45] If in some future case this interpretation of the Commission's authority under Section 5 is contested in and upheld by the courts, the door would be open to a US antitrust policy regime in which deception in standard-setting would be an offense even if it could not be shown to affect the standard adopted.

While it may be appropriate to make at least certain forms of deceptive conduct in standard-setting illegal even absent an impact on the standard selected, however, it does not seem particularly natural to do this under the antitrust umbrella. In US and the EU, competition policy has in recent decades been focused on the socially undesirable acquisition or exercise of market or monopoly power. It has not established or even sought to establish principles of 'unfair competition' that do not involve market power.

For this reason among others, Kobayashi and Wright [2009] argue that antitrust is less well-suited to deal with deception in standard-setting than the US patent law doctrine of equitable estoppel: roughly, the principle that if a patent-holder engages in deception on which another party relies, it cannot sue that other party for patent infringement. They also argue that provisions of state contract and tort laws can be used to deal with troll-like behavior and hold-up. Further, individual firms have always been able to protect themselves from hold-up (though not, of course, from troll-like behavior) by bilateral ex ante negotiation of royalty rates.[46] When coupled with a FRAND commitment not to charge substantially different royalty rates ex post to similarly situated licensees, licenses obtained ex ante by a few firms can serve to extend some measure of hold-up protection to other potential licensees. Of course, since many observers consider these tools to have proven inadequate in aggregate, it may be useful to sharpen one or more of them legislatively.

Antitrust authorities have played a generally positive role in recent years by enabling practices and processes that serve to reduce ex ante uncertainty regarding ex post licensing terms, though, as I argued in Section V, they seem to have been too little concerned with the dangers of licensee collusion. The movement on both sides of the Atlantic away from per se condemnation of consideration of royalty rates in standard-setting processes is certainly a positive step, for instance. In addition, the favorable business review letters issued in 2006 and 2007 by the US Department of Justice in response to proposals from two standard-setting organizations – VITA and IEEE-SA, respectively, are at least interesting experiments with multi-lateral mechanisms to reduce ex ante uncertainty that stop short of both collective negotiation and formal ex ante competition.[47]

The core of the VITA proposal is a requirement that participants in any standard-setting processes disclose all patents that may become essential to the standard being developed, along with the maximum royalty rates and the most restrictive non-royalty provisions they would demand. Individual working group members are permitted to consider these rates and terms in developing the standard, but they are not permitted to negotiate or discuss them. The IEEE-SA proposal involves voluntary disclosure of potentially essential patents, along with maximum royalty rates or most restrictive non-royalty terms. If patents and licensing terms are disclosed, working groups may use them to evaluate the relative costs of alternative standards, though specific licensing terms may not be discussed.[48]

Both mechanisms involve limitations on communication. If these limitations prove unenforceable, these mechanisms may enable licensee collusion. In its response to the IEEE-SA (Barnett [2007]), the US Department of Justice noted that discussions of costs 'could … rise to the level of joint negotiation of licensing terms' but simply said that such negotiation would be analyzed under the rule of reason, which could be read as encouragement of collective negotiation. In any case, experience with these two new mechanisms should be carefully monitored so that it can help shape future policies toward SSOs and their activities.

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[1] http://standards.ieee.org/announcements/media.html.

[2] *Ibid.*

[3] As Shapiro [2001b] notes, quality, design, or performance standards can be more easily used as collusive or exclusionary devices than the compatibility standards that are most common in the IT/communications sector.

[4] See Geradin [2006] for a useful general discussion of standard-setting processes.

[5] Lévêque and Ménière [2008].

[6] See Tirole et al [2003] and Rysman and Simcoe [2008].

[7] For discussions of relevant US proceedings, see Farrell et al [2007], Ganske [2008], Hovenkamp [2008], and Wright [2009]. Zoettl et al [2009] provide a global overview of recent developments at the intersection of antitrust and patent law.

[8] This strategy, which involves accumulation of large patent portfolios for strategic reasons, has been colorfully described as 'Mutually Assured Destruction' by the US Federal Trade Commission [2003, ch. 2, pp. 30-31].

[9] In the US, see Jaffe and Lerner [2004], US Federal Trade Commission [2003], US National Academy of Science [2004], and, for an analysis stressing differences among industries, Burk and Lemley [2009]. Harhoff [2006] and Harhoff et al [2007] argue that these problems are emerging in the EU.

[10] For discussions of this issue, see Shapiro [2001a] and Padilla and Teece [2007].

[11] Other factors may also have complicated standard-setting. For instance, Simcoe [2008] argues that the slow-down in standards production at the Internet Engineering Task Force

between 1993 and 2003 can be attributed in large measure to distributional conflicts created by the rapid commercialization of the Internet.

[12] For discussions see Geradin et al [2008c], Padilla and Teece [2007] and the references they cite. Simcoe [2006] attributes the rapid increase in intellectual property disclosure in a sample of standard-setting organizations in the early 1990s to the rise of small innovation specialist firms. This development would have been impossible without strong intellectual property rights. For example, Hall and Ziedonis [2001] argue that the strengthening of patent rights in the 1980s contributed to the rise of 'fabless' semiconductor design firms.

[13] See the references cited in note 7, above.

[14] *eBay, Inc. v. MercExchange, LLC*, 547 U.S. ___ (2006), slip opinion available at http://www.supremecourtus.gov/opinions/05pdf/05-130.pdf. The discussions of 'non-practicing entities' by the US Federal Trade Commission [2003; ch. 2, pp. 30-31; ch. 3, pp. 38-41] provide additional evidence of pervasive hostility; see also the references cited by Geradin et al [2008c].

[15] See Lemley [2008, n. 2] on the origin of this term. Some observers confine the use of the term 'troll' to small firms that acquire patents only for the purpose of suing and would use the term 'patent ambush' for the behavior described here. Lemely [2008], Geradin et al [2008c], and the references they cite provide discussions of alternative definitions.

[16] On the *Rambus* case, see Wright [2009]; more general discussions of related issues are provided by Farrell et al [2007], Villarejo and Banasevic [2008], and Hovenkamp [2008].

[17] Large technology-based firms may have portfolios of thousands of patents, each with multiple claims. To require a single complete search would be sufficiently burdensome as to

discourage participation in standard-setting, and multiple searches might be required as a standard-setting process shifts direction over time and patent portfolios change. (See Miller [2007] on this latter point.) Thus few SSOs require even a single complete search, but without a complete search, individuals participating in standard-setting may be unaware of relevant patents held by their employers. Further complications are the incentive to over-disclose to avoid litigation and the offsetting incentive to make only vague disclosures in order not to reveal R&D strategies. For relevant discussions, see Chiao et al [2007], Farrell et al [2007], Lemley [2002], and Simcoe [2006].

[18] Lévêque and Ménière [2007] show that reducing or eliminating the risk of hold-up by all potential licensors may benefit licensors as well as consumers by encouraging the entry of manufacturing specialists.

[19] See Chiao et al [2007] and Lemley [2002]. In what follows I will use FRAND to refer to both sorts of commitment for simplicity.

[20] Thus, for instance, the US Federal Trade Commission recently found that a reasonable royalty is 'the amount the industry participants would have been willing to pay to use a technology over its next best alternative prior to the incorporation of the technology into a standard' (Opinion of the Commission on Remedy, In re Rambus, Inc., FTC Docket 9302, at 17, February 5, 2007, available at http://www.ftc.gov/os/adjpro/d9302/070205opinion.pdf). Geradin et al [2008b] and Geradin and Rato [2007] reject this standard and argue that FRAND simply implies a commitment to negotiate in good faith. Miller [2007] argues that signatories to FRAND commitments have given up the right to obtain injunctive relief. Layne-Farrar et al [2007] note that some have argued that FRAND implies 'numerical

proportionality': all essential patents should receive equal royalty rates. Lemley [2002] argues that FRAND is a commitment to license, with a court to determine whether the offered rates are reasonable.

[21] The available evidence, such as it is, suggests that royalty-stacking is not generally important: compare Shapiro [2006], Lemley and Shapiro [2007], Geradin et al [2008a], Denicolò et al [2007], and Padilla and Teece [2007].

[22] It does not seem uncommon for royalty agreements in practice to involve lump-sum payments instead of or in addition to per-unit or ad valorem royalties. It is worth noting, however, that if a royalty agreement involves a substantial lump-sum component, it will differentially disadvantage small firms and may thus be challenged as violating the non-discrimination portion of a FRAND commitment.

[23] Kim [2004] analyzes this same two-stage model with $\gamma = 1$, while Schmidt [2008] considers a more general model of downstream competition. The standard-padding model of Dewatripont and Legros [2008] is also related to this analysis, though they assume away downstream competition and use the Shapley value rather than some non-cooperative process to divide royalties among holders of essential patents.

[24] In more realistic settings in which firms differ – perhaps because of differences in intellectual property, manufacturing facilities, or distribution channels – standards that would raise total welfare may also fail to be adopted because they would increase the profits of some firms but not others.

[25] Schmidt [2008] provides a useful exposition.

[26] See, e.g., Shapiro [1985].

[27] It is straightforward to demonstrate that the qualitative comparisons in this paragraph also hold when N = 2 for any $\gamma \in [0,1]$.

[28] This model builds on the analysis of Layne-Farrar et al [2007, Sect. IV.A.] and seems broadly consistent with the discussion in Farrell et al [2007, p. 642].

[29] If this assumption alone is violated, the bid evaluator's task becomes more complex to describe precisely, but it remains fundamentally the same: to compare total royalty plus production cost for all possible standards.

[30] If one firm sets its royalty rate a penny too high so that even one inequality is violated, all get zero. When there are multiple equilibria, as there typically are, it is not clear how a bidding game could be designed to select one of them in practice.

[31] I am indebted to a referee for the observation that this property follows from Theorem 2 in Bernheim and Whinston [1986], since the firms in this model are restricted to make unconditional bids.

[32] Layne-Farrar et al [2007, Section IV.B] discuss ex ante application of the Shapley value from cooperative game theory as a fairness-driven alternative to ex ante competition. The Shapley value approach also bases rewards on incremental contributions, but it has the somewhat unpalatable implication that technologies considered but not included in a standard typically receive positive royalties.

[33] If quality differences were simple enough – relating only to durability, for instance, or to the flow of homogeneous services provided – all participants might have the same willingness to pay for increments to quality. But such unanimity will hold only in very special cases.

[34] See the discussion of the 'toehold effect' by Geradin et al [2008b].

[35] Consumers might disagree. It is easy to show that with equal royalty rates total output would be higher under the integrated firm's standard than if the innovation specialist prevailed. Evaluating derivatives of equation (3) at r = 0 shows that for small and equal royalty rates, consumers would prefer the integrated firm's standard.

[36] For more extensive discussions of the limitations of formal ex ante competition, see Geradin [2006], Geradin and Layne-Farrar [2007], and Geradin et al [2008b].

[37] See also Antitrust Modernization Commission [2007, ch. I.D], where a rule of reason analysis of collective negotiation is recommended, but no guidelines for such analyses are provided, and Masoudi [2007].

[38] See also Lemley [2007].

[39] For other discussions of collective negotiation, see Geradin [2006], Layne-Farrar et al [2008], Lemley [2007], Sidak [2008], and Swanson and Baumol [2005, pp. 13-14]. Note that with downward-sloping demand for the final product, collective negotiation without a licensor cartel will not remove incentives for royalty-stacking. And, as with ex ante competition, since knowledge accumulates during standard-setting processes it is not clear when negotiations should take place.

[40] This is, again, related to the toehold effect discussed by Geradin et al [2008b].

[41] The denominator on the right of equation (22) is always positive in the relevant region. It is minimized as a function of γ at $\gamma = (2N\text{-}1)/3(N\text{-}1)$. It is positive at that point when $N = 2$ and increasing in N for $N \geq 2$.

[42] Numerical evaluation shows that for $0 < \gamma < 1$ and $2 \leq N \leq 30$, the ratio of maximum total profit in regime IF to that in regime IS declines with N: as N rises, both r and s are optimally

increased to restrict competition, but higher values of r magnify the profit-reducing output distortion between firm 1 and the other manufacturers. For N in this range, this ratio is minimized for $0.65 < \gamma < 0.85$ and the minima always exceed 0.89.

[43] Thus while the Antitrust Modernization Commission [2007, p. 121] notes that the exercise of shared monopsony power might force rates below 'a reasonable level,' it does not suggest how this danger might be avoided. In a widely-cited speech, Majoras [2005] argues that if SSO members jointly lack buying power, 'they would be not be able to impose a lower than competitive rate,' though in that case it is not clear what the point of joint negotiations would be. She argues that the exercise of monopsony power would be limited both by patent-holders' ability to decline to participate (and risk having their technologies excluded from the standard) and by mutual forbearance among integrated firms (which would also operate without collective negotiation). Skitol [2005] argues that a variety of untested procedural safeguards could avoid licensee cartel behavior, and Farrell et al [2007, pp. 632-3] simply assert that it is worth running some risk of licensee cartel behavior in order to reduce the hold-up problem. On this last assertion, see Sidak [2008].

[44] This language is from Meyer [2008], then a senior official in the US Department of Justice. His subsequent assertion that SSOs 'should be confident that they have substantial legal breathing room' seems to signal that antitrust supervision in the US would be very permissive.

[45] On the *N-Data* settlement, see the Commission's statement, available at http://www.ftc.gov/os/caselist/0510094/080122statement.pdf, as well as the dissent by Chairman Majoras, available at http://www.ftc.gov/os/caselist/0510094/080122majoras.pdf.

See also Froeb and Ganglmair [2009], Ganske [2008], Lande [2009], Kobayashi and Wright [2009], and Layne-Farrar [2009].

[46] See Layne-Farrar et al [2008] for a useful comparison of ex ante bilateral negotiation with collective negotiation, and see Farrell et al [2007, pp. 238-41] for a discussion of non-discriminatory royalties. Note that if a technology licensed ex ante is not included in a standard ex post, the licensee will generally be out only its licensing costs – which one could think of as the premium for insurance against hold-up.

[47] Barnett [2006] and [2007]. See Masoudi [2007] for discussions and more detailed summaries of these proposals, and see Sidak [2008] for a critique.

[48] Disclosures to the IEEE-SA are posted on its website, http://standards.ieee.org/db/patents/. It is interesting that as of July, 2008, no maximum rates had been posted.