PRICING PATENTS FOR LICENSING IN STANDARD SETTING ORGANIZATIONS: MAKING SENSE OF *FRAND* COMMITMENTS

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Abstract

We explore potential methods for assessing whether licensing terms for intellectual property declared essential within a standard setting organization can be considered fair, reasonable, and non-discriminatory (FRAND). We first consider extending *Georgia-Pacific* to a standard setting context. We then evaluate numeric proportionality, which is modelled after certain patent pool arrangements and which has been proposed in a pending FRAND antitrust suit. We then turn to two economic models with potential. The first—the efficient component-pricing rule (ECPR)—is based on the economic concept of market competition. The second—-the Shapley value method—is based on cooperative game theory models and social concepts for a fair division of rents. Interestingly, these two distinct methods suggest a similar benchmark for evaluating FRAND licenses, but ones which might appeal differently to the courts and competition authorities in the US as compared to Europe. We find that under any approach, patents covering "essential" technologies with a greater contribution to the value of the standard and without close substitutes before the standard gets adopted should receive higher royalty payments after the adoption of the standard.

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1. INTRODUCTION

Fair, Reasonable, and Non-Discriminatory—an interesting collection of commonly used, but emotion-laden words that become even more emotionally charged when strung together. The acronym FRAND, which yokes these words together, turns out to have considerable practical importance, especially in standard-setting situations. A FRAND commitment has serious legal implications, a commitment to offer intellectual property such as patents to licensees on fair, reasonable, and non-discriminatory terms and conditions. Unfortunately, even though many are committed to FRAND licensing, there is no universally agreed upon operational definition of that commitment.[1]

Intellectual property rights, especially patents, have become a customary feature in standard-setting efforts over the last few decades. For example, the European Telecommunications Standards Institute (ETSI) considers having patents in their standards as "inevitable and unavoidable" (Bekkers, Verspagen and Smits 2002:173). Along with these unavoidable patents have come rules regarding their disclosure and their licensing. Most standard setting organizations (SSOs), including ETSI, request that their members make reasonable efforts to identify and disclose any intellectual property that might be relevant for a standard under development.[2] Once disclosed, most SSOs also request that members agree to license their relevant patents on FRAND terms.[3] (In the US, RAND, which drops "fair", is required instead.) Given the high

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[1] Swanson and Baumol (2005, page 5) note: "It is widely acknowledged that, in fact, there are no generally agreed tests to determine whether a particular license does or does not satisfy a RAND commitment." Goldstein and Kearsey (2004, page 27) echo this: "Unfortunately, these terms [RAND and FRAND] are not well defined. Ambiguity in the definition of 'FRAND' is, in our opinion, one of the core problems in the licensing of rights to patents essential for implementation of a written technical standard." Likewise Rapp and Stiroh (2002, page 9) state: " The typical SSO patent policy mandating that a royalty be "fair, reasonable and non-discriminatory" gives little guidance for royalty determination because "reasonable" can mean different things to a technology owner and a technology buyer." For an excellent survey of the debate surrounding FRAND, see Geradin (2006).

[2] Firms not making relevant disclosures risk litigation over unfair business practices. See, for example, Federal Trade Commission, In the Matter of Rambus, Inc., Docket No. 9302, Opinion of the Commission (2006).

[3] For a discussion of SSO intellectual property rules, see Benjamin Chiao, Josh Lerner, and Jean Tirole (2005).

stakes frequently involved in standard-setting,[4] it is no surprise that the definition of FRAND has been the subject of heated debate in recent years.

One school of thought is that FRAND commitments are meant to address a prominent concern in standard-setting: the adoption of a technology into a major standard could confer substantial market power, or substantially increased market power, on its owner. Companies with patents that have been selected for a standard—rendering them "essential" since those patents are "required" to meet the standard[5]—may be tempted to opportunistically abuse this market power; for example, by refusing to license or charging excessively high royalty rates.

In fact, several recent cases have involved such claims, focusing directly on SSO members' FRAND commitments. Within the US, Broadcom alleged that Qualcomm's patent licensing policies violated its FRAND commitment to ETSI for the mobile telephone 3G standard, and violated the Sherman Act in the process.[6] Nokia is also pursuing Qualcomm, although in a different US court and without reference to antitrust law.[7] The primary charge in the Nokia case is that a member's FRAND promise to an SSO, like ETSI, forms an enforceable contract.[8] Thus Nokia is claiming that Qualcomm breached its contract by offering licensing terms that, in its view, are not FRAND. Nor is the US the only FRAND battle front. In Europe, six telecommunications firms (including Broadcom and Nokia) have alleged that Qualcomm's patent licensing policies violate European antitrust law—specifically Article 82 (Telecomworldwire October 28, 2005).[9] Conflicting definitions of FRAND lie at the heart of all of these cases.

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[4] See, for example, Brian DeLacey, Kerry Herman, David Kiron, and Josh Lerner (2006).

[5] "Required" may often be too strong a word. See the discussion of how and why patents get disclosed to SSOs in Chiao, Lerner, and Tirole (2005). Moreover, even if a patent is technically essential for implementing a standard, it might be relatively easy to invent around, or it might cover an optional feature of the standard that can be omitted in some applications.

[6] Broadcom Corp. v. Qualcomm, Inc., No. 05-3350 (D. N.J. Aug. 31, 2006). The court granted summary judgement in Qualcomm's favor.

[7] Nokia Corp. v. Qualcomm, Inc., No. 06-509 (D. Del Aug. 16, 2006).

[8] Earlier cases have involved similar claims of contract, but settled prior to a ruling. See ESS Technology, Inc. v. PC-Tel, Inc., No. C-99-20292 (N.D. Cal. Nov. 4, 1999); Agere Sys. Guardian Corp. v. Proxim, Inc., 190 F. Supp. 2d 726 (D. Del. 2002).

[9] Ericsson, NEC, Panasonic, and TI are the four remaining complainants.

In this paper, we discuss ways in which the courts in the US and Europe might evaluate what behaviour is and what is not compliant with SSO members' FRAND commitments. That is, we attempt to give more tangible meaning to the concept of FRAND licensing. Section 2 briefly reviews the intellectual property and SSO literatures, which find patent values to be highly unequal, to put the FRAND problem into context. Section 3 discusses two options for giving content to FRAND that emerge from the courts. One option is extending *Georgia-Pacific*, which is the primary case guiding reasonable royalty determination in patent infringement cases in the US. *Georgia-Pacific* lays out 15 factors that should be accounted for when calculating reasonable royalty rates, most of which can be easily extended to a standard setting context. The second option is numeric proportionality, which the European complainants in the *Qualcomm* case have put forth as a definition for FRAND. Under numeric proportionality, each firm contributing patents to a standard would receive a share of the total royalties for the entire standard in proportion to the number of patents it reports as "essential" (Ericsson Press Release 2005; Chappatte 2006). Of course, the total royalty rate for the standard would still need to be determined, so even under this option *Georgia-Pacific* factors might play a role. Numeric proportionality can lower transaction costs, but generally at the expense of efficiency and equity.

The next section, Section 4, turns to models in the economics literature that show promise of providing plausible benchmarks for FRAND: the Efficient Component-Pricing Rule (ECPR) and the Shapley value. ECPR was proposed in the late 1970s as a method for ensuring that pricing "bottleneck" facilities, like local electricity or telephone networks, in the face of competition in related services would be consistent with economic efficiency (Willig 1979; Baumol 1983).[10] We first consider ECPR as a possible benchmark for RAND cases in the US, where economic efficiency concepts tend to be favoured. We next consider the Shapley value, based on cooperative game theory, which was proposed by Lloyd Shapley in 1953 as a "fair" method for dividing the rents generated by multiple cooperating participants in any unspecified activity (Shapley 1953). The Shapley value approach holds promise as a possible

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[10] For a recent application of ECPR to FRAND, see Swanson and Baumol (2005).

benchmark for FRAND cases in the EU, where economic efficiency is viewed as important but fairness considerations are also given considerable weight.[11] At the end of this Section, we compare these two economic approaches, which remarkably often lead to the same answer despite their dramatically different philosophical bases.

In Section 5, we summarize and conclude our analysis. Regardless of whether economic efficiency or fairness is the paramount concern, one cannot ignore the contribution a patent makes to the value of a standard nor the existence of substitute technologies in any sensible, fair distribution of rents. That means numeric proportionality rules will only be applicable under narrow circumstances. While the *Georgia-Pacific* factors make good guidelines for FRAND licensing evaluations under general circumstances, we argue that the two economic models provide the most solid framework for courts and competition authorities faced with FRAND cases.

2. LICENSING, PATENT VALUE AND STANDARD SETTING

Scholars and practitioners have been struggling with how, in general, to value intellectual property for quite some time. The literature on patent licensing, especially the theoretical literature, is vast.[12] No *one* method for establishing a price emerges from that literature. Of those methods that have been suggested, most have both advantages and disadvantages and must therefore be evaluated in light of the situation at hand.

The more accepted methods for pricing intellectual property are based on traditional financial analysis. This approach equates the price of a patent to the expected discounted stream of benefits derived from practicing and/or licensing the patent (Parr and Smith 1994). Because the future typically involves choices, Pakes (1986) suggests a somewhat more general approach relying on option pricing.[13] These financial approaches link the value of a patent to what we will term as its "marginal" or "incremental" contribution. That is, (a) its contribution to the value of the products

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[11] See Christian Ahlborn and Carsten Grave (2006) and David J. Gerber (1998).
[12] For surveys of the theoretical literature, see Kamien (1992); see also Scotchmer (2004).
[13] Ariel Pakes (1986) develops a model in which patents are compared to options. For a discussion of the strengths and weaknesses of option value analyses, see Josh Lerner and John Willinge (1996: section 5).

and/or services that embed its technology and (b) the existence of current and/or potential alternatives.

In practice these approaches may be hard to implement. Estimating the future stream of revenues "due" to a patent owner for a patent as employed by a licensee requires estimating how much a particular patent contributes to a good or service, as distinct from other intellectual property embedded in that good or service plus all of the other contributors to revenues, such as marketing and promotions. Furthermore, calculating the appropriate license revenues also requires estimating the willingness to pay of a third party, in light of its current and likely future alternatives. Potential licensees always have the option of not taking out a license if the royalty sought makes some other technology (or some other business entirely) more economically attractive. The option value approach makes this explicit, as substitute technologies and the option of "doing nothing" can be included on the option tree.

Despite the difficulties involved in measuring patent value, it is widely recognised that only a handful of patents are highly valuable—because they influence follow-on innovations and/or cover commercially successful technologies, products or services for which there are no available substitutes—while the majority of patents hold very little value to either the original patent holder or any one else. In other words, the distribution of patent values is highly skewed.[14]

While patent valuation in the standard-setting context has some unique aspects, there is reason to believe that patent value will be uneven here as well. The manner in which patents are disclosed to a standard setting organization ensures that this will be the case. First, deciding when to disclose a patent as "reading on" a standard (i.e., relevant to it) is a judgement call. Even companies participating in the standard making process may not be clear on whether their patents are essential for a standard. As one book on licensing technology explains:

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[14] Skewness refers to the shape of the distribution curve. In this case, the curve is shifted to the left, with a large peak at very low values and a long "tail" representing a small number of patents with high values. For examples in the literature discussing the skewed distribution of patent value, see F.M. Scherer, S. Herzstein, Jr., A. Dreyfoos, W. Whitney, O. Bachmann, C. Pesek, C. Scott, T. Kelly, and J. Galvin (1959); J.O. Lanjouw, A. Pakes and J. Putnam, (1998); D. Harhoff, F. Narin, M. Scherer and K. Vopel, (1999); F. M. Scherer and D. Harhoff (2000); Wesley M. Cohen and Stephen A. Merrill (2003).

Today there is substantial confusion about which patents are essential for any technical implementation of a standard. If the standard explicitly incorporates a patent, then of course there is little problem, but that happens only rarely. More commonly, each patent must be evaluated by *someone*, according to *some methodology*, who will determine whether the patent is essential according to that methodology (Goldstein and Kearsey 2004).

Empirical research supports this observation. In interviews, Chiao, Lerner, and Tirole (2005:5-6) find that the size and complexity of some firms' patent portfolios make it difficult for firms to know which of their patents read on a standard; some respondents likened the task to the search for a needle in a haystack. This can be especially true if the firms send only technical specialists to SSO meetings, without including upper management or strategic decision makers.[15] Chiao et al. (2005:6) also report that some firms argue that disclosing specific patents reveals valuable information to rivals about future technology strategies. Recognition of these legitimate business concerns is likely one reason that SSOs like ETSI (2005) simply request that members use "reasonable endeavours" to identify relevant intellectual property, rather than demand an exhaustive reporting.

Weighing against the incentives not to disclose too much is an incentive to disclose more than is needed. In the United States, the courts have found in several cases that failing to disclose intellectual property to an SSO in a timely fashion constitutes fraudulent or unfair behaviour, with remedies typically stripping or at least limiting the offending companies' intellectual property rights.[16] Likewise, the European Commission has shown its determination to prevent "patent ambush". Competition Commissioner Neelie Kroes recently stated:

Standards are of increasing importance, particularly in hi-tech sectors of the economy. It is crucial that standard-setting bodies establish rules

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[15] Including strategic decision makers in the team for standard setting organization meetings is a relatively new phenomenon. See, e.g., Gandal, Gantman, and Genesove, (2004).

[16] See *In re Dell Computer Corp.* (FTC Docket No. C-3658); *Stambler v. Diebold, Inc.*, 11 U.S.P.Q. 2d (BNA) 1709 (E.D.N.Y. 1988); *Potter Instrument Co. v. Storage Tech. Corp.*, 207 U.S.P.Q. (BNA) 763 (E.D. Va 1980); and *Wang Labs., Inc. v. Mitsubishi Elec. Am. Inc.*, 860 F. Supp. 1448, 30 U.S.P.Q. 2d (BNA) 1241 (C.D. Cal. 1993). See also, United States District Court for the Eastern District of Virginia. Judge Robert E. Payne. Rambus, Inc. v. Infineon Techs. AG, 164 F. Supp. 2d 743, 2001 U.S. Dist. LEXIS 11871 (E.D. Va., 2001). Of course, there have been other cases brought in U.S. courts that were decided in favour of the defendants, such as *Wang Labs., Inc. v. Mitsubishi Elecs. Am., Inc*., 103 F.3d 1571 (Fed. Cir. 1997).

which ensure fair, transparent procedures and early disclosure of relevant intellectual property. We will continue to monitor the operation of standard-setting bodies in this regard.[17]

As a result of these factors, the list of disclosed "essential" patents for a given standard is likely to be a mixture of the patents that firms can readily identify, those that firms are not too reluctant to disclose for valid strategic reasons, and those that may or may not be genuinely essential for implementation but are included as insurance against the threat of non-disclosure litigation.

Aside from requesting disclosure of the relevant intellectual property, and demanding that the patents disclosed as essential be licensed on FRAND terms, SSOs generally do not venture to define, request, or even advise on any specific licensing terms. In fact, we are not aware of any SSO that explicitly sets out what licensing terms must be to comply with a member's FRAND commitment. This lack of specificity is not surprising. Licensing is, among other things, a pricing matter, and antitrust authorities have traditionally been highly sceptical of organizations where competitors meet to discuss business plans and pricing strategies.

While the lack of definition within standard setting organizations is understandable (and perhaps even optimal), it also leaves the courts and competition authorities to their own devices in making FRAND a practicable concept. In the remainder of the paper, we consider the options open to the courts and the competition authorities for giving FRAND specific meaning.

3. COURT-BASED RULES

Two options for defining FRAND come through the courts. The first is the framework employed for judging reasonable royalties in patent infringement cases: the *Georgia-Pacific* factors. The second is the proposal that the complainants in the

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[17] See, *e.g.*, the Competition Commission's press release from December 2005 on their review of IPR rules at ETSI, available at
http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/1565&type=HTML&aged=0&language=EN&guiLanguage=en.

European case have put forth: numeric proportionality. In this section, we discuss these two potential approaches, pointing out any advantages or disadvantages.

A. *Georgia-Pacific*'s Fifteen Factors

Within the US, the seminal case for establishing reasonable royalties for patent infringement is *Georgia Pacific v. United States Plywood*, decided in 1970 in the Southern District of New York.[18] In that case, the court found that United States Plywood infringed Georgia Pacific's patent for decorative striated plywood panels. The Judge then proposed 15 factors that should be taken into consideration when calculating a reasonable royalty rate for the purposes of determining damages:

1. The royalties received by the patentee for the licensing of the patent in suit, proving or tending to prove an established royalty.

2. The rates paid by the licensee for the use of other patents comparable to the patent in suit.

3. The nature and scope of the license, as exclusive or non-exclusive; or as restricted or non-restricted in terms of territory or with respect to whom the manufactured product may be sold.

4. The licensor's established policy and marketing program to maintain his patent monopoly by not licensing others to use the invention or by granting licenses under special conditions designed to preserve that monopoly.

5. The commercial relationship between the licensor and licensee, such as, whether they are competitors in the same territory in the same line of business; or whether they are inventor and promotor.

6. The effect of selling the patented specialty in promoting sales of other products of the licensee; the existing value of the invention to the licensor as a generator of sales of his non-patented items; and the extent of such derivative or convoyed sales.

7. The duration of the patent and the term of the license.

8. The established profitability of the product made under the patent; its commercial success; and its current popularity.

9. The utility and advantages of the patent property over the old modes or devices, if any, that had been used for working out similar results.

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[18] Georgia-Pacific Corp. v. U.S. Plywood Corp., 318 F. Supp. 1116 (D.N.Y. 1970). Legal scholars appear to agree that the fifteen "*Georgia-Pacific* factors have served as the standard framework … for over 30 years." Epstein, Roy J. and Alan J. Marcus, "Economic Analysis of the Reasonable Royalty: Simplification and Extension of the Georgia-Pacific Factors," *Journal of Patent and Trademark Office Society*, Vol. 85, July 2003, p. 555.

10. The nature of the patented invention; the character of the commercial embodiment of it as owned and produced by the licensor; and the benefits to those who have used the invention.

11. The extent to which the infringer has made use of the invention; and any evidence probative of the value of that use.

12. The portion of the profit or of the selling price that may be customary in the particular business or in comparable businesses to allow for the use of the invention or analogous inventions.

13. The portion of the realizable profit that should be credited to the invention as distinguished from non-patented elements, the manufacturing process, business risks, or significant features or improvements added by the infringer.

14. The opinion testimony of qualified experts.

15. The amount that a licensor (such as the patentee) and a licensee (such as the infringer) would have agreed upon (at the time the infringement began) if both had been reasonably and voluntarily — who desired, as a business proposition, to obtain a license to manufacture and sell a particular article embodying the patented invention — would have been willing to pay as a royalty and yet be able to make a reasonable profit and which amount would have been acceptable by a prudent patentee who was willing to grant a license.[19]

The majority of these factors are directly applicable to FRAND evaluations in a standard setting context, especially for patents with a licensing history prior to their inclusion in a standard. Those factors not already applicable could be easily extended. For instance, factor 13 could be modified to read "the portion of the realizable profit that should be credited to the standard component covered by the invention as distinguished from other components, both patented and non-patented, …"

Despite the detail and the length of the *Georgia-Pacific* list, the factors do not in fact prescribe the exact method for calculating reasonable royalties. They are instead the guidelines against which specific reasonable royalty approaches are generally judged. In infringement suits, both sides typically present their own calculations and the presiding judge rules on which of the two is more reasonable under the circumstances at hand, or throws both proposals out and offers his or her own calculation. The judge has

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[19] This is by necessity a hypothetical exercise, since in fact there was no willing licensee and no willing licensor, otherwise there would have been no infringement case. A point recognized in the *Georgia-Pacific* decision, and by subsequent courts, such as the one that decided *Panduit* in 1978. Panduit Corp. v. Stahlin Bros. Fibre Works, Inc., 575 F.2d 1152 (6th Cir. 1978). The exercise is worthwhile nonetheless since it casts the reasonable royalty question in the specific circumstances of the firms and patents involved

considerable discretion over the particulars, including the choice of an accounting method.[20]

A similar process might work in FRAND disputes as well. FRAND would be left as a largely undefined but enforceable promise with an SSO. In the event of a dispute, such as the cases currently underway in the US and Europe, the disputing parties would put forth their best arguments in support of specific licensing terms. The judge would either choose one of those proposals or justify a third, which the parties would then have to implement.

B. Numeric Proportionality

The complainants in the EC case argue that all patents which are "essential" to a standard should be regarded as equally valuable and treated symmetrically, since they all afford patent holders the same market power (or hold up power) ex post (Chappatte 2006). Extending this line of thought, the complainants propose that royalties satisfying the FRAND promise are those that are proportional to the number of essential patents contributed to the standard. If 100 patents are found to be essential, and firm A holds 10 of them, firm A should receive 10% of the total royalty the standard commands. On the face of it, this proposal may appear quite egalitarian, and thus at least likely to satisfy the "fair" part of FRAND.

Numeric proportionality rules are used today in some licensing settings. For instance, several recently formed patent pools, all of which grew out of standard setting efforts, use numeric proportionality formulae to distribute the pool's royalty earnings among participants (Layne-Farrar and Lerner, 2006). The primary motivation for adopting numeric rules is lower transaction costs. Simple numeric formulae make royalties easy to calculate and administer and easy for patent holders to verify.

This one advantage, however, is offset by a number of disadvantages. The first is a practical concern. Numeric rules only make sense when the group of patents defining the licensing universe is boiled down to those patents that are truly essential for

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[20] See, for example, the discussion in Smithkline Diagnostics, Inc. v. Helena Laboratories Corp., 926 F.2d 1161 (Fed. Cir. 1991).

the standard. The patents *declared* as "essential" for a standard may or may not be either technically or commercially essential. As discussed above, the circumstances under which patents are identified as "essential" may lead to less than perfect disclosure for a number of reasons. Nor do SSOs typically evaluate submissions to determine essentiality (Goldstein and Kearsey 2004). As a result, mere self-reporting is not enough to establish whether a patent is genuinely needed for a standard. A rule compensating companies holding patents of questionable relevance, but which are nonetheless declared essential, on the same terms as those companies holding truly essential patents would not satisfy either the "fair" or the "reasonable" aspects of FRAND.

In order to implement a numeric proportionality rule, then, all licensors would have to agree on a definition of essentiality and then submit their patents for independent review to determine which met that definition. Defining essentiality entails a number of strategic decisions, such as whether or not to cover required technical elements for the core product only, or whether to cover optional features as well. The definition might also include commercially essential patents, where the patent may not be required to get a standard to work but is required to make it palatable to consumers. After essentiality had been clearly defined, licensors would need to agree on who would conduct the evaluations for essentiality. As patent review is a subjective art, the choice of an independent reviewer could be contentious.[21] These steps are, in fact, the steps that the patent pools choosing numeric proportionality rules have followed. While the process is clearly doable, its necessity points out that numeric proportionality rules are not as simple or as straightforward as they might first appear.

If independent essentiality determinations were not made, a numeric proportionality rule would create harmful incentives for patenting behaviour and would therefore have detrimental effects on intellectual property rights and standard-setting. Consider a world in which such a rule exists and is understood to exist by all SSO participants. Each company participating in standard-setting would have a strong incentive to file for as many patents as it can. The larger is its portfolio, regardless of

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[21] Patents are complex legal and technical documents. The reviewer would need to be well versed in both patent law and the technology at hand.

the technological contributions of the patents comprising that portfolio or the nature of their next best alternatives, the larger would be its share of the royalties for the standard. If an invention can be separated into two distinct patents rather than merely adding to the number of claims for one patent, rational firms would make that separation. Companies would attempt to patent even relatively minor incremental innovations, all in the hopes of building the largest portfolio of "essential" patents as feasible. Companies would then report as many patents as possible to the SSO as being essential to a standard, knowing that the SSO would not evaluate the patents to determine whether they are, in fact, essential.[22] In short, a poorly implemented numeric proportionality rule would not only fail to satisfy FRAND principles,[23] it would also encourage a proliferation of patenting of minor innovations.[24]

More troubling, however, is the potential for disproportionate payments even with well-designed numerically proportionate royalty rules. This seemingly contradictory statement follows from the fact that not all patents are born equal. The intellectual property literature has made it clear that patents differ in terms of their technological contributions, the value of the products which embed those contributions, and the nature of the next best alternatives (Parr and Smith 1994; Toikka 2000). The available evidence shows that patent values as a general matter do reflect those differences and, consequently, vary enormously. If a technology is easy to invent around or has a ready supply of close substitutes, it is likely to receive a relatively lower compensation than others. There is no reason to impose different valuation principles for technologies in a standard-setting context. Common sense suggests that it cannot be "fair", "reasonable", or "non-discriminatory" to offer the holder of easily substitutable patents the same compensation as the holder of a critical, irreplaceable patented technology supporting the same standard.

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[22] Participants may be unwilling to review competitors' claims of essentiality (Chiao et al., 2005:6, footnote 3). ("In fact, U.S. legal rules mandating trebled damages for wilful infringement lead firms to discourage their engineers from even examining the patent portfolios of their competitors.").
[23] That is, it would be both unfair and unreasonable since companies with large portfolios of relatively unimportant patents would capture the most royalty earnings, while firms with a smaller number of critical patents would receive less.
[24] It would thus exacerbate any worries over patent proliferation and patent thickets, already a hotly debated in the academic literature and popular press. For influential papers on patent thickets, see Shapiro (2001) and Heller and Eisenberg (1998); for a press example, see Danny Bradbury, "Canadian Innovation Choked by U.S. Laws," NAT'L POST, Nov. 17, 2003, at FE01.

As a consequence of the diversity in patent value, numeric proportionality rules will only make sense in a limited set of circumstances. For instance, when SSO members' IP contributions are roughly symmetric in value, numeric proportionality rules will not sacrifice economic efficiency or fairness, which dictate that a firm's share should equal its marginal contribution to the standard. Proportionality may also be appropriate in the rare event that members' numeric shares correlate highly with their contribution shares of the standard's value. In this case, numeric proportionality rules mimic value proportionality ones. Correlation of this type can occur in patent pool settings as a result of self-selection into the pool, but we would not expect this condition to hold generally within SSOs (Layne-Farrar and Lerner, 2006).

4. ECONOMIC RULES

We turn away now from rules proposed in litigation settings to those proposed in the economic literature. We first discuss a recent paper by Swanson and Baumol (2005) that suggests a strategy for making FRAND operational in a standard-setting environment. Their proposal is rooted in the concept of economic efficiency. For the second economic approach we apply a cooperative game theory model to FRAND. This second option might hold appeal for European audiences. We close the section by comparing the two models.

A. A Market Efficiency Based Approach

Swanson and Baumol develop a market/efficiency-based framework for evaluating reasonable and non-discriminatory royalties by considering intellectual property competition before and during the standard-setting process. In essence, their approach relies on the fact that while a standard is developing, multiple technologies (supported by rival firms) may compete for inclusion in the standard. This *ex ante* competition can be harnessed to provide a benchmark for what is fair, reasonable, and non-discriminatory *ex post*, after the standard has been set and competition among technologies has thereby been diminished. We begin by summarizing their model. We

then extend their *ex ante* competition analysis to account for multiple components and contributors to a standard.

1. The Swanson-Baumol Model

Swanson and Baumol consider the case in which a standard involves choice of a single technology to produce a given downstream product. They suppose an SSO holds an auction over competing technologies during the development phase, with the winner of the auction becoming the standard. During the auction, intellectual property (IP) holders would need to submit offers for a license fee per unit of output to downstream users of the standard, who would then choose which patent should be embodied in a standard. The outcome of such an auction would, Swanson and Baumol argue, provide a basis for what constitutes "reasonable" license fees, because it would fully reflect the state of competition among potential IP providers existing prior to the selection of a standard. This reasonable level of royalty rates would of course be constrained by the price of the final product in the downstream market. If a proposed royalty rate were too high, then the license fee would result in downstream manufacturers producing at a loss and they would therefore veto the IP technology during the auction.

Under some simplifying assumptions, Swanson and Baumol show that the auction will be won by the "best" IP option—under their assumptions, the option that permits production of the downstream product at the lowest cost. This IP will be licensed at a fee equal to the recurring costs of licensing plus the difference in value between the best and next-best IP alternatives. This hypothetical auction is the foundation for the *fair* and *reasonable* aspects of the licensing rule that Swanson and Baumol propose.

They then adapt the "efficient component pricing rule" to satisfy the *non-discriminatory* component of FRAND:[25] a competitively neutral license fee should compensate the IP owner both for the incremental costs of licensing IP and the

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[25] Compliance with ECPR is necessary for a license fee to satisfy the non-discriminatory component of FRAND when the licensor also participates in the downstream market. As noted above, the ECPR was developed in the context of pricing the services of public utility bottlenecks, like local telephone networks, when the owner of the bottleneck is in competition (in long distance services, for instance) with a rival to which is sells the bottleneck's services.

opportunity cost of licensing the technology. Faced with such a fee, the IP holder will be indifferent between licensing the technology to rivals and producing the product itself.

Consider a vertically integrated IP holder which considers the fee per unit of downstream output, P_i, at which it could license its technology on non-discriminatory terms. Let $P_{f,i}$ denote the price of the final product using the technology owned and licensed by company i, and assume that the final products of the IP owner and licensees are perfect substitutes.[26] The efficient component pricing rule requires that the royalty rate fee charged by company i satisfies:

(1) $$P_i = P_{f,i} - IC_{r,i}.$$

According to equation (1) the non-discriminatory license fee P_i is equal to the implicit price firm i charges itself for the technology: the final product price, $P_{f,i}$, less the licensor's incremental costs of remaining inputs, $IC_{r,i}$, such as capital and labour. Thus, the per-unit value of the IP is defined by the marginal contribution of the technology to the value of the final good. Efficiency requires that, holding other inputs constant, an increase in the price of the final good be matched by an increase in the license fee charged to third parties. The license fee set by equation (1) makes the licensor indifferent between producing a unit of the final product itself and allowing downstream competitors to produce that unit licensing its IP. Note that when the IP technology is used as an input in different final products, the implicit price the licensor charges itself will generally differ, and thus so will the non-discriminatory license fee charged to third parties.

Swanson and Baumol show that ECPR is a necessary and sufficient condition for a licensing fee to be non-discriminatory.[27] And, finally, they demonstrate that the ECPR license fee obtained from equation (1) above will be the same as the "reasonable" royalty rate resulting from the auction-like process described above so long as "downstream barriers to entry are low, *regardless of competitive conditions in the*

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[26] For simplicity, we set the recurring cost of licensing IP equal to zero.
[27] This result is established in page 33 of their paper and denoted as the "Level-Playing-Field Theorem".

technology licensing market" (Swanson and Baumol 2005:39). If the license fee is too low it will attract new entrants, pushing the final product price down until equation (1) matches the fee. Alternatively, if the license fee is higher than that defined by equation (1), downstream producers will reject it since at that level they would produce at a loss.

2. Extending the Model

While Swanson and Baumol's *ex ante* auction approach provides an elegant solution to determining whether a license price meets FRAND terms, their analysis rests on some strong simplifying assumptions. Most importantly, the standard they consider requires only one patented technology, which is then used as an input in the production of the final good: one patent held by one firm becomes one standard, which defines one product.

Standards rarely, if ever, consist of just one patent, however. To the contrary, most standards, especially those defining complex products and services, include many IP contributions covering complementary aspects of the product and are proffered by many different IP developers. For example, the mobile phone UMTS standard at issue in the FRAND cases listed earlier covers radio access networks (the WCDMA air interface for the mobile phone to base station leg of a call), core networks (for handling the call after it reaches a base station), system architecture features (such as coding and encryption methods), plus several other backward compatibility and feature-driven components. All told, the essential IP declared to ETSI for the WCDMA/UMTS standard includes over 4,000 patents held by over 45 companies as of early 2006.[28]

The contribution of multiple parties to a standard significantly complicates the FRAND question. What defines FRAND licensing commitments for individual parties? How will royalty payments compare or be distributed among participants? The Swanson-Baumol analysis does not address these concerns. While applying their model to competing multi-patent standards may define a reasonable overall level of royalties, it does not provide a means for dividing those royalties among participants in the

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[28] As measured by declared essential patents, issued worldwide, posted on ETSI's website for UMTS and other 3G projects. See http://webapp.etsi.org/IPR/Search.asp. Note that while many more thousands of patents are listed for these projects on the website, as of 20th March 2006 a great many of these are duplicate entries. After duplicate patent numbers are eliminated, around 4,650 patents remain, covering patents issued across the globe.

winning standard. Moreover, the Swanson-Baumol non-discriminatory royalty benchmark, the implicit price the IP owner charges itself (which equals the opportunity cost of a lost sale), cannot be applied when multiple complementary patents contribute to a standard. To manufacture the final product, each IP owner needs cross licenses for the components of the standard for which it does not hold intellectual property rights. Therefore, the opportunity costs cannot be expressed in terms of lost sales in the downstream market since the firm cannot manufacture the final good without additional intellectual property.

With these issues in mind, we start our model extension. Assume that a standard consists of two complementary components, *a* and *b*, each developed by distinct companies and each protected by a patent.[29] In what follows, "*a*" and "*b*" refer to a component-patent-company combination. The value of the standard per unit of final output, which, following Swanson-Baumol, one can think of as the difference between the competitive price of the final product and the incremental cost of other inputs, is given by W_{ab}. The standard only has value when both components are present; both components are strict complements; both add value. All components included in the standard are, at least to some degree, important and necessary for the standard to function properly. The cumulative royalty rate for the standard is given by the sum of the royalty rates for the two components, i.e., $P_{cum} = P_a + P_b \leq W_{ab} = P_{final\_good} - Costs$.

Let us assume that the SSO determines the reasonable level of royalties by holding two simultaneous auctions: one for each of the complementary components. The auction mechanism works in two stages. In the first stage, patent holders quote their royalty rates non-cooperatively. Each of them sets its rate so that (a) it is not undercut by competing technologies and (b) it is consistent with the royalty rate paid for the complementary component. In a second stage, each licensor decides whether or not to be part of the standard given the resulting royalty rates. We solve this game by backward induction looking for subgame perfect Nash equilibria (SPNE).[30]

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[29] This is a simplifying assumption that does not change the main results. The results still hold true in the general case, with *n* IP components produced by the same company, or *n* IP components produced by *z* companies.
[30] Since our purpose is to lay out the possible tools that courts and competition authorities can use to define FRAND, we do not go into detail on the derivation of any equilibria.

The solution to the second stage is trivial: each patent holder licenses its patent if and only if its royalty rate exceeds the incremental cost of licensing its technology, which as above is assumed to be zero for simplicity. That is, $P_i \geq 0$ for $i = a, b$. For the first stage of the auction process, we consider the following five alternative scenarios: (1) perfect competition ex ante among rival technologies for both components; (2) perfect competition for one of the components and no competition for the other; (3) perfect competition for one of the components and imperfect competition for the other—i.e. there exists a close, but not perfect substitute; (4) no competition for either of the two components; and (5) no competition for one component and imperfect competition for the other. Under the five different scenarios, the outcome of the auction and the resulting FRAND rates will be different.

Case 1: Perfect competition ex ante in the market for both of the IP components

With perfect competition ex ante for both IP components necessary for a given standard, the equilibrium royalty rate of each component of the standard is given by the incremental cost of licensing that component, which is assumed to be zero without loss of generality. This equilibrium is unique. When ex-ante perfect substitutes to a technology exist, an IP owner cannot extract any positive profits since it has no market power in the auction. In the battle to be included in the standard, the license fee is bid down to the point where it is just enough to cover the incremental costs of licensing. Thus, licensors cover their costs only, while licensees (or end-users of the product) appropriate all of the rents from the standard.

Case 2. Perfect competition ex ante for one of the components; no competition for the other

With perfect competition for component *b*, no provider of the corresponding IP can extract any profit from licensing. On the other hand, the patent holder without a substitute (the company delivering component *a*) can do so. In the unique equilibrium of the simultaneous auction game, the IP holder facing no competition captures the full value of the standard:

(2) $$P_a = P = W_{ab}; P_b = 0.$$

Case 3. Perfect competition ex ante for one of the components; imperfect competition ex ante for the other

Assume there is still perfect competition for component b, but component a now faces competition from component c. Component c is a close, but not perfect, substitute for component a and is produced by a third company. Now two standards are possible, with values W_{ab} and W_{bc}, where $W_{ab} > W_{bc}$. In equilibrium, $P_b = 0$, as before. The royalty rate charged for component a in this case is limited to the incremental value of the corresponding IP over the next best alternative. Because the (a,b) standard is superior to the (c,b) standard, company a can win the auction by setting a license fee such that the net value of the (a,b) standard to all licensors, $W_{ab} - P = W_{ab} - P_a$, is slightly higher than the net value of the (c,b) standard with a royalty rate of zero. Thus, in the unique SPNE of this auction game,[31] component a's IP owner captures the full incremental value:

(3) $$P_a = P = W_{ab} - W_{bc}; P_b = 0.$$

Case 4. No competition ex ante for either of the two components

Suppose there is no competition ex ante for any of the two components; there is a single supplier of the IP necessary to produce a and a single supplier of the IP necessary to produce b. In that case, any pair of royalty rates (P_a, P_b) such that (1) $P_i \geq 0$ for $i = a, b$ and (2) $P_a + P_b = W_{ab}$ constitutes a SPNE of the auction game. Condition (1) ensures that it is in the interest of companies a and b to join the standard. Note that for any value of $P_a < W_{ab}$, the best response of the owner of patent b is to set $P_b = W_{ab} - P_a$, which implies condition (2) above. Patent holder b cannot be better off by deviating from this strategy. Setting a lower royalty rate will only benefit licensees. And setting a higher rate would cause the total royalty rate to exceed W_{ab} and would

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[31] We assume for simplicity that in case of a tie in the royalty rates quoted by the owners of components a and c, the SSO selects the component with a greater absolute contribution to the standard: component a.

result in market collapse, since the value of the standard W_{ab} is defined as the difference between the price of the final good and the cost of all other inputs.

Case 5. No competition ex ante for one of the components; imperfect competition ex ante for the other

In the last of the five scenarios we consider, there is a single supplier of component *b*, and component *a* faces competition from component *c* exactly as in Case 3, above. As in Case 3, the royalty rate charged for component *a* here is limited by the incremental value of the IP over the next best alternative: $P_a \le W_{ab} - W_{bc}$. If company *a* tried to set a higher rate, it would be successfully undercut by company *c*. Furthermore, as in Case 4, the royalty rate charged for component *a* is also limited by the royalty rate charged for the complementary component *b*: $P_a + P_b = W_{ab}$. Therefore, following the same logic as in the previous scenario, we can show that any pair (P_a, P_b) such that (1) $P_i \ge 0$ for $i = a, b$, (2) $P_a \le W_{ab} - W_{bc}$ and (3) $P_a + P_b = W_{ab}$ constitutes a SPNE of the auction game. Although there may be equilibria in which component *a* may generate a higher royalty than component *b*, even when the former faces competition and the latter does not, the maximum royalty rate that can be charged for *a*, $W_{ab} - W_{bc}$, is below the maximum royalty rate that can be charged for *b*, W_{ab}.

In conclusion, we have that in equilibrium, (1) the royalty rates charged for components *a* and *b* are additive; (2) they are non-decreasing in the value of the standard (which in turn is defined by the value of the final good less other costs), and strictly increasing in the value of the standard in the absence of perfect competition; (3) when a component faces imperfect competition, its royalty rate equals its incremental contribution to the value of the standard; and (4) the equilibrium royalty rate for a component to the standard is lower when it faces competition from other components and is minimal when competition is perfect.

B. A Cooperative-Game Theoretic Approach to FRAND

Some might argue that efficiency-based rules, which treat competitive market outcomes—even monopolistic ones—as optimal and ignore issues of equity, cannot be

counted on to produce outcomes that are fair or reasonable. In Europe concepts of fairness are generally more important than they are in the US, where economic efficiency is typically the foremost concern.[32] An alternative approach to defining FRAND incorporates a normative interpretation and is based on cooperative game theory.[33]

A simple model proposed by Shapley (1953) defines a means for dividing rents among participants of any cooperative group, such as an SSO which has the owners of complementary patents as its members. The model has a number of attractive features in relation to the notions of fairness and reasonableness. In words, the model divides rents (or costs) among players belonging to a group according to their average marginal or incremental contribution to alternative combinations of the members of the cooperative group. (What is meant by "average" here is made precise below.) The Shapley value thus "to some extent is a synonym for the principle of marginal contribution—a time honoured principle in economic theory" Winter (2002:10).[34] It abstracts away from market competition in defining a "just" benchmark for a distribution of payments. As Young (2005:267) states:

> [T]he idea that rewards should be in proportion to contributions has a considerable ethical appeal in itself, and appears to reflect widely held views about what constitutes "just compensation" without any reference to the theory of perfect competition.

Shapley's assumptions and solution are quite general, but they can easily be restated in the standard-setting context. Suppose there are several patents (or other pieces of intellectual property) that might be used in a particular standard. Let N denote the set of all these patents, let S be any subset of N, and let $v(S)$ be the total (not per-unit) economic value, net of licensing costs, of the best standard that can be devised using the patents in S. Clearly $v(T) = 0$ if the patents in set T cannot support a workable standard, and $v(N)$ is the best possible standard, which is assumed to be adopted by the

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[32] See note 11.
[33] "Cooperative game theory does not set out to describe the way individuals behave. Rather, it recommends reasonable rules of allocation, or proposes indices to measure power." Winter (2002:2057).
[34] For useful expositions and discussions of the Shapley value, see Luce and Raiffa (1957); Shubik (1983); and Owen (1982).

SSO. Let $P_i(v)$ be the value received by the owner of patent i, for $i \in N$. Shapley argued that any fair and reasonable method of dividing a standard's total value among the relevant patent holders should satisfy four basic conditions:

- *Efficiency*: The total value of the standard is distributed among all patents; nothing is left over: $\sum_{i \in N} P_i(v) = v(N)$.[35]

- *Anonymity*: The value received by any patent is independent of how it is numbered and of who owns it. In particular, if patents i and j are symmetric, in the sense that they each contribute the same amount to the standard, their payoffs should be equal as well: $P_i(v) = P_j(v)$.

- *Dummy*: If a patent doesn't contribute anything to any possible standard, it is a dummy, and it receives a payoff of zero. That is, if $v(S \cup i) - v(S) = 0$ for every $S \subset N$, then $P_i(v) = 0$.[36]

- *Additivity*: Suppose that a set of patents can support a second standard that is unrelated commercially to the one considered so far. That is, the value of either standard depends only on the patents on which it is based, not on the value of patents involved in the other standard. Let *w(S)* be the value of the best second standard that can be supported with the set of patents *S*. The assumption is that in this case payoffs to individual patents will be the same whether the two standards are analyzed separately as two cooperative games or together as a single cooperative game: $P_i(v + w) = P_i(v) + P_i(w)$, for all $i \in N$.

Remarkably, Shapley demonstrated that one and only one method of dividing value satisfies all four of these axioms (Roth 2005:4-7):

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[35] In a standard setting context, this condition implicitly assumes that while patent holders need to be given incentives to develop their IP, this is not so for downstream manufacturers. Moreover, unlike the analysis of the previous section, it is assumed here that the total value captured by IP owners in aggregate is independent of the extent and nature of IP competition ex ante. Relaxing this assumption would not alter our conclusions regarding the relative compensations of patent holders with different average marginal contributions to the standard.

[36] $S \cup i$ denotes the set of all patents in *S* plus patent *i*.

$$(4) \qquad P_i(v) = \sum_{i \notin S \subseteq N} \frac{|S|!(n-|S|-1)!}{n!} \left(v\big(S \cup \{i\}\big) - v(S) \right),$$

where $|S|$ is the number of patents in set S and n! (n factorial) equals n × (n − 1) × … × 3 ×2× 1.

This forbidding formula has a simple and intuitive interpretation, which is also useful in computation (Luce and Raiffa 1957:250; Owen 1982:197; Shubik 1983: 181). Suppose that there are *n* patent-owners, one for each patent involved. (By the anonymity assumption, nothing would be affected if groups of "patent-owners" were in fact employees of a small number of firms that actually owned the patents.) Suppose the patent-owners arrive at the SSO in random order each with her patent in her pocket, with all possible arrival sequences equally likely. Now suppose that in each sequence, each patent-owner receives the amount by which her patent increases the value of the best standard that can be built from the patents that are already at the SSO when she arrives. That is, if the set of patents *S* is at the SSO when patent *j* arrives, *j*'s owner receives $v(S \cup j) - v(S)$. The Shapley value gives *j* the average of such contributions over all possible arrival sequences – each patent thus receives the average (over arrival sequences) of its marginal contribution.

One surprising result from this model is that in general, as we illustrate in a particular case below, patents that are not part of the ultimate standard will, if they are not dummies (as defined above), receive non-zero value. While this might strike some as unfair since even though the contribution is not included in the final standard, if it is a viable alternative that could have been chosen it still receives a payout. This finding is clearly at odds with the ECPR, where only those patents that are included in a standard can receive any payout at all. It does, however, match certain notions of fairness in that everyone who participates in a meaningful way is compensated. It also captures the ex ante presence of alternatives.

To illustrate how the Shapley value works, let us consider the two-component case analyzed in Section 4. Suppose only one patent for component *a* is available, while a number of firms have patents for component *b*, denoted as $b_1, b_2, b_3, \ldots b_n$. Suppose for

simplicity that the value of a standard involving *a* and *any* patent on component *b* is equal to 1. How do the "fair and reasonable" returns to the firms vary with the number of holders of patents on component *b*? Analysis of two special cases will illuminate the path to the general answer.

Case A: n = 1; one holder of a patent on component *a* and one holder of a patent on component *b*

There are two possible orderings for the arrival of the two patent-owners: (1) *a* arrives first and b_1 arrives second, or (2) b_1 is first and *a* is second. In the first case, *a* receives nothing, since a standard supported only by a patent on one component has no value by assumption, and b_1 receives 1, the value of a workable standard. In the second case, *a* receives 1 and b_1 receives zero. Thus, the value player *i* contributes, $v_i(\{i,j\})$, in arrival ordering $\{i,j\}$ is given by:

$$v_a\left(\{a,b_1\}\right) = 0; v_{b_1}\left(\{a,b_1\}\right) = 1; v_a\left(\{b_1,a\}\right) = 1; \text{ and } v_{b_1}\left(\{b_1,a\}\right) = 0.$$

The average contribution of player i, z_i, is therefore equal to:

$$z_a = \frac{1+0}{2} = \frac{1}{2} \text{ and } z_{b_1} = \frac{1+0}{2} = \frac{1}{2}.$$

Because the Shapley approach divides rents according to average contributions (e.g., $P_i = z_i$), in this case the Shapley solution divides total value evenly between the holders of the two patents. Note that this case corresponds to Case 4 in Section 3. The royalty rates derived under the Shapley approach constitute a SPNE of the auction game analysed in previous Section, though there are many other equilibria which cannot be justified in Shapley value terms.

Case B: n = 2: two *b*'s and one *a*

With one *a* and two *b*'s, b_1 and b_2, there are six possible orderings for the arrival of the patent-owners:

$$\{a,b_1,b_2\}, \{a,b_2,b_1\}, \{b_1,a,b_2\}, \{b_1,b_2,a\}, \{b_2,a,b_1\}, \text{ and } \{b_2,b_1,a\}.$$

a's marginal contribution in each of the possible orderings is:

$$v_a\left(\{a,b_1,b_2\}\right) = v_a\left(\{a,b_b,b_1\}\right) = 0, \text{ and}$$

$$v_a\left(\{b_1,a,b_2\}\right) = v_a\left(\{b_2,a,b_1\}\right) = v_a\left(\{b_1,b_2,a\}\right) = v_a\left(\{b_2,b_1,a\}\right) = 1$$

b_1's marginal contributions are given by:

$$v_{b_1}\left(\{b_1,a,b_2\}\right) = v_{b_1}\left(\{b_1,b_2,a\}\right) = v_{b_1}\left(\{a,b_2,b_1\}\right) = v_{b_1}\left(\{b_2,a,b_1\}\right) = v_{b_1}\left(\{b_2,b_1,a\}\right) = 0$$
$$v_{b_1}\left(\{a,b_1,b_2\}\right) = 1$$

And by symmetry, b_2's marginal contributions are:

$$v_{b_2}\left(\{b_1,a,b_2\}\right) = v_{b_2}\left(\{b_1,b_2,a\}\right) = v_{b_2}\left(\{a,b_1,b_2\}\right) = v_{b_2}\left(\{b_2,a,b_1\}\right) = v_{b_2}\left(\{b_2,b_1,a\}\right) = 0$$
$$v_{b_2}\left(\{a,b_2,b_1\}\right) = 1 .$$

Thus, the average marginal contributions of a, b_1, and b_2 are equal to:

$$z_a = \frac{4}{6} \text{ and } z_{b_1} = z_{b_2} = \frac{1}{6}.$$

Here, even though it might make technical sense for the standard to be based on only one of the two component b patents, both b_1 and b_2 are entitled to royalties according to the Shapley value. Note also that under the efficiency-based approach of the previous section, company a would obtain all rents, $z_a = 1$, while companies b_1 and b_2 would obtain zero.

Case C: The general case, n-1 *b*'s and one *a*

If a arrives first, its marginal contribution is zero. The probability of this happening is $\frac{1}{n}$. In all other cases, which have total probability $\frac{n-1}{n}$, a's marginal contribution is 1. Hence, a's expected (or average) marginal contribution is

$$z_a = \Pr\left(a \text{ arriving first}\right) \cdot v_a\left(\text{when } a \text{ arrives first}\right) +$$
$$\Pr\left(a \text{ not arriving first}\right) \cdot v_a\left(\text{when } a \text{ does not arrive first}\right)$$

Or in notational form,

(5)
$$z_a = \frac{1}{n} \cdot 0 + \frac{n-1}{n} \cdot 1 = 1 - \frac{1}{n}.$$

As all b's are identical and receive in total $\frac{1}{n}$, the amount a does not receive, b_i's expected marginal contribution is given by:

(6)
$$z_{b_i} = \frac{1}{n-1}\left(1 - \left(1 - \frac{1}{n}\right)\right) = \frac{1}{n(n-1)}.$$

Note that as the number of holders of economically interchangeable patents on component b, n-1, approaches infinity, the players' average contributions become:

$$\lim_{n \to \infty} z_a = \lim_{n \to \infty} \left(1 - \frac{1}{n}\right) = 1 \text{ and } \lim_{n \to \infty} z_{b_i} = \lim_{n \to \infty} \frac{1}{n(n-1)} = 0.$$

In words, as the number of b's—economically interchangeable patents on one of the standard's necessary components—increases, the holder of the unique patent for the other component, a, receives the entire value of the standard, and each b's average marginal contribution becomes 0. More generally, as the number of IP owners competing to contribute the same component increases, the average marginal contribution of each individual party decreases, and their total Shapley value return falls to zero, assuming their IP is interchangeable.

Cases B and C are related to Case 1 in Section 3: there is no competition for component a but component b faces perfect competition. Note that the Shapley value only coincides with the equilibrium outcome of the auction game in the limit, i.e., when the number of alternatives for component b, n, goes to infinity (See Section 5 below). For finite n the Shapley value implies a lower (higher) compensation for component a (respectively, component b).

Case D: The b_i patents are not perfect substitutes

Suppose $N = 2$, the standard based on (a, b_2) has value 1 as before, and the standard based on (a, b_1) has value $1+\delta$. This is related to Case 3 in Section 4, in which there is imperfect competition for one component. Under these assumptions, b_1 will contribute $1+\delta$ if it arrives second after a (1 sequence), δ if it arrives third (2

sequences), and nothing otherwise. *a* will contribute 1 if it arrives second after b_2 (1 sequence), $1+\delta$ if it arrives after b_1 (3 sequences), and nothing otherwise. b_2 gets 1 only when it arrives second after *a* (one sequence) and nothing otherwise.

Averaging, *a* gets $\frac{4}{6}+\frac{\delta}{2}$, b_1 gets $\frac{1}{6}+\frac{\delta}{2}$, and b_2 gets $\frac{1}{6}$. The final standard is clearly (a,b_1), but b_2 receives royalties. One can think of this as the sum of two standards, the one for which b_1 and b_2 are perfect substitutes with value 1, and one for which *a* and b_1 are essential and that has total value δ.

It is straightforward, but somewhat tedious, to extend this analysis to the general case in which the value of the (a,b_1) standard is $1+\delta$ and the value of an (a, b_i) standard is 1, for $i = 2,\ldots,n$-1. In this case *a* receives $\left(1-\frac{1}{n}\right)+\frac{\delta}{2}$, b_1 receives $\frac{1}{n(n-1)}+\frac{\delta}{2}$, and the other b_i receive $\frac{1}{n(n-1)}$ each. In the limit as *n* becomes large, *a* receives 1, the entire value of the basic standard, and splits δ, the value of the improvement for which b_1 is also essential, with b_1.

Case D is related to Case 5, where one component faces no competition and there is imperfect competition for the other. The Shapley outcome would constitute one equilibrium of the auction game, but there could be other equilibria. For example, component *a* could receive in equilibrium $1 + \delta$ (more than under the Shapley approach) or just 1 (less than under Shapley). We close this Section by exploring in greater detail the relationship between the two economic approaches and their robust policy implications.

C. Reconciling the Two Economic Approaches

The two approaches developed above are based on very different fundamental assumptions. The driving force behind the auction approach is market competition and efficient pricing—non-cooperative, winner-take-all principles. The Shapley value approach, in contrast, is based on fairness principles: it compensates parties on the basis of their average marginal contributions in a cooperative game regardless of efficiency or

market conditions. Despite their very different starting points, however, we have shown that these two approaches have the same basic implications and agree completely on two important properties that any defensible definition of FRAND must satisfy.

First, both approaches imply that a critical factor affecting patent holders' compensation is the presence of close substitutes. In the Swanson-Baumol analysis, the presence of perfect substitutes drives economic profits down to zero, while the absence of competition rewards a pioneer fully for its IP innovation. The Shapley value method for allocating payments implies that the more substitutes any patent has, the lower its "fair and reasonable" share of value.[37]

Second, the level of competition is a key determinant of the value of the patent. As the number of competitors for a component in a standard increases, the lower the ex ante market power possessed by any of them, and thus the lower the returns under the Swanson-Baumol approach. Similarly, the more competitors a given patent-owner faces under the Shapley value approach, the less common will be arrival sequences in which it has a significant marginal contribution. (In Case C above, for instance, any individual b had a non-zero marginal contribution only if a arrived first and it arrived second.) Put another way, the fraction of coalitions to which an IP owner has a large marginal contribution decreases, and its IP value measured by the average marginal contribution falls as well. With the market-based approach, a lack of substitute technologies confers ex ante market power to the IP owner during the auction phase, while the presence of alternative technologies reduces that power. In both approaches, the fiercer the competition for any component, the lower the effective level of any individual related IP contribution and therefore, the lower the value of the corresponding payout.

Third, and perhaps most important for their applicability to FRAND litigation, both approaches to dividing rents ignore any market power that being included in a standard might bestow. This is clearly true by explicit assumption for the Swanson-Baumol method, which relies on ex ante auction prices to determine ex post payouts.

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[37] The analysis of Case D in Section 5, above, shows that even imperfect substitutes decrease Shapley value returns: the smaller is δ or the larger is n, the lower the share of b_1, even though its patent has no perfect substitutes. Case 3 in Section 4 indicates that a similar property is satisfied by the Swanson-Baumol ex ante auction approach.

The Shapley value method of distributing rents bases payoffs on ex ante marginal contributions, so even IP that is not part of the "winning" standard receives some payoff, as long as its average marginal contribution to some collections of patents is positive.

Finally, as the number of close substitutes for a component increases and approaches infinity, our extension of the auction approach and the Shapley value approach lead to identical allocations of royalty payments. The following two properties indicate the equivalence of the two approaches in the limit and, we would argue, should be satisfied by any reasonable FRAND definition.

> ***Property 1.*** *As the number of perfect substitutes for a piece of intellectual property approaches infinity, the IP holder's royalty payments defined by the Shapley value (average marginal contribution) approaches the licensee payments defined by the ex-ante auction model.*

Proof: Assume the set-up from Case 2 above: a standard consists of two complementary components, *a* and *b*, with *n*-1 perfect substitutes for component *b*. The value of the standard is given by $W(v_a, v_b)$, again defined as the difference between the final product price and the cost of other inputs. Both components are essential, i.e. the standard is worth nothing if either component is missing from the standard. From equations (8) and (9) it follows that the average marginal contributions of components *a* and *b* are equal to: $P_a = z_a = W(v_a, v_b) - \dfrac{1}{n}$ and $P_b = z_b = \dfrac{1}{n(n-1)}$. In the limit, as the number of perfect substitutes to component *b*, i.e. *n*-1, grows to infinity, the components' average marginal contributions to the value of the standard become:

$$\lim_{n \to \infty} P_a = \lim_{n \to \infty} \left[W(v_a, v_b) - \frac{1}{n} \right] = W(v_a, v_b) \text{ and}$$

$$\lim_{n \to \infty} P_b = \lim_{n \to \infty} \left(\frac{1}{n(n-1)} \right) = 0.$$

In words, in the limiting case all the value of the standard, $W(v_a, v_b)$, is derived from the contribution of component a. Thus, the company contributing a appropriates all rents from the standard while the companies contributing b's get nothing.[38] Thus, as the number of perfect substitutes of component b grows, the royalty payments, proportional to the components' Shapley values, approach the royalty payments derived from an ex ante auction in equation (7).[39]

Property 2. *More valuable intellectual properties receive more rent.*

We have seen above that when patents or other IP have perfect substitutes, they are less valuable to the standard and they receive less in either ECPR or Shapley value payouts. Let us now consider a slightly more complex situation that extends Case C. Instead of two competing standards, here there are three possible standards: one using components a and b with value $W(v_a, v_b)$, one using components b and c with value $W(v_b, v_c)$, and one using all three components with value W^*. All these values are computed assuming that only one standard will be offered to the market. Suppose $W^* > W(v_a, v_b) > W(v_b, v_c)$. One might expect a to receive a larger share of W^* than c as the second of these inequalities shows it to be more valuable.

Let us first consider the Shapley value. There are, as before, six arrival sequences. In all of them the first arrival makes zero marginal contribution, but the second and third arrivals make positive marginal contributions. Enumerating and averaging we obtain

$$P_a = z_a = \frac{1}{6}\Big[W(v_a, v_b) + 2\big(W^* - W(v_b, v_c)\big)\Big],$$

$$P_b = z_b = \frac{1}{6}\Big[2W^* + W(v_a, v_b) + W(v_b, v_c)\Big], \text{ and}$$

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[38] The royalty payments do need to be incentive-compatible for IP owners to license their technology, so b's license fees should cover the incremental costs of licensing, which we have neglected for simplicity.

[39] Note that under the ECPR an IP owner will get reimbursed for his incremental costs irrespective of how small the marginal contribution of his technology is, as long as it is sufficient to cover those costs. Likewise, under the Shapely value, owners whose marginal contributions are positive on any arrival sequence receive royalty payments.

$$P_c = z_c = \frac{1}{6}\Big[W\left(v_b, v_c\right) + 2\left(W^* - W\left(v_a, v_b\right)\right)\Big].$$

It is easy to show that $P_b > P_a > P_c$. A little reflection shows that b's ability to form a workable standard with a or c makes it the most valuable of the three.

Now suppose there are *n-2* perfect substitutes for b. As n increases we know that the total royalties of all of b's go to zero. What about a and c? In a fraction $\frac{1}{n}$ of the arrival sequences a arrives first and has no marginal contribution, and similarly for c. In the limit as n increases, these sequences have zero effect on average marginal contributions, and only sequences in which a perfect substitute for b arrives first matter. In half of these a arrives before c, and their marginal contributions are $W\left(v_a, v_b\right)$ and $\left[W^* - W\left(v_a, v_b\right)\right]$, respectively. In the other half of the relevant sequences, c arrives before a, and their marginal contributions are $W\left(v_b, v_c\right)$ and $\left[W^* - W\left(v_b, v_c\right)\right]$, respectively. Thus in the limit, the three payouts are:

$$\lim_{n\to\infty} P_a = \frac{1}{2}\Big[W\left(v_a, v_b\right) + \left(W^* - W\left(v_b, v_c\right)\right)\Big],$$

$$\lim_{n\to\infty} P_b = 0, \text{ and}$$

$$\lim_{n\to\infty} P_c = \frac{1}{2}\Big[W\left(v_b, v_c\right) + \left(W^* - W\left(v_a, v_b\right)\right)\Big].$$

As expected, $P_a > P_c > P_b$ in the limit.

Now let us consider the ex ante auction. The process of ex ante competition is necessarily more complex with multiple components, and Swanson and Baumol do not deal with this case. In Case 3, only the *(a,b)* and *(b,c)* standards were feasible and we showed that *(a,b)* would emerge under our assumptions, with a receiving $P_a = \Big[W\left(v_a, v_b\right) - W\left(v_b, v_c\right)\Big]$ and both b and c receiving zero. In comparison with the Shapley value analysis—where the full standard value is divided by the SSO members

every time—with ex ante competition, the total profit realized by the IP holders is reduced.

Suppose the (a,b,c) standard is invented, and there are multiple substitutes for b. Component a's owner can block this standard by refusing to participate (or perhaps vote against it within the SSO), so a will need to receive at least $P_a = \left[W\left(v_a, v_b\right) - W\left(v_b, v_c\right)\right]$ in order to support the standard. Prior to the (a,b,c) invention, none of the b's received anything, and none can block the new standard, so none will receive anything here either. Component c's owner can also block the new standard by refusing to participate, so it will presumably receive positive rent, but at what level?

We extend the model as follows. Suppose that companies a and c demand royalty payments sequentially. Suppose further that a and c move first with equal probability. The alternative standards, (a,b) and (b,c), provide threat points for the negotiations over the standard (a,b,c) and thus should inform the payoff outcome. Which threat point proves relevant depends on the sequence of moves: the standard (a,b) constitutes the threat point when c moves first, and (b,c) when a moves first. Consider first the outcome of the sequential royalty-setting game when a moves first. It is straightforward to show that there is a unique equilibrium where a receives W^* and c receives zero. Instead when c moves first, the unique equilibrium involves a receiving $\left[W\left(v_a, v_b\right) - W\left(v_b, v_c\right)\right]$ and c appropriating the residual $W^* - \left[W\left(v_a, v_b\right) - W\left(v_b, v_c\right)\right]$. Consequently, the expected payoffs of companies a and c equal respectively:

$$\frac{1}{2}\left(W^* + \left[W\left(v_a, v_b\right) - W\left(v_b, v_c\right)\right]\right), \text{ and}$$

$$\frac{1}{2}\left(W^* - \left[W\left(v_a, v_b\right) - W\left(v_b, v_c\right)\right]\right).$$

Clearly the royalty payments received by a exceed those received by c, just as in the Shapley analysis. These results would extend to other game forms under some regularity assumptions, so in general we would expect that the payout ordering follows the contribution ordering noted above, namely $P_a \geq P_c \geq P_b = 0$.

5. CONCLUSIONS

We have presented four possible methods that the courts and competition authorities might use as benchmarks for FRAND evaluations. The first two are based on court cases. The fifteen factors in *Georgia Pacific* that guide reasonable royalty determinations for patent infringement cases are the most obvious starting point for FRAND, and they appear to be readily applicable to reasonable royalties within SSOs. That said, the factors leave the specific method of royalty determination an open question. The numeric proportionality rule suggested in the European Commission case is more problematic. While it can lower the transaction costs involved in determining FRAND royalties, it is only appropriate in a narrow set of circumstances. If applied outside of those circumstances, numeric proportionality would result in non-FRAND rates.

The other two methods we considered are based on existing economic models which, when extended to standard setting contexts, have strong implications for determining fair, reasonable, and non-discriminatory royalties. One starts from market solutions, while the other is rooted in cooperative game theory. Despite their contrasting origins, both the ECPR and the Shapley value analyses come to qualitatively similar solutions: FRAND terms are only satisfied when standard participants whose patents make greater incremental contributions to the value of the standard receive higher royalty payments than other participants. The ECPR and Shapley value models developed in this paper, while they do not fully capture the complexities of real world intellectual property licensing within standard setting, do satisfy all three criteria encompassed in the acronym FRAND.

We can view the two economic model methods as similar to the *Georgia-Pacific* factors in that they could guide ex post evaluations even though they do not provide an explicit formula. That is, we do not argue that license fees should actually be set by either the ECPR or Shapley value approach, as it would be difficult, time consuming, and generally contentious to determine the incremental contributions of the many patents that are reported as essential to most standards. When ex post litigation occurs,

however, these two approaches could be employed to assess the royalty rates that parties have set through bilateral negotiations. Consistent with reasonable royalty calculations in the context of patent infringement, the models here could provide structure for a court review. The various parties could make their cases in court for the *relative* values of their IP contributions to the standard, in the context of other options considered during the standard's early developmental phases. If a component had multiple alternatives before the standard was settled, its incremental contribution, properly measured, may be close or equal to zero. Precise marginal contributions to the standard are not really necessary, just relative contributions. License terms meeting a fair, reasonable, and non-discriminatory benchmark must allow companies with pivotal contributions to a standard to benefit from relatively better licensing terms.

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