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Efficient Level of SEPs Licensing

Abstract

We study the question whether a holder of standard essential patents (SEPs) should be allowed to choose the level in the value chain at which to offer a FRAND license to its SEPs. We give a positive answer to this question for two reasons. First, the SEP holder and the social planner tend to choose the licensing level that, other things being equal, minimizes transaction costs. Second, the SEP holder maximizes total output, which is often aligned with social welfare maximization by the planner. These two factors make it likely that the SEP holder chooses the efficient level of SET licensing.

JEL-Codes: K210, L400, O340.

Keywords: standard-essential patents, SEP licensing, FRAND, telecommunications, royalty base, licensing level, alignment of incentives.

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Efficient level of SEPs licensing

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Executive summary

Our paper examines the question whether a holder of standard essential patents (SEPs) should be allowed to choose the level in the value chain at which to offer a FRAND license for its SEPs. Various papers at the intersection of law and economics have addressed this question, presenting both arguments in favor of compelling the SEP holder to license component manufacturers (we refer to this also as 'upstream' licensing or UL) and arguments

in favor of allowing the SEP holder to license end product makers ('downstream' or DL). This literature has helped to identify factors that one should consider when selecting the optimal licensing level. However, it could not answer the question about what the optimal licensing level is. The reason for this is that there is not such a thing as a single optimal licensing level. Rather, the optimal licensing level varies across situations, depending on factors such as the market structure and the use of technology.

We tackle the question about the optimal licensing level head-on, by analyzing how well the SEP holders' incentives in the choice of the licensing level are aligned with those of a benevolent social planner in that choice. If the incentives are well-aligned, the choice of the licensing level can be left with the SEP holder. Our analysis is not exhaustive in that we only consider several determinants of the optimal licensing level: transaction costs, efficient differentiation in licensing terms, the optimal mix of implementation effort, entry incentives, and pricing distortions. We find strong support for the conclusion that the SEP holder's selection of the licensing level will be typically aligned with that of the benevolent social planner, which supports the decision to not impose any restrictions on the SEP holder's selection at the level at which to license its SEPs.

We start by focusing on the role of transaction costs, which are an important factor in selecting the optimal licensing level, as commentators and industry experts on both sides of the debate agree. Transaction costs are a broad category of costs that the SEP holder and licensees incur in reaching and enforcing FRAND license agreements. In some circumstances, such as in the smartphone industry, transaction costs are likely minimized when the SEPs are licensed at the downstream level.[1] In some other applications, however, component-level licensing is plausibly better at minimizing transaction costs.[2] We find that the SEP holder will choose the licensing level that

[1] Although, component-level licenses were not uncommon even in the era of smartphones. During the early period of mobile telecommunications development, the most important SEP holders were also important manufacturers of mobile telecommunication equipment and mobile phones; cross-licensing at the end-product level was important in that context. A notable exception is Qualcomm, an important SEP holder who only manufactured mobile phones (Q phone) for a relatively short period of time in the late nineties. Qualcomm sold its manufacturing interest to Kyocera (mobile phone division) and Ericsson (infrastructure division) in 1999.

[2] This argument has, for example, been made in relation to the IoT. A potential reason is that component manufacturers may be more familiar with the relevant technology than end-product makers and therefore better placed to efficiently negotiate a FRAND license

minimizes its private transaction costs, which often also minimizes the overall transaction costs. However, there is no similarly strong relation between an implementer's preferred licensing level and minimal overall transaction costs. This is because an implementer can avoid transaction costs altogether by pushing licensing to a level at which the implementer it is not active—irrespectively from whether or not the licensees' transaction costs at that level are lower.[3] Our analysis of transaction costs therefore favors leaving the choice of the licensing level to the SEP holder.

We also consider how the choice of licensing level may affect the social welfare by affecting (i) the efforts to implement the standard by component manufacturers and end-product makers; (ii) market entry; and (iii) differentiation in licensing terms. We find that also in these dimensions the incentives of SEP holders are generally well aligned with the incentives of a benevolent social planner. This is because the SEP holder will have a strong incentive to grant a license at a level that maximizes the overall industry output, which is often closely related to the social planner's objective to maximize overall welfare.

Output expansion and higher overall welfare can be achieved by choosing the licensing level to induce a higher implementation effort, more entry, or more efficient differentiation in licensing terms. Assuming that "FRAND is FRAND"—that is, that SEP holder is entitled to the same royalty per-unit of end product irrespectively of the licensing level—it is easy to see why SEP holders have an interest in large industry output. Indeed, the only way for a SEP holder to increase its royalty revenue is to increase the overall industry output. In contrast, for given margins, the implementers have an

(see, e.g.,. Henkel 2021). We do not examine whether this is actually the case in practice. Proponents of component-level licensing also highlight the legal risks for a component manufacturers operating without a license and without guarantees that the final product manufacturers using their components have obtained a license. While this is a relevant consideration, we understand that the prevailing legal view is that SEP holders must ensure access to standard technology to all implementers, which can be effectively achieved in ways other than by granting a direct license. (see, e.g., Borgehetti et al. 2021) Accordingly, we do not analyze this factor.

[3]The implementer's incentives may, however, be aligned with the planner's in situations where the implementer is integrated forward or backward, or where negotiations of FRAND royalties take place simultaneously with negotiations of the terms of supply for the implementing components. In this case, the implementer, be it the component manufacturer or end product maker, may internalize the effect of shifting transaction costs to a different level.

interest in boosting their private output, which is only loosely related to the total industry output. The incentive of the implementer to maximize its profits therefore tends to be separated further from the objective of the social planner compared to the same objective of the SEP holder. This analysis therefore also supports the decision to leave to the SEP holder the decision to select the level at which to license its SEPs.

1 Introduction

If economic efficiency is the goal, should a standard-essential patent (SEP) holder be required to grant a license on fair, reasonable and non-discriminatory (FRAND) terms to a component manufacturer who asks for it? Or should it be allowed to deny granting such a license, choosing the end-product level[4] instead? While much debated, this question has not been properly analyzed.[5] The opposing camps in the debate have been pitching arguments in favor of the final product level license against those in favor of the component level license. The debate has helped identify the factors that are relevant to the optimal choice of the licensing level; alas, it could not produce a definitive answer. This is because the optimal licensing level depends on how the licensed technology is used. The end-product and component licensing camps are both right, only not in the same circumstances.

We tackle the question of optimal licensing level by analyzing whose incentives—the SEP holder or the implementer's—are better aligned with those of a benevolent social planner when choosing the licensing level. Our analysis is not exhaustive in that we only consider several important determinants of the optimal licensing level: transaction costs, possibility of differentiation in licensing terms, pricing distortions, entry incentives and the role of implementation effort. We find that SEP holder's incentives in the choice of the level of licensing of SEPs tend to be aligned with the incentives of a social planner, whereas those of implementers do not. This is because both SEP holder and the social planner want to minimize transaction costs and to increase the industry output level. An implication of this is that, most of the time, the choice of the licensing level can be left with the SEP holder.

[4] We call this DL for 'downstream licensing' in the Appendices; a license to component manufacturer is called UL for 'upstream licensing'.

[5] Several commentators have analyzed whether the duty to license at the component level exists either under contract law (the FRAND commitment) or competition law.

This also speaks for not imposing any restrictions on the SEP holder's choice of the level at which to license its SEPs.

Although the specific goal of a FRAND commitment varies across standard developing organizations (SDOs), it typically seeks to promote the success of the standard by balancing the interest of various participants of the standardization process. For example, the FRAND commitment of the European Telecommunications Standards Institute (ETSI) seeks to promote the creation and implementation of new standardized telecommunication technologies that best meet the technical objectives of the European telecommunications sector.[6] To achieve this goal, ETSI's FRAND commitment seeks to balance between the need to provide access to technologies that are essential to practice a standard and the need to fairly reward SEP holder for their contributions.

The premise of ETSI's framework is that the FRAND objective can best be achieved by fostering efficient private negotiations between implementers and inventors of these technologies, i.e., the SEP holders. The framework recognizes that efficiency of private negotiations requires a clear assignment of IP rights. The institutional and regulatory infrastructure of the patent system provides such an assignment.[7] On top of the patent system, however,

[6] European Telecommunication Standards Institute [ETSI], ETSI Intellectual Property Rights Policy, Annex 6, Rules of Procedure, § 3 (Sep. 3, 2020), https://www.etsi.org/images/files/IPR/etsi-ipr-policy.pdf : 'It is ETSI's objective to create STANDARDS and TECHNICAL SPECIFICATIONS that are based on solutions which best meet the technical objectives of the European telecommunications sector, as defined by the General Assembly. In order to further this objective the ETSI IPR POLICY seeks to reduce the risk to ETSI, MEMBERS, and others applying ETSI STANDARDS and TECHNICAL SPECIFICATIONS, that investment in the preparation, adoption and application of STANDARDS could be wasted as a result of an ESSENTIAL IPR for a STANDARD or TECHNICAL SPECIFICATION being unavailable. In achieving this objective, the ETSI IPR POLICY seeks a balance between the needs of standardization for public use in the field of telecommunications and the rights of the owners of IPRs. IPR holders whether members of ETSI and their AFFILIATES or third parties, should be adequately and fairly rewarded for the use of their IPRs in the implementation of STANDARDS and TECHNICAL SPECIFICATIONS.'.

[7] Coase (1960) argued that, from an economic perspective, the goal of the legal system should be to establish a structure of rights such that economic efficiency is attained. Coase considered bargaining over an externality from a productive activity in an example of crop damage caused by straying cattle. He explained that negotiations among the affected parties, the rancher and the farmer, would result in an efficient and invariant outcome as long as (1) transaction costs are zero and (2) the rights are well-defined. Coase's argument assumes uncertainty away.

the framework imposes additional constraints on how a SEP holder can exercise its patent rights; notably, in terms of the level of royalties the SEP holder can request and conditions under which it can refuse to grant a license. This is in recognition of the special nature of SEPs. In our analysis, we therefore make the following assumptions on FRAND royalties.

Assumption 1. A FRAND royalty reflects the value of the licensed technology.[8]. We take this to mean that the FRAND royalty will be proportionate, in some way, to the value of technology in use.[9]

This is an uncontroversial assumption. An implication is that the SEP holder is entitled to a larger royalty for the product that relies to a greater extent on the patented technology for its value in use.[10]

Assumption 2 – Ad valorem downstream. The license specifies a FRAND royalty as a percentage of the sales if applied at the level of the final product.

In principle, parties might agree on different royalty structures: ad valorem royalties, per unit royalties, or lumpsum payments. However, ad val-

[8]Ericsson, Inc. v. D-Link Systems, Inc., 773 F. 3d 1201, 1226 (Fed. Cir. 2014): 'The essential requirement is that the ultimate reasonable royalty award must be based on the incremental value that the patented invention adds to the end product.'; European Commission (2017), at 6: 'Licensing terms have to bear a clear relationship to the economic value of the patented technology.'

[9]We make no assumptions on how that value should be determined. It could, for example, be the "incremental value" over the next best alternative before standardization, as some economists have suggested is a valid FRAND benchmark, or it may be determined in some other way.

[10]See Nokia Solutions v. Daimler Ag., 2 O 34/19 (Landgericht Mannheim Aug. 18, 2020) at 53 (Ger.): 'In the starting point, there is usually not precisely one single contractual structure (in particular not a single specific equivalence relationship between license rights and their remuneration) that satisfies the FRAND criteria in terms of content. Rather, there are frequently a large number of possible contractual arrangements and license rates that are fair, reasonable or appropriate and non-discriminatory. What can be considered fair and reasonable differs in particular from sector to sector and over time'; European Commission (2017) at page 8: 'There is no one-size-fit-all solution on what FRAND is: what can be considered fair and reasonable can differ from sector to sector and over time. Efficiency considerations, reasonable license fee expectations on both sides, the facilitation of the uptake by implementers to promote wide diffusion of the standard should be taken into account.'

orem royalties are pertinent in the licensing of telecommunication technologies at the level of the final product. We allow for both per unit and (in some scenarios) ad valorem royalties at the component level.

Assumption 3 – FRAND is FRAND. For any given sales volume of the final product, FRAND royalties are equal irrespectively of whether the licenses are concluded at the component or end-product level.

Our understanding is that Assumption 3 has been confirmed by courts and enjoys broad recognition. For example, SEPs Expert Group (2021) has asserted that 'the value of a SEP licence should not depend on the level in the value chain where the licence is taken. When, for example, a licence for SEPs that are fully implemented in an end product is granted to an OEM for a certain FRAND royalty, that royalty should not change if that same SEPs were alternatively licensed to a Tier-1 or Tier-2 supplier for a product that also fully implements those SEPs. In other words, FRAND is FRAND regardless of the licensing level'.[11]

Assumption 4 – Single-level licensing. Royalties will be imposed at one level only.

We motivate this by the patent exhaustion doctrine.[12] From the point of view of economics, single-level licensing may be rationalized by saving on transaction costs. For example, if transaction costs of licensing are fixed and approximately the same on upstream and downstream level, choosing to license on a single level allows to save around 50% of such costs Additionally, the single-level licensing assumption is motivated by the risk of double dipping or, alternatively, by the risk of potential licensees at different levels of the value chain pushing the royalty burden on each other.[13]

[11] see also Nokia Solutions v. Daimler AG., 2 O 34/19 (Landgericht Mannheim Aug. 18, 2020) at 55 (Ger.): 'finding that a FRAND royalty should allow the SEP holder to participate in "the economic benefits of the technology in the salable end product" even if the license is executed elsewhere in the supply chain than with the end-product manufacturer.'

[12] The United States Supreme Court reaffirmed the validity of the patent exhaustion doctrine in Quanta Computer, Inc. v. LG Electronics, Inc. : 553 U.S. 617 (2008)

[13] See SEP Expert Group (2021), p. 11. Some members of the Expert Group believed that, for this principle to work in practice, a degree of horizontal and vertical coordination between SEP holders and licensees may be needed.

Corollary to Assumption 4 – Access to all. When licensing takes place at the final level, the component manufacturers can access the technology without significant additional costs to them.[14]

Some commentators suggested that, in case FRAND royalty is collected at a component level, it should be fully passed on to the final product level.[15] We do not think it is realistic to generally expect that. A potential exception is when the component manufacturer acts as an agent for the end-product markets. We do not consider the latter situation in our analysis. Instead, how much of the royalty the upstream component manufacturer will pass on downstream will typically depend on a number of factors, among which is its bargaining power in relation the final device maker. We therefore do not assume a full pass-on of royalties charged upstream.

Under these assumptions, our main insights are as follows. While both SEP holders and implementers generally prefer the level of licensing that minimizes their private transaction costs, it is the SEP holder's transaction costs that tend to be more closely related to the overall transaction costs. An implementer could eliminate its transaction costs by pushing the licensing to a level where it does not operate. The incentive to do so will be present irrespectively of the transaction costs that SEP holders and implementers would incur at that level. When, however, a SEP holder advocates for another licensing level for the sake of reduction in its transaction costs, this will tend to be aligned with the planner's incentives to keep overall transaction costs low. Indeed, to the extent that the SEP holders bear the larger share of transaction costs or the change in the licensing level affects the total transaction costs and those of the SEP holder in the same direction—as is often the case as we argue below—we expect the SEP holder's incentives to be aligned better than the implementer's with the incentives of the planner.

Moreover, because of certain features of the FRAND licensing framework, SEP holders will have a strong incentive to grant a license at a level that maximizes the overall industry output. This is straightforward to see when the SEP holder is entitled to the same royalty per-unit of end product—no more, no less—irrespectively of the licensing level (assumption 3). In this case, the only way for a SEP holder to increase its royalty revenue is to increase the overall industry output, e.g., by encouraging implementation investments or

[14] For an overview of tools that parties might use to grant access to a patented technologies without a license see Heiden et al (2021).

[15] See, e.g., SEPs Expert Group (2021), p. 12

by encouraging entry. At the same time, the overall industry output is often closely related to the social planner's objective to maximize overall welfare. This means that the incentives of the SEP holder and the planner will also often be aligned. In contrast, for given margins, the implementers have an interest in boosting their *private* output which is only loosely related to the total industry output. The incentive of the implementer to maximize its profits therefor tends to be separated further from the objective of the social planner compared to the same objective of the SEP holder.

The rest of the paper is organized as follows. Section 2 provides a brief review of the relevant literature. In Section 3, we identify key sources of transactions costs in SEP licensing, and analyze how transaction costs depend on the level in the value chain where the patents are licensed. In Section 4, we discuss three partial models, each devoted to a particular aspect of economic interaction along the value chain, to analyze how the choice of licensing level affects social welfare. Finally, in Section 5, we provide a more general characterization of the extent to which incentives of various economic actors and social planner are aligned.

2 Literature review

The various streams in the debate on the optimal level of licensing can be organized around three questions. First, what is the proper FRAND royalty and how will the licensing level affect the ability of a SEP holder to extract royalties? Second, how does the licensing level affect the costs of reaching and enforcing the agreement for the SEP holder and implementer? Third, how does the licensing level affect the economic behavior of economic actors and the overall social welfare?

In addressing the first question, proponents of component level licensing are concerned that downstream level licensing may allow SEP holders to capture a part of the value of technologies and components that are unrelated to SEPs (e.g. Henkel, 2021). Proponents of end-product level licensing argue that SEP holders are entitled to a part of the value that arises from the synergies between the complementary technologies of a same standard once they have been implemented together in an end product. The authors in this camp stress that, in many industries, this value can only be captured at the end-product level as the full functionality of the standard is only fully realized in the end-product device (e.g. Sidak 2014). Our approach is not related to this disagreement – our starting point is that FRAND is FRAND regardless of the level at which the SEP is licensed. Correspondingly, it is not the SEP holder's revenue per licensed unit that will be affected by the choice of licensing level, but the behavior of economic agents involved.

In addressing the second question, several authors have highlighted that licensing at the component level may be impractical and would involve significant costs. SEPs are often licensed as a portfolio, and major portfolios usually consist of a broad array of patents that read on (i) various components alone, (ii) various components in combination, (iii) complete handsets alone, (iv) complete handsets in networks (see Putnam & Williams 2016). When SEP portfolios cannot be broken down to a single component, licensing at the component level may become impractical. If a component maker receives a license exhausting a subset of SEPs covering a standard, end-device manufacturers would still need a license for the remaining SEPs that read on downstream devices and networks. Borghetti et al. (2021) argue that the best approach in this case is to have only one license where most or, better, all the patents in a portfolio are infringed and exhausted by the sale of the licensed product, which is optimally achieved by licensing at the end-device level.

Developing concerns of practicality and efficiency, SEP Experts Group (2021) explains that SEP holders may opt to license at a single level of the value chain where the number of potential licensees is the smallest in order to reduce transaction costs associated with licensing. Indeed, when an innovator owns several patented technologies included in the same standard, with each technology being implemented at a different level in the value chain, licensing at a unique level in the value chain saves on transaction costs.[16] We take the issue with transaction costs seriously in this paper and analyze different sources of such costs in detail, discussing the implications on the incentives in Section 3.

Further, according to the SEP Experts Group (2021), a SEP holder will often target the level where the whole (or almost) whole of its SEPs are im-

[16]SEP Experts Group (2021) also notes the potential of single-level licensing to reduce the risk of 'double dipping'—i.e., collecting royalties twice for the same SEP—as licensing at each level would require each license to be accurately defined and delineated from each other with respect to scope and with respect to the SEPs used. Inversely, licensing at a single level also reduces the risk of under-compensation for the licensor if potential licensees at different levels of the value chain try to push the royalty burden to other levels in the value chain to minimize their own royalty payments.

plemented. This will crucially depend on the industry in question. Whereas mobile telecommunication and automotive industries feature relatively few and typically large end-product manufacturers implementing SEPs, the Internet of Things (IoT), for instance, is characterized by thousands of implementers which are frequently small and medium-sized enterprises (SMEs) or startups. Henkel (2021) argues that, in this context, end-device licensees are often at a great bargaining disadvantage vis-à-vis the licensors because of information asymmetry.[17]

Because of the high degree of fragmentation of the IoT downstream markets, approaching each individual implementer to negotiate a license would come at great search and other transaction costs for the SEP holders. Henkel (2021) concludes that, with end-device level licensing, many implementers will either not be approached at all, refuse to take a license, or take a license for a rate that might not be the same as their competitors. Hence, prudent implementers that are more willing to take a license will be put at a competitive disadvantage against those of their competitors who prefer to go forward without taking the licenses. Another logical conclusion from consideration of IoT industry is, however, that the SEP holders will also prefer upstream licensing (that involves much fewer negotiation partners) to save on transaction costs. This example is an illustration of the more general concept that we discuss in detail in this paper: the SEP holder will often prefer the level of licensing that is also optimal for the society.

There have only been a few attempts to address the third question in a formal economic analysis. Layne-Farrar et al. (2014) thus develop a 'royalty allocation neutrality' principle, stating that the level at which patent licensing takes place does not matter from a social welfare perspective. They consider a SEP holder licensing a cost-reducing technology to both upstream and downstream producers in the same value chain. The authors show that only the aggregate royalty per unit sold in the downstream market matters

[17] He explains that SMEs and startups often lack knowledge regarding IoT technologies and related patents, and generally ignore SEP licensing practices, the set of potential licensors, and the finer points of SEPs and FRAND. Unlike the SEP holders which are typically large and financially powerful, SMEs and startups suffer from resource constraints limiting their ability to acquire technical and legal advice and/or to engage in litigation, such that they would often perceive the SEP licensing process as non-transparent, dysfunctional, and unfair. This lack of information regarding licensing obligations would also create financial uncertainty for these firms as they cannot reliably predict in advance which demands for SEP royalties will come up later and how much royalty burden will they have to support.

for equilibrium outcomes when the final price of each good is increasing in its marginal cost and negotiations are Pareto-efficient. They provide two examples when these conditions are satisfied: with either (i) two standalone monopolies on each level of the value chain (each of which may or may not face moral hazard when exerting costly effort); or (ii) there is an integrated producer and one or more standalone downstream producers.

The authors also consider scenarios where the neutrality principle fails. Firstly, with asymmetric information, such that the patent holder does not observe the final quantity sold, producers have an incentive to under-report their sales in order to decrease the royalties to be paid. The patent holder may then have an incentive to spread the royalty burden across the value chain such that it can check whether the numbers reported by the upstream producer are consistent with those reported by the downstream producer, but put a bigger burden of the stage of the process where the monitoring cost is the lowest and where the price margins are the highest. Secondly, when enforcement is an important concern and injunctions are available, the SEP holder may want to prefer those stages in which licensees compete less and therefore have higher margins. Thirdly, when an upstream producer serves several differentiated downstream producers for which the same input has a different added value, but is legally unable to price discriminate. In this case, if the SEP holder differentiates his royalties to the upstream producer depending on the downstream product in which the input is incorporated, the upstream producer will not be able to fully pass-on his royalty burden to the downstream producers and will be forced to fix a uniform upstream price that will under-serve (or not serve at all) the downstream markets where consumers have the lowest valuations. Thus, it is optimal in this setting that the royalty is collected downstream.

Our analysis is related to that of Layne-Farrar et al. (2014), but we focus on the questions of alignment of incentives of various market participants with those of the social planner whereas these authors focus on the neutrality result and conditions under which it breaks down.

Also in this group, Llobet and Padilla (2016) analyze the welfare implications of ad valorem and per-unit royalties in a context where an upstream innovator licenses its technology to a pure downstream producer. The royalty rate is determined in Nash bargaining. The authors find that, in many contexts, ad valorem royalties lead to both lower prices and higher innovation.

Though these authors do not explicitly model upstream implementers, per-unit royalty of Llobet and Padilla (2016) can be rationalized, in some circumstances, as a component-level licensing. Our analysis in the subsection 'The role of implementation effort' is reminiscent of these authors', but is actually very different. First, we do account for an upstream implementer explicitly. Second, we require royalty payment to be the same per unit regardless of licensing regime rather than allow negotiations to affect this payment. Third, we focus on alignment of incentives rather than simple welfare comparison in the two licensing regimes.

Padilla and Wong-Ervin (2017) discuss whether a refusal to license to component manufacturers could allow a vertically integrated SEP holder to bundle its component (the bundled product) with its essential patent portfolio (the bundling product) in order to monopolize the component market. The authors rule out the risk of foreclosure of this bundling strategy if 1) the vertically-integrated firm does not assert its patents at the component level, and if 2) it licenses its SEP portfolio to end-product manufacturers on FRAND terms, irrespectively of whether they source components from its own subsidiary or from the non-integrated rivals. This paper is complementary to our analysis as we do not study foreclosure strategies.

3 Transaction costs in the FRAND licensing of mobile telecommunication SEPs

Transaction costs encompass a variety of overheads related to striking a deal and completing a trade. These costs directly reduce welfare and should therefore be minimized. In SEP licensing, both the SEP holder and the licensee will incur—perhaps asymmetrically—transaction costs. Besides being wasteful directly, transaction costs may also hamper innovation and implementation incentives for SEP holders and implementers. Accordingly, to the extent the choice of the licensing level affects transaction costs, a social planner would consider these effects. Taking everything else as given, and abstracting away from the indirect loss of value due to the effect of transaction costs on innovation and implementation incentives, the social planner would choose the level where the overall transaction costs are minimized.

While the SEP holder can reduce its own transaction costs by appropriately choosing the licensing level, it can never entirely eliminate these costs. In contrast, the implementer can do so by pushing the licensing to a level where it does not operate. The SEP holder's and the social planner's incentives in relation to the licensing level are thus aligned in the part of the overall transaction costs that the SEP holder incurs. But there is no part of transaction costs over which the incentives are aligned between the implementer and the planner. Accordingly, if the SEP holder tends to bear the larger share of transaction costs or if the change in the licensing level tends to affect the total transaction costs and those of the SEP holder in the same direction—and we will shortly argue that this is often the case—we may expect the SEP holder's incentives to be aligned better than the implementer's with the incentives of the planner.

We now turn to a detailed analysis of transaction costs and their role in the choice of the optimal licensing level. Coase (1960) and Dahlman (1979) identify the following four categories of transaction costs:

1. Search costs - as the parties to a transaction seek each other out (these costs are sunk by the time negotiations start);

2. Bargaining costs - incurred as the parties negotiate the terms of the agreement;

3. Monitoring costs - as the parties ensure the terms of trade are adhered to; and

4. Enforcement costs - if the terms are breached and legal action ensues.

3.1 Search costs

In the context of SEP licensing, search costs are likely lower for implementers than for SEP holders. Because of FRAND, manufacturers of components or end products that implement SEPs without securing a license do not have to fear that they would be held up by excessive royalties demands. Accordingly, the implementers do not need to search for the SEPs that their products may infringe; instead, they can wait for the SEP holders to inform them of that.[18] In contrast, if a SEP holder wants to get paid a royalty for its patents, it must identify the infringing products and present the manufacturer with its patent claims. This puts the bulk of the burden of search costs on SEP holders' shoulders. This burden may be enhanced by the fact that the implementers have no, or little, interest in actively seeking a license before the implementation.

[18] FRAND commitments are also important in terms of alleviating the chilling effect that uncertainty—a source of search costs—on the terms of legal use could have on adoption of technology when this is associated with irrecoverable investments.

In relation to minimization of the overall search costs, we can therefore expect that the SEP holders' incentives will often be aligned more closely than implementers' to the social planner's incentives.

3.2 Bargaining costs

Before concluding a license, the SEP holder and implementer must agree what share of the product's value can be attributed to the patented technology. To reach the agreement, the SEP holder and the prospective licensee will often have to engage in arm's-length negotiations. Arguments and proposals of one party will trigger counter-arguments and proposals from the other. The need for this back-and-forth process between the prospective parties to the agreement suggests that the change in the licensing level will often affect the parties' bargaining costs in the same direction—either increasing or reducing those costs for both parties. This symmetry implies that the SEP holder's incentives to choose the value so as to minimize its private costs of bargaining tends to be aligned with the planner's incentive to minimize the total cost of this category of transaction costs across SEP holders and implementers.

Since bargaining costs are in large part related to the determination of the value of licensed SEPs, we examine the factors, and associated bargaining costs, that will play a role in determination of this value. They are as follows: (i) the use of technology, (ii) the availability of alternatives in that use, and (iii) the scope of license.

3.2.1 The role of use of technology

FRAND royalties reflect the incremental, for the end-product, value of the patented technology under consideration. Thus, the value of technology will depend on the functionality that the technology provides and on how this functionality is used in the end product. To reach an agreement on FRAND royalty, the parties must roughly agree about that value.[19] A technology generates its entire value only when it is used by end consumers. To see this, consider that no value is generated if a technology is implemented in a component that does not end up being incorporated into a product and used

[19] Or, more precisely perhaps, they must roughly agree on how the court is likely to assess their respective arguments about what the appropriate FRAND royalties are, given the patents and infringing products under consideration, given that negotiations take place in the shadow of litigation and court FRAND determination.

by an end consumer. Accordingly, in most applications (we present several caveats later), it appears that the licensing parties will find it easiest to agree on the value of technology when bargaining takes place at the end-product level—closest to where the relevant value is generated.

The value of patents will also often be easier (less costly) to determine at the end-product level because of the pervasive complementarities—affecting the value of standardized technology as implemented in a product—between various patented and non-patented technologies that end-products implement. Conversely, it is difficult to determine and agree on that value at the component level because it is rarely known in advance how exactly various components will be combined in the final product. Even with such knowledge, however, the value determination at the component level is complicated by the fact that components may be used in multiple final products.

3.2.2 Alternatives to the patent portfolio under consideration

For minimizing bargaining costs, everything else being given, the level where both the SEP holder and licensee can best consider the alternatives to the technology is preferred. This is because the value of a license to the implementer—and ultimately final users—depends on the alternatives that the patented technology has. The set of alternatives will often be larger at the end-product level, and may also include the option not to incorporate the patented technology. In negotiations, this option may not be present for—or fully understood by—the component maker.

3.2.3 Scope of license

The value of a license for a SEP portfolio depends on the scope of the license, which the parties to negotiations must agree on. A broader scope generally implies higher FRAND royalty.

The scope of the license may include territorial limitations, types of products that the license covers, and other limitations. Often it is easiest for the parties to accurately delineate the optimal scope of a FRAND license at the end-product level. This is because the end-product manufacturer has a better view of the products that will incorporate the technology under consideration, and where it will sell these products. The higher the uncertainty about the intended scope of use of technology, the more costly it will be for the parties to agree a FRAND royalty. At the component level, the scope of use is more uncertain than at the end product level, as components are more anonymous.

3.3 Monitoring costs

When SEPs are licensed at the end-product level, the license agreements often specify FRAND royalties as a fixed share of—a royalty rate on—the future value of sales of the products implementing the licensed technology.[20] And when licensed at the component level, the royalties are often a fixed amount per component unit. The royalty rate or per-component fee are set in the licensing agreement and thus known to both parties in advance. But the value of sales—volume in the case of per-unit license fees—as the other component of FRAND royalty, is not fixed until later when sales are realized; even then, it will only be accurately known to the licensee.

To minimize its licensing expenses, the licensee will have an incentive to under-report its sales.[21] To ensure that it can effectively enforce the licensing agreement, the SEP holder will therefore need to be able to monitor future sales. An improvement in the effectiveness of monitoring can contribute to the reduction of transaction cost, because it reduces the uncertainty about the value of the agreement for both parties, when the licensee can behave opportunistically. All else being given, we can expect the SEP holder to prefer to license at the level where monitoring is more effective, which will, however, also contribute to the reduction in the overall transaction costs in alignment with the planner's incentives.

Often, monitoring at the level of final product will be less costly and more precise compared to the component level monitoring because prices of final products are public and independent market analysts often report unit sales. Moreover, if the value of component sales were used as the base in a FRAND license, the component manufacturer would have an incentive to offer discounts on the relevant component in exchange for a higher price on another component that is not encumbered by SEPs. The SEP holder does not participate in supplier-OEM negotiations and could not detect and prevent such conduct. This may explain why, when licensing takes place at the component level, it is typically set as a fixed fee per unit.

[20] This reduces the risk for the licensee relative to a fixed royalty.

[21] This point is also noted in Layne-Farrar et al. (2014).

3.4 Number of licenses that need to be concluded

The number of licenses that will have to be concluded affects transaction costs in a straightforward way. While the number of SEP holders remains the same irrespectively of the level at which the SEPs are licensed, the number of licensees may change substantially as we move across levels. For example, in the IoT space, a large variety of end products by different manufacturers may be using a smaller variety of components that implement SEPs. The reverse may be true in mobile telecommunications.

All else being equal, a SEP holder will prefer to license at the level where the number of implementers is lower—at the component level for IoT applications, and at the end product level in mobile telecommunications. In this dimension, the SEP holders private incentives are aligned with the planner's incentive to reduce the overall transaction costs. This cannot be said for an implementer who can minimize the number of transactions by shifting the licensing level away from those where it operates, irrespectively of whether this increases the number of licenses that would have to be concluded.

4 Efficient choice of licensing level: effort, variety and entry

Having discussed transaction cost as perhaps the most important determinant of the licensing level considered in the literature so far, we now turn to other factors. We identify various factors that determine how implementation efforts improve the end-product, pricing distortions, effects on entry and variety, as well as price discrimination as further potential determinants of the optimal licensing level.

We consider two scenarios: ad valorem royalties at both levels and per-unit royalty at the upstream level—the latter to account for the fact that per unit royalty is the more common rule in reality when licensing takes place upstream.

4.1 The role of implementation effort and pricing

A common interpretation of FRAND royalty is that it is the royalty level that strikes an optimal balance between the incentives of (future) SEP holders to invest in innovation and the incentives of manufacturers to invest in implementation and adoption of the standard. The amount of FRAND royalty per implementing unit (where the relevant unit is end-product) should be roughly comparable—we assume equal—regardless of the place in the value chain from which it is charged (Assumption 3 – FRAND is FRAND). Faced with the institutional constraint that all royalties for a given technology must be collected either downstream or upstream (Assumption 4 – patent exhaustion doctrine), the social planner will choose to impose the royalties at the level where the social cost of reducing implementation investment and demand (output) is minimal.

4.1.1 The role of effort: a model with elastic demand and efficient negotiations

We first consider a setting with inelastic demand for end products and efficient negotiations between upstream and downstream firm.[22] Though such setting may not be very realistic, it allows us to focus on the most direct effects of the choice on the implementation effort while abstracting from pricing inefficiencies.

We find that with ad valorem royalties at both levels, the socially optimal licensing level is determined by (i) the relative importance of the implementation effort at different levels of the value chain; (ii) 'royalty base' effect of the change in the licensing level (that tends to favor DL); and (iii) 'double distortion' effect of the change in level (that tends to favor UL).

The 'double distortion' effect of the DL regime works as follows. As the licensing parties engage in efficient negotiations, any reduction of the downstream revenue from royalty collected at that level means lower revenue that the licensing parties can share and with that a proportionate reduction in the upstream revenue. The DL, which reduces downstream revenue for the royalties collected there, thus distorts both downstream and upstream level implementation effort by reducing the available industry revenue by the same factor.

In contrast, a UL regime does not cause an effort distortion downstream. This is because the upstream revenue on which an ad valorem royalty rate is imposed represents a fixed transfer between the parties whose size does not change the total industry revenue and is irrelevant to the optimal choice

[22]This assumption is key to the discussion that follows immediately below, and is only justified in settings where the component manufacturer engages in arm's length negotiations on the terms of supply to the end-product manufacturer.

of effort of the downstream firm. The royalty imposed on the upstream manufacturer, therefore, does not create a 'double distortion'. This effect tends to favor UL.

The 'royalty base' effect, however, tends to favor DL. This is because the royalty base in the UL regime is smaller as long as the component manufacturer does not appropriate all the surplus in bargaining—a plausible assumption, in our view. Because of the smaller royalty base, the royalty rate needed to raise the same income from royalties (which must be the case under the 'FRAND is FRAND' assumption 3) is higher than in the DL regime. Accordingly, the distortion on the implementation effort in UL is higher compared to the DL regime.

Trading-off the 'double distortion' and 'royalty base' effects involves assessing the social cost of distorting downstream implementation effort versus those of distorting upstream implementation effort, both of which depend on the role of effort at each level in creating value for consumers. For example, everything else being given, if technology can be successfully implemented and broadly used without any implementation effort at the upstream level, the social planner will prefer to charge royalties upstream.

If upstream royalty is per unit, there is no distortion on implementation effort. There is, correspondingly, no 'royalty base' effect, and UL is therefore unambiguously welfare-superior in this case.

While the SEP holder is by construction indifferent between the two regimes in this setting (Assumption 3: FRAND is FRAND), the licensees prefer the licensing on the opposite end of the value chain when both royalties are ad valorem. When UL involves per unit royalty, the licensees are indifferent between the two regimes. In any event, the licensees' incentives in the licensing regime choice are not aligned with those of the social planner.

Appendix A contains a formal representation of this discussion. In particular, we consider the following sequential game. On stage 1, the FRAND royalty rate is set by the social planner (including the level at which the rate is applied) under the restriction that SEP holder gets the same royalty regardless of the regime (Assumption 3). On stage 2, the implementers upstream and downstream, as well as the potential SEP holder, chose their implementation/innovation efforts. On stage 3, the upstream component manufacturer negotiates a fee for the supply of components with the downstream implementer. On stage 4, the downstream implementer sells the end product to the consumer with inelastic demand and that each unit of the end product needs a unit of the component.

Analyzing the subgame-perfect equilibrium of this game allows us to formulate the following proposition:

Proposition 1 *In the setting with inelastic demand and efficient negotiations,*
1. When royalty is ad valorem, regardless of the licensing level,
a. both implementers prefer UL whenever it results in positive profit of the final product manufacturer;
b. social planner prefers DL or UL depending on the magnitude of 'double distortion' and 'royalty base' effects, as well as on the relative importance of the different types of implementation effort for value creation.
2. When upstream royalty is per unit (and downstream royalty is ad valorem),
a. both implementers are indifferent between the two licensing regimes;
b. social planner prefers UL as it is non-distortive.

The proof of Proposition 1 is left to Appendix A.

4.1.2 The role of price: a model with elastic demand and linear pricing

To study the additional factors that play a role in the choice of licensing level when demand depends on price, we consider a setting with isoelastic demand in this subsection.[23] To keep the analysis tractable, we assume linear pricing and no implementation effort at upstream level. In particular, a monopolist component manufacturer sets the component price and does not need to invest into implementation. Downstream, there is a single manufacturer which can invest into implementation effort that shifts the demand function upward.

With elastic demand—in the previous setting the demand was inelastic—the 'royalty base' effect has a new dimension that pushes the social planner to prefer DL for a fixed effort level. This is because output tends to be larger with licensing at that level. Indeed, as before, the royalty rate needed to raise the same income from royalties is higher in the UL regime than in the DL regime. With the elastic demand, however, this does not only distort

[23] Demand function is called isoelastic when it is characterized by a constant (independent of price) price elasticity, a measure that formalizes a notion of sensitivity of demand to a price change.

effort, but also leads to higher price (and lower output) and therefore causes allocative inefficiency.

We show that the preferences of the SEP holder in terms of the choice between UL and DL regimes are aligned with the social planner's. In particular, both prefer DL for a fixed level of effort. This is because higher output (or lower consumer price) maximize both welfare and SEP holder's income in this setting. This result obtains for both royalty structures that we consider.[24]

This alignment result does not generally obtain for the incentives of implementers. The downstream producer prefers UL for given level of output (whereas both SEP holder and social planner are indifferent). This is because the setting is characterized by cost amplification (pass-on is greater than unity), and so the downstream markup is larger the higher the upstream royalty payment, whereas it is independent of the downstream royalty payment.

For the upstream producer, the result is dependent on the royalty structure. With ad valorem royalties on both levels of the value chain, the upstream markup does not depend on the royalty rates (the upstream pass-on is equal to unity), and so it is in the interest of upstream producer to maximize output as much as it is in the interest of SEP holder and social planner. In other words, in this case, the incentives of these 3 agents are aligned. With per unit royalties upstream, however, there is cost amplification also upstream, and the component manufacturer prefers UL for the same level of output. Its incentives are therefore not aligned with those of the social planner in this case.

Formalizing the discussion above allows us to formulate the following proposition.

Proposition 2 *In the setting with isoelastic demand and linear pricing, and for a fixed level of implementation effort,*
1. Both social welfare and SEP holder's income are maximized in the licensing regime that maximizes output (DL).
2. The preference of the downstream producer regarding the licensing level includes comparing downstream markups across regimes in addition to the output. While output is maximized with DL, the markup is higher with UL.

[24] Recall that throughout the paper we consider two alternative royalty structures: (i) ad valorem royalties at both levels; (ii) ad valorem royalty downstream vs per unit royalty upstream.

3. The preference of the upstream producer regarding the licensing level includes comparing upstream markups across regimes in addition to the output. The markup is higher with UL when the royalties upstream are per unit; it is constant across the licensing regimes when the royalties are ad valorem.

The proof of Proposition 2 is left to Appendix B.

To summarize the discussion and the proposition, the incentives of the SEP holder and the social planner are aligned, whereas the incentives of the implementers and the social planner are generally not aligned in the model with elastic demand when the implementation effort is fixed.

In the next section ('Alignment of incentives'), we consider if the alignment and misalignment results survive in a richer setting that includes heterogenous good downstream and involves a possibility to charge different royalties for different downstream products. Before that, however, we discuss other factor that may effect the choice of licensing level: entry and variety.

4.2 Stimulating entry

When considering effects of a choice of the licensing regime in the longer run, it is important to take into account how this may affect entry at each level of the value chain and how, in turn, this will affect the overall welfare.

In general, entry possibilities will differ between upstream and downstream levels. Moreover, the effect of entry on overall demand and welfare may differ significantly depending on whether the entry takes place at the upstream level or at the downstream level. Entry in a differentiated downstream industry is likely to expand demand, whereas upstream demand is largely derived from downstream, and so upstream entry is more likely to increase competition at that level rather than create additional aggregate demand. A social planner would take into account both different possibilities of entry and different implications of entry for the welfare in its choice of licensing level.

In a simple model with monopolistic competition downstream (continuum of potential entrants) and quantity competition upstream, we show that the incentives of SEP holders and the planner are aligned as they both prefer a licensing regime with higher overall production. This alignment result is quite general: The SEP holder has an interest in increasing the total output so as to increase its royalty revenue, while the social planner has an interest in increasing the total output so as to increase total surplus.

The specific modeling choice allows us to illustrate this intuition clearly, without analyzing factors other than demand expansion, as, e.g., the effects of product heterogeneity and price differentiation discussed in the next subsection. In particular, we assume that every downstream firm faces a unitary demand that is independent of the demand that other downstream firms face. Further, we assume that downstream firms are non-strategic price-takers that simply enter the market as long as they are sufficiently efficient to operate profitably at given prices for end products, downstream royalties and the component prices. Upstream firms compete in quantities producing homogeneous component, subject to free entry.

In this setting, the upstream firms are indifferent between the two licensing regimes because of free entry, as they get zero profit regardless of the regime. The incentives of social planner, the SEP holder, and the downstream firms are aligned; the latter because higher output also means lower price of the component and therefore higher profit for each active downstream firm.

When upstream royalty is per unit rather than ad valorem, there is a perfect pass-through of upstream royalty downstream and the two regimes lead to the same outcome. All the actors are indifferent between the two regimes in this scenario.

The formal analysis of this model is in Appendix C.

4.3 Efficient price discrimination

To the extent product differentiation is present downstream and the same component is used, UL may be inefficient when it is limited to a uniform rate (e.g., because of arbitrage). Downstream, different rates may be applied according to the share of the patented technology in the value of the differentiated products that minimizes the distortion of consumer demand (similar to the Ramsey pricing principle).

This effect does not arise if the value of the patented technology corresponds to the revenue of the downstream manufacturer from the product. This is because, in this case, different value will imply different product price, so the optimal royalty rate can be the same without weakening price discrimination.

However, such perfect correspondence between the price of the final product and the value of the patented feature is not a rule. For illustration, consider a situation in which the demand for two products is the same (two products generate the same value for the consumer), but the share contributed by the patented feature is higher for one product than for another. In this situation, royalty rate as a share of price must be higher for the first product, on the efficiency as well as on the equity grounds. The implied royalty per unit of the final good sold should also be higher for the first product.

With uniform upstream licensing (which, as we know from Llobet and Padilla 2016, can be thought of as per unit royalty downstream even if collected ad valorem upstream), such differentiation is not possible. Both the manufacturer of the first product and the manufacturer of the second product will pay the same price for the component that entails the patented technology. This will lead to implicit cross-subsidization of the first product.

Such cross-subsidization will lead to inefficiency in the form of distorting production decision of the downstream firms (as less patented-technology-intensive good will be under-produced and may be even shut down in extreme case), but may reduce the aggregate distortion on the level of implementation effort (the more patented-technology-intensive good will be charged less providing extra incentive to invest into its implementation effort), resulting in a potential trade-off that the license regime designer would have to also take into account.

5 Alignment of incentives

As analyzed in the previous section, various factors determine the optimal choice of the licensing level, and different mechanisms are at play. Nevertheless, the overarching idea emerges from the consideration of these factors and mechanisms that the incentives to choose a particular level of licensing are likely to be better aligned between the SEP holder and social planner as compared to SEP implementers at different levels of the value chain.

In this section, we consider this idea more closely by extending our analysis of elastic demand as formulated in proposition 2. Assume that the value of the patented technology is correlated positively with the 'quality' of a product and consumers value higher quality more. Suppose, further, that there are two independent goods (final products) characterized by different quality levels, but otherwise having identical demand functions. We assume that the royalty rate downstream is ad valorem, whereas the royalty rate upstream is per unit.

Once the implementation effort is realized, the contribution of the patented technology to the quality level of each of the two products is fixed. In Appendix D, we formally analyze how a change in the contribution of the patented technology to the quality of one good, while keeping that contribution to the quality of another good fixed, affects the payoff of economic actors and the social planner in the two licensing regimes.

By varying the contribution, we can study the circumstances under which one or the other regime is preferred and infer how the incentives of various players are aligned with those of the social planner and with one another.

Upstream, we consider a single component manufacturer who pays per unit license fee in case the UL is chosen. We evaluate the average royalty for the purpose of Assumption 3 at downstream level.

In this setting, we can show that the SEP holder would always choose the level of licensing in which the total output is maximized. Intuitively, because the average license fee is the same across regimes, the only way to increase the royalty revenue for the SEP holder is to increase the total production.

For the social planner, the same is true to the extent that maximizing the total production is aligned with maximizing the welfare. While, in many cases, this will indeed be the case, there may also be circumstances in which this does not hold. The welfare is also determined by the output, but it is not only the total output that matters. The distribution of output between the two goods may be important as well, because the higher-quality good is more valuable in terms of welfare.

It is generally possible that welfare is maximized at one licensing level whereas total output is maximized at another level. For example, if one licensing regime results in a higher output of the more valuable (higher quality) good, it can well be that the total output is higher in the other licensing regime because of the higher production of the less valuable good. That would be the case when the regime preferred by the SEP holder (with a lot of lower quality good) is not socially optimal.

For the component manufacturer, it is also the total output rather than its distribution between the two goods that affects its preferred licensing regime. This is not surprising, because the upstream manufacturer can sell its component to both final good manufacturers. However, another, and often more decisive factor for the component manufacturer will be its ability to pass-on the royalty to the final producers, as this directly affects the relative profitability of each regime. In that sense the incentives of the planner and the upstream manufacturer diverge.

When the pass-on ability is imperfect (pass-on rate is below unity), the component manufacturer's preference is shifted towards the DL. Then, in the instances when the social planner prefers UL either because it maximizes total output or because it maximizes the output of the more valuable good, the choice of component manufacturer will be different from the socially optimal choice.

To sum up the argument, the SEP holder only cares about the total output; the component manufacturer cares about the total output and the upstream pass-on; and the social planner cares about the total output and its distribution. The discrepancy in incentives of SEP holder and the social planner may only arise in exotic cases when the distribution of output is very asymmetric and shifted considerably towards the good of lower quality. The discrepancy in incentives of the component manufacturer and the social planner is, at the same time, more systematic, as it is likely to arise whenever the total output is maximized with DL when the pass-on is imperfect, and whenever the total output is maximized with UL and the pass-on is greater than unity. In this sense, the incentives of the SEP holder and the social planner tend to be more closely aligned than those of the component manufacturer and the social planner.

Finally, the downstream producers each only consider the own output and own pass-on in their choice of the preferred licensing regime. These own measures may only accidentally have the same ranking as the total output and its distribution. The incentives of downstream producers are therefore generally not aligned with those of the social planner.

To finish up the discussion of the alignment, we provide, also in Appendix D, two illustrations of incentives alignment for particular classes of demand functions: isoelastic and linear.

Our main take from these illustrations is twofold. First, a particular functional form may significantly narrow down the scope for misalignment of incentives across all participants. Specifically, the isoelastic demand results in a broad alignment of the incentives of the SEP holder, social planner and component manufacturer for a large range of parameter values.

Second, relegating the choice of license level to component manufacturer may be dangerous because it may prefer to shut down the market for lower-quality product altogether by charging a too high price for its component. That is what happens in our setting with linear demand when the patented technology is very important for the quality of one of the product. In such circumstances, while DL is welfare-superior and the component manufacturer would choose to serve both markets in this regime, it prefers UL and serving the higher-quality market only. The SEP holder, as well as the social planner, always prefer both markets to be served.

6 Conclusion

Our analysis indicates that a SEP holder's incentives in the choice of the level of licensing of SEPs tend to be aligned with the incentives of a social planner better than the incentives of implementers are. This suggests that SEP holders, rather than implementers, should be allowed to choose the level in the value chain where the license is granted and royalties are charged. We have identified at least two factors that contribute to the alignment of incentives between a SEP holder and the social planner: the desire to minimize transaction costs and to increase the industry output level.

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Appendix A - Inelastic demand and efficient bargaining

Here we consider a simple setting where the upstream component manufacturer negotiates a fee for the supply of a given volume of components with the downstream implementer. Simultaneously, the (potential) SEP holder chooses the level of effort in innovation. We assume that the demand for end products is inelastic and that each unit of the end product needs a unit of component.

With inelastic demand, the welfare can be written simply as

$$P(e)(v(m,u) - m - u) - e, \quad (1)$$

where v is the value of the product to consumer, m is implementation effort downstream, u is implementation effort upstream, e is the effort that the SEP holder puts in innovation that will result in SEPs, and P is probability of successful innovation.

Lemma 1 *The first-best solution to the problem of maximizing (1) is characterized by $v_m = 1$ and $v_u = 1$.*
Proof. *Follows directly by maximizing (1) with respect to efforts m and u.* ■

Denote by δ the share of value that is captured by the manufacturers (it is lower than unity, perhaps because of competition or incomplete knowledge of this value by manufacturer). Further, Denote by r_m the ad valorem royalty rate downstream and by r_u the ad valorem royalty rate upstream.

Lemma 2 *The efforts of implementors rationally expecting the outcome of efficient negotiations is implicitly determined by $(1 - r_m)\delta v_m = 1$ and $(1 - r_u)(1 - r_m)\delta v_u = 1$.*
Proof. *The surplus for downstream firm from bargaining is $(1 - r_m)\delta v - m - q$ (each bargain happens after the technology becomes available and a part of the standard) and the surplus of the upstream firm is $(1 - r_u) q - u$. The bargaining problem is therefore*

$$((1 - r_m)\delta v - m - q)^{\gamma} ((1 - r_u) q - u)^{1-\gamma}.$$

Maximizing this, we get

$$q = \left(\gamma \frac{u}{1 - r_u} + (1 - \gamma)\left((1 - r_m)\,\delta v - m\right)\right)$$

as a bargaining solution. The choice of effort by the downstream firm will be determined by maximizing

$$\gamma\left((1 - r_m)\,\delta v - m\right) - \gamma \frac{u}{1 - r_u},$$

which results in $(1 - r_m)\,\delta v_m = 1$, *Q.E.D. The choice of effort by the upstream firm comes from maximizing*

$$(1 - \gamma)\left((1 - r_u)\left((1 - r_m)\,\delta v - m\right) - u\right),$$

resulting in $(1 - r_u)(1 - r_m)\,\delta v_u = 1$, *Q.E.D.* ■

The two lemmata allow us to formulate the following Corollary:

Corollary 1 *The lower the distortion on implementation effort caused by royalties, the closer the decentralized solution to the first-best.*

The corollary essentially assures us that less distortion from royalties is better from the social point of view (which does not need to be true in settings where distortions are to some extent socially beneficial). Finally, the following lemma characterizes optimal royalty rates in each of the licensing regimes.

Lemma 3 *Assumptions 3 and 4 imply that* $\exists K \in R_+ | P'(e)\,K = 1$ *and either* $\delta v r_m = K$ *or* $r_u\left((1 - \gamma)(\delta v - m) + \gamma \frac{u}{1 - r_u}\right) = K$.

Proof. *SEP holder chooses its effort by maximizing*

$$P\left(r_m \delta v + r_u\left(\gamma \frac{u}{1 - r_u} + (1 - \gamma)\left((1 - r_m)\,\delta v - m\right)\right)\right) - e.$$

Denote royalty revenue by $K := r_m \delta v + r_u\left(\gamma \frac{u}{1 - r_u} + (1 - \gamma)\left((1 - r_m)\,\delta v - m\right)\right)$. *The optimal effort choice then implies that* $P'(e)\,K = 1$. *Under assumption 4, either* $r_u = 0$ *or* $r_m = 0$. *In the former case,* $K = r_m \delta v$, *and in the latter case,* $K = r_u\left(\gamma \frac{u}{1 - r_u} + (1 - \gamma)\left((1 - r_m)\,\delta v - m\right)\right)$, *Q.E.D.* ■

Corollary 2 *Under Assumption 3, the problem of the choice of the optimal licensing level has to be solved for a given innovation effort level e.*

Now, we are ready to prove Proposition 1 that is formulated in the main text.

Proof of Proposition 1 - statement 1. Formally, the problem of the choice of the optimal licensing level under Assumptions 3 and 4 with ad valorem royalties is to maximize (1) on the set of two alternatives: $\{(0, r_m); (r_u, 0)\}$ with r_u determined from the solution of

$$\delta v_m = 1,$$
$$(1 - r_u)\,\delta v_u = 1,$$
$$r_u \left((1 - \gamma)(\delta v - m) + \gamma \frac{u}{1 - r_u} \right) P'(e) = 1,$$

which is a system of 3 equations in 3 variables (m, u, r_u) and therefore must have a solution unless constraint qualification breaks down. Analogously, r_m together with m and u can be determined from the solution of

$$(1 - r_m)\,\delta v_m = 1,$$
$$(1 - r_m)\,\delta v_u = 1,$$
$$\delta v r_m P'(e) = 1.$$

The three conditions in each case are established by lemmata 1-3. Corollary 1 tells us that we can compare the two regimes in turns of distortions to implementers' effort. In UL case, there is no distortion on downstream effort (compared to laissez-faire, i.e., the situation without royalty payments), and the distortion on upstream effort can be measured by r_u. In DL case, the distortion is both on downstream and upstream effort ('double distortion' effect), but it is smaller than in the upstream licensing and can be measured by $r_m = \frac{r_u}{\delta v}\left((1 - \gamma)(\delta v - m) + \gamma \frac{u}{1 - r_u}\right) < r_u$ ('royalty base' effect). The loss of welfare caused by the distortion of effort choice does not only depend on the size of the distortion, but also on how valuable the effort is for generating value, i.e., on the functional form of $v(m, u)$. This completes the proof of statement 1b of the proposition.

To consider the preference of the implementers, note that the profit of the downstream firm is $\gamma\left((1-r_m)\,\delta v - m - \frac{u}{1-r_u}\right)$, and so it is straightforward that the downstream firm prefers UL whenever

$$\delta v - m - \frac{u}{1-r_u} > 0, \tag{2}$$

, i.e., whenever it gets positive profit in UL regime. The upstream firm's profit is $(1-\gamma)\left((1-r_u)\left((1-r_m)\,\delta v - m\right) - u\right)$, which, using lemma 3, can be written as

$$(1-\gamma)\left(\left(1-\frac{r_u}{\delta v}\left((1-\gamma)\,(\delta v - m) + \gamma\frac{u}{1-r_u}\right)\right)\delta v - m - u\right)$$

with DL and $(1-\gamma)\left((1-r_u)\,(\delta v - m) - u\right)$ with UL. Comparing the two, we arrive at exactly the same condition (2). This completes the proof of statement 1a of the proposition.

Proof of proposition 1 - statement 2. When the upstream license fee is per-unit rather than ad valorem, with r_u being fixed fee that must be paid for each unit of the component that uses the patented technology The surplus of the upstream firm is then $q - r_u - u$. Following the same steps as for ad valorem fee, we can get results that are analogous to lemmata 1-3. In particular, modified lemma 3 states that $K = r_m \delta v$ with DL and $K = r_u$ Based on these results, the problem of the choice of the optimal licensing level with per unit royalties upstream is to maximize (1) on the set of two alternatives: $\{(0, r_m)\,; (r_u, 0)\}$ with r_m determined from the solution of

$$(1-r_m)\,\delta v_m = 1,$$
$$(1-r_m)\,\delta v_u = 1,$$
$$P'(e)\,r_m \delta v = 1;$$

and r_u determined from the solution of

$$\begin{aligned} \delta v_m &= 1, \\ \delta v_u &= 1, \\ P'(e)\,r_u &= 1. \end{aligned}$$

In UL case, $r_u = \frac{1}{P'(e)}$ and does not distort the implementors' effort. In case of downstream licensing, the distortion is both on downstream and upstream effort ('double distortion' effect). Compared to the ad valorem royalties, "royalty base" of UL disappears. Because the distortion of the inventor's effort is the same in both regimes, the UL is preferred. This completes the proof of statement 2b of the proposition. The profit of the downstream firm is $\gamma\left(\left(1-r_m\right)\delta v-m-u-r_u\right)$ and that of the upstream firm is $\left(1-\gamma\right)\left(\left(1-r_m\right)\delta v-m-u-r_u\right)$. Since $r_m=\frac{r_u}{\delta v}$, both firms are strictly indifferent between the two regimes. This completes the proof of statement 2a of the proposition.

Appendix B - Elastic demand and linear pricing

Consider (elastic) downstream demand $d\left(a,p\right)$ with a reflecting the value of the product to the consumer. The final product producer acts as a price-taker in the market for the component, which price q is set by an upstream producer. The downstream firm can make costly investment (implementation effort) $k\left(a\right)$ that increases the value of parameter a. The decision to invest comes as a first stage in the game because downstream manufacturer can take the upstream producer's price decision into account when deciding on investment.

The downstream firm maximizes

$$\left(\left(1-r_m\right)p-q\right)d\left(a,p\right),$$

where r_m is the license rate with DL, by choosing the final good price. The optimal price is then

$$1-\frac{q}{\left(1-r_m\right)p}=-\frac{1}{\varepsilon},$$

where ε is consumer demand elasticity. We further limit our consideration to the class of isoelastic functions $d=ap^{\varepsilon}$, in which case the downstream price can be explicitly written as

$$p=\frac{q}{\left(1-r_m\right)\left(1+\frac{1}{\varepsilon}\right)}. \tag{3}$$

The upstream firm maximizes

$$\left(\left(1-r_u\right)q-c\right)d,$$

where r_u is the license rate with UL and c is marginal cost of component manufacturer. The resulting upstream price is

$$q = \frac{c}{(1 - r_u)\left(1 + \frac{1}{\varepsilon}\right)}, \tag{4}$$

The implementation effort is determined by

$$((1 - r_m)\, p - q)\, d - k\,(a)\,,$$

resulting in the optimal choice following

$$((1 - r_m)\, p - q)\, p^{\varepsilon} = k'\,(a)\,. \tag{5}$$

While the rhs is the same under the two regimes, the lhs differs. Substituting for q and p, the lhs can be expressed as

$$-\frac{1}{1+\varepsilon}\,(1 - r_m)^{-\varepsilon}\left(\frac{\varepsilon}{1+\varepsilon}\right)^{1+2\varepsilon} c^{1+\varepsilon}\,(1 - r_u)^{-1-\varepsilon}\,.$$

The higher this expression is, the higher the distortion on innovation effort will be, given $k\,(a)$ is a decreasing convex function. The distortion on effort is therefore higher under DL if $(1 - r_m)^{-\varepsilon} < (1 - r_u)^{-(1+\varepsilon)}$. When $r_i = r_u$, this is satisfied and the effort distortion is indeed higher under DL. Under assumption 3, however, we have $r_m p = r_u q$ and therefore

$$\frac{r_m}{1 - r_m} = \frac{r_u}{1 - r_u}\left(1 + \frac{1}{\varepsilon}\right),$$

which implies $\frac{r_m}{1-r_m} < \frac{r_u}{1-r_u}$ and, further, $r_m < r_u$. Since both $(1 - r_m)^{-\varepsilon}$ and $(1 - r_u)^{-(1+\varepsilon)}$ are decreasing in corresponding license rates, the effect of the choice of the level of the licensing level on the downstream effort is ambiguous.

Proof of Proposition 2 - ad valorem royalties. The social welfare can be written as a sum of consumer surpluses and producer surplus net of investment cost:

$$a\int_{p}^{+\infty} x^{\varepsilon} dx + (p - c)\, ap^{\varepsilon} - k\,(a)\,.$$

This is maximized by choosing royalty rates subject to the incentive

compatibility (market interaction) constraints and minimal level of per unit royalties R. The latter takes the form of $r_m p \geq R$ with DL and $r_u q \geq R$ with UL. Simplifying the expression for the social welfare, we get

$$d\left(\frac{p\varepsilon}{1+\varepsilon}-c\right)-k\left(a\right). \tag{6}$$

Fixing the effort, we can compare the first term across the two regimes. Substituting d and p with their equilibrium expressions with help of (3) and (4), we arrive at the condition for DL to be preferred:

$$\begin{aligned} &\left(\frac{1}{1-r_u}\right)^{\varepsilon}\left(\frac{1}{1-r_u}\left(\frac{\varepsilon}{1+\varepsilon}\right)^3-1\right) \\ < \quad &\left(\frac{1}{1-r_m}\right)^{\varepsilon}\left(\frac{1}{1-r_m}\left(\frac{\varepsilon}{1+\varepsilon}\right)^3-1\right). \end{aligned}$$

Because $r_m < r_u$ as established earlier, this is satisfied if the expression on either side is decreasing in the corresponding royalty rate. To see if this is the case, we compute the corresponding derivative. It can be shown that its sign is the same as the one of the following expression:

$$\varepsilon\left(\left(\frac{\varepsilon}{1+\varepsilon}\right)^3-(1-r_i)\right)+\left(\frac{\varepsilon}{1+\varepsilon}\right)^3,$$

where $i \in \{u, m\}$. Since a royalty rate is defined on $[0, 1]$ and the expression is monotonically decreasing in this royalty rate, it suffices to show that the expression is negative at $r_i = 0$ to prove that either side of inequality above is decreasing in r_i. At $r_i = 0$, the expression becomes

$$\varepsilon\left(\left(\frac{\varepsilon}{1+\varepsilon}\right)^3-1\right)+\left(\frac{\varepsilon}{1+\varepsilon}\right)^3,$$

which is negative for $\varepsilon < -1$. The social planner therefore prefers DL with the fixed implementation effort.
SEP holder's revenue is $ap^{\varepsilon}R$, which is clearly decreasing in consumer

price (and therefore increasing in output). Consumer price itself can be computed from (3) and (4) to be equal to

$$\frac{c}{(1-r_i)\left(1+\frac{1}{\varepsilon}\right)^2},$$

which is clearly higher with UL, as $r_u > r_m$. The SEP holder therefore prefers DL, its incentives being aligned with those of social planner. This completes the proof of statement 1 of the proposition for the case of ad valorem royalties.
The upstream firm's profit is $-\frac{1}{1+\varepsilon}cd$: the markup does not vary across licensing regimes, and the ranking is therefore completely determined by the output. The incentives of the upstream manufacturer and the SEP holder are perfectly aligned in this formulation. This completes the proof of statement 3 of the proposition for the case of ad valorem royalties.
The downstream firm's profit is $-\frac{1}{1+\varepsilon}\frac{c}{(1-r_u)\left(1+\frac{1}{\varepsilon}\right)}d$, i.e., it is determined by the output and by the markup, positively affected by the license rate in UL. Because of this extra preference for UL, the downstream producer's incentives are not aligned with those of the social planner, the SEP holder, or the upstream producer. This completes the proof of statement 2 of the proposition for the case of ad valorem royalties.

Proof of Proposition 2 - per unit royalties upstream. When the royalty upstream is per unit and downstream is ad valorem, the downstream optimization does not change, resulting in (3). The upstream firm maximizes

$$(q-r_u-c)\,d,$$

where r_u is the upstream license rate and c is marginal cost of component manufacturer. The resulting upstream price is

$$q=\frac{c+r_u}{1+\frac{1}{\varepsilon}}. \quad (7)$$

The welfare is maximized analogously to as in ad valorem formulation subject to analogous constraints and can be compactly written as in (6). Consider setting r_m in such a way that it implies $pr_m = r_u$:

$$\frac{c}{(1-r_m)\left(1+\frac{1}{\varepsilon}\right)^2}=r_u.$$

From (6), the part of welfare that does not involve cost of effort can be written as

$$a\left(\frac{ck}{\left(1+\frac{1}{\varepsilon}\right)^2}\right)^{\varepsilon}\left(\frac{ck}{\left(1+\frac{1}{\varepsilon}\right)^2}\frac{\varepsilon}{1+\varepsilon}-c\right),$$

where $k=\frac{1}{1-r_m}$ with DL and $k=1+\frac{1}{1-r_m}$ with UL. Clearly, $1+\frac{1}{1-r_m}>\frac{1}{1-r_m}$, so the DL is preferred if the expression above is decreasing in k. Because consumer price is increasing in k and the welfare is decreasing in price, the expression above indeed has to decrease in k. DL is thus preferred by the social planner.

The SEP holder prefers the regime with higher output and therefore lower consumer price. That is expressed from (3) using (7) as

$$\frac{c}{(1-r_m)\left(1+\frac{1}{\varepsilon}\right)^2}$$

with DL and

$$\frac{c+r_u}{\left(1+\frac{1}{\varepsilon}\right)^2}$$

in UL. Because $\frac{c}{r_u\left(1+\frac{1}{\varepsilon}\right)^2}=1-r_m$, the former can be written as

$$\frac{cr_u\left(1+\frac{1}{\varepsilon}\right)^2}{c\left(1+\frac{1}{\varepsilon}\right)^2}=r_u.$$

Clearly, $\frac{c+r_u}{\left(1+\frac{1}{\varepsilon}\right)^2}>r_u$ and so SEP holder prefers DL. This completes the proof of statement 1 of the proposition for the case of per unit royalties upstream.

The downstream firm's profit is

$$-\frac{\varepsilon}{(1+\varepsilon)^2}(c+r_u)\,d,$$

making this firm clearly prefer UL for a fixed output level. This completes the proof of statement 2 of the proposition for the case of per unit royalties upstream.

The upstream firm's profit is

$$-\frac{1}{1+\varepsilon}(c+r_u)\,d,$$

which indicates that upstream firm, too, prefers UL for a fixed output level. This completes the proof of statement 3 of the proposition for the case of per unit royalties upstream.

Appendix C - the role of entry

Here we consider how the choice of licensing level may affect the incentives of firms at the upstream and downstream level to enter the industry.

Setting

Suppose there is a continuum of firms downstream that vary in their efficiency, each characterized by parameter θ distributed over a unit interval according to a cdf F. The parameter (think, for example, of marginal cost) indicates a minimal markup that the firm needs to get from implementing the technology in question in order to enter the industry. The markup of the downstream firm is $(1-r_m)\,p-q$, and so all the firms with higher θ will enter, generating the licensor revenue $r_m pF\left((1-r_m)\,p-q\right)$. The derived demand for the component is (assuming linear one-to-one technology) is then $y=F\left((1-r_m)\,p-q\right)$

Upstream, component manufacturers (upstream firms) compete a la Cournot, facing inverse demand

$$q=(1-r_m)\,p-F^{-1}(y)\,.$$

A single manufacturer's problem is then

$$(1-r_u)\left((1-r_m)\,p-F^{-1}(y)\right)y_i-C,$$

where C is fixed cost necessary to run the upstream business. The optimal output is then determined by

$$\left(-\left(1-r_u\right)\frac{\partial F^{-1}(y)}{\partial y}\right)\frac{y}{n}+\left(1-r_u\right)\left((1-r_m)\,p-F^{-1}(y)\right)=0$$

in symmetric case and n determined by zero profit condition

$$(1-r_u)\left((1-r_m)\,p-F^{-1}(y)\right)\frac{y}{n}=C$$

Under assumption 3, if the court decides that the relevant rate is r_m, the corresponding upstream relevant rate is $r_u = \frac{r_m p}{q}$. This way, the same value per unit is extracted from any level of the value chain. We consider the two scenarios.

Comparison of licensing regimes

Under downstream licensing, the equations above will look like

$$\begin{aligned} \left((1-r_m)\,p - F^{-1}(y)\right) y &= nC, \\ \frac{\partial F^{-1}(y)}{\partial y} y &= n\left((1-r_m)\,p - F^{-1}(y)\right); \end{aligned}$$

for upstream licensing, they will look like

$$\begin{aligned} (1-r_u)\left(p - F^{-1}(y)\right) y &= nC, \\ \frac{\partial F^{-1}(y)}{\partial y} y &= n\left(p - F^{-1}(y)\right). \end{aligned}$$

With $r_m p = r_u q$, written as

$$r_m p = r_u\left(p - F^{-1}(y)\right),$$

we have the comparison between

$$\begin{aligned} \left((1-r_m)\,p - F^{-1}(y)\right) y &= nC \\ \frac{\partial F^{-1}(y)}{\partial y} y &= n\left((1-r_m)\,p - F^{-1}(y)\right) \end{aligned}$$

for DL and

$$\begin{aligned} \left((1-r_m)\,p - F^{-1}(y)\right) y &= nC \\ \frac{\partial F^{-1}(y)}{\partial y} y &= n\left(p - F^{-1}(y)\right) \end{aligned}$$

for UL. We see that the zero profit condition is exactly the same, so we are left with comparing the FOC. Clearly, the rhs is higher under the upstream licensing. The rhs is a marginal benefit of an extra unit for the upstream manufacturer, and therefore equilibrium output is higher under the upstream licensing.

The downstream firm's markup (and also profit because of its zero mass) is $(1-r_m)\,p - q = F^{-1}(y)$. By construction, the entry happens when the downstream margin goes up, and so the incentives of downstream firms are aligned with those of social welfare. The upstream firm's profit is zero by construction, so the upstream firms are indifferent between the regimes.

Per-unit upstream license fee

A single manufacturer's problem is

$$\left((1-r_m)\,p - F^{-1}(y) - r_u\right) y_i - C,$$

where C is fixed cost necessary to run the upstream business. The optimal output is then determined by

$$\left(-\frac{\partial F^{-1}(y)}{\partial y}\right)\frac{y}{n} + (1-r_m)\,p - F^{-1}(y) - r_u = 0$$

in symmetric case and n determined by zero profit condition

$$\left((1-r_m)\,p - F^{-1}(y) - r_u\right)\frac{y}{n} = C$$

Under assumption 3, if the court decides that the relevant rate is r_m, the corresponding upstream relevant rate is $r_u = r_m p$. This way, the same value per unit is extracted from any level of the value chain. We consider the two scenarios.

Under downstream licensing, the equations above will look like

$$\begin{aligned}\left((1-r_m)\,p - F^{-1}(y)\right) y &= nC,\\ \frac{\partial F^{-1}(y)}{\partial y} y &= n\left((1-r_m)\,p - F^{-1}(y)\right);\end{aligned}$$

for upstream licensing, they will look like

$$\begin{aligned}\left(p - F^{-1}(y) - r_u\right) y &= nC,\\ \frac{\partial F^{-1}(y)}{\partial y} y &= n\left(p - F^{-1}(y) - r_u\right).\end{aligned}$$

With $r_m p = r_u$, we have the comparison between

$$\begin{aligned}\left((1-r_m)\,p - F^{-1}(y)\right) y &= nC\\ \frac{\partial F^{-1}(y)}{\partial y} y &= n\left((1-r_m)\,p - F^{-1}(y)\right)\end{aligned}$$

for downstream and

$$\begin{aligned}\left((1-r_m)\,p-F^{-1}(y)\right)y &= nC \\ \frac{\partial F^{-1}(y)}{\partial y}y &= n\left((1-r_m)\,p-F^{-1}(y)\right)\end{aligned}$$

for upstream. We get equivalence of the outcomes.

Appendix D - Alignment of incentives

General formulation

Assume there are two different products with demand for the first product being smaller (at any price). Assume further that there is a "quality" feature a_i with $\kappa_i a_i$ being due to patented technology and an ad valorem FRAND rate is exogenously determined to be $\eta\kappa_i$. For expositional purpose only, consider $\eta = 1.$ and the relation between κ_1 and κ_2 is not restricted. Assume further an upstream monopolist with a linear price q. The downstream maximization problems are

$$(p\,(1-\kappa_i)-q)\,x\,(p,a_i)$$

resulting in FOCs

$$(1-\kappa_i)\,x\,(p,a_i)+(p\,(1-\kappa_i)-q)\,x_p\,(p,a_i)=0.$$

Totally differentiating, we can establish how final good price changes with the price of the component:

$$\frac{dp_i}{dq}=\frac{x_p\,(p,a_i)}{\pi_{pp}}, \tag{8}$$

where $\pi_{pp} < 0$ is the second derivative of downstream firm's profits with respect to price.

The upstream monopolist's problem is to maximize

$$(q-t_u-c)\sum x\,(p,a_i)$$

with respect to q, where t_u is per unit royalty rate in UL. This results, using (8), in FOC

$$\sum x\,(p,a_i)=-\,(q-t_u-c)\sum\frac{x_p^2\,(p,a_i)}{\pi_{pp,i}}$$

Assumption 3 needs to be interpreted here as $\kappa_i p_i x(p, a_i)$ generally varies by i. The most natural interpretation appears to be

$$t_u = \frac{\sum \kappa_i p_i x(p_i, a_i)}{\sum x(p_i, a_i)},$$

where all prices are assessed at DL regime values. In words, the income that SEP holder gets per unit with UL, t_u, is equal to its average income per unit with DL, $\frac{\sum \kappa_i p_i x(p_i, a_i)}{\sum x(p_i, a_i)}$.

The consumer surplus is

$$\sum \int_{p_i}^{+\infty} x(p, a_i)\, dp,$$

which is ceteris paribus increasing in each good's quantity (and decreasing in each good's price). While, in general, the welfare-superior regime may be at either level, there is a reason to believe that the choice of the SEP holder would be more aligned with welfare-optimization than that of the implementers. While implementers will often prefer raising royalties on the opposite side of the value chain (as detailed further), the SEP holder's incentive is to maximize the output given a royalty that is per-unit the same in both regimes. The welfare-optimization goal is very close: the social planner would also maximize total quantity, but for optimal mix between the two products.

Formally, the welfare maximiser prefers DL if

$$\begin{aligned} & \sum \left(\int_{p_i}^{+\infty} x(p, a_i)\, dp + p_i x(p_i, a_i) \right) |_{\kappa_i} \\ \geq & \sum \left(\int_{p_i}^{+\infty} x(p, a_i)\, dp + p_i x(p_i, a_i) \right) |_{t_u}, \end{aligned}$$

whereas the PH does so if

$$\sum \kappa_i p_i x(p_i, a_i) |_{\kappa_i} \geq t_u \sum x(p_i, a_i) |_{t_u},$$

both subject to the constraint

$$t_u = \frac{\sum \kappa_i p_i x(p_i, a_i)}{\sum x(p_i, a_i)} |_{\kappa_i}$$

Using this constraint, we can write the PH's preference for DL as

$$t_u \sum x(p_i, a_i)|_{\kappa_i} \geq t_u \sum x(p_i, a_i)|_{t_u},$$

which is clearly the condition for total output to be higher under DL, $\sum x(p_i, a_i)|_{\kappa_i} \geq \sum x(p_i, a_i)|_{t_u}$.

Note that while the PH is interested in the ranking of output, the social planner is interested in the ranking of the total surplus. For each product, higher output is unequivocally associated with higher total surplus. The discrepancy in the incentives of the PH and the social planner may therefore only arise for a special class of demand systems that are characterized by significant asymmetry. This is largely ruled out by the assumption that the demand for two products is the same up to the parameter a_i. In this case, the incentives of PH and social planner are necessarily aligned at least when a_1 and a_2 are not drastically different.

The upstream manufacturer prefers DL if

$$(q-c)\sum x(p_i, a_i)|_{\kappa_i} \geq (q-c-t_u)\sum x(p_i, a_i)|_{t_u}$$

Though total output also features in this comparison, another (and often more decisive) factor will be whether pass-on is smaller or greater than unity. This is because the pass-on will determine the ranking of upstream margins across the two licensing regimes and generally may revert the output ranking. When pass-on is perfect, $(q-c)|_{\kappa_i} = (q-c-t_u)|_{t_u}$ and the incentives of upstream producer are aligned with those of the PH.

The downstream manufacturer i prefers downstream licensing if

$$(p_i(1-\kappa_i)-q)\, x(p_i, a_i)|_{t_i} \geq (p_i - q)\, x(p_i, a_i)|_{t_u}$$

This will depend on the ranking of output for product i and both upstream and downstream pass-on. Downstream manufacturer is interested in production and price for its good only, rather than total production or total surplus. The incentives of the downstream manufacturers are therefore cannot be perfectly aligned with those of social planner.

In the following, we provide two illustrations of our results with particular demand functions: (i) isoelastic; and (ii) linear.

Illustration

Consider the following parameterization: $\kappa_1 = \frac{1}{4}$,$\kappa_2 = k$, $a_1 = 1, a_2 = 2, c = 0.1$. For each demand function, we plot the welfare and rewards of different actors under the two regime as functions of k. This parameter shows how valuable the patented technology is for the product 2, the higher-demand product. In our parameterization, for $\kappa_2 < \frac{1}{8}$, the absolute value of the patented technology is greater in product 1, for $\frac{1}{8} < \kappa_2 < \frac{1}{4}$, the share of value due to the patented technology is greater in product 1, but its absolute value is greater in product 2, and for $\kappa_2 > \frac{1}{4}$, both share and absolute value are greater in product 2.

Isoelastic demand

Consider isoelastic demand, $a_i p^{\varepsilon}$ with $\varepsilon = -2$.

For all figures below, black curve stands for the DL regime, blue curve stand for the UL regime. Figure 1 shows how DL is dominant in terms of welfare for most of the range of parameter k.

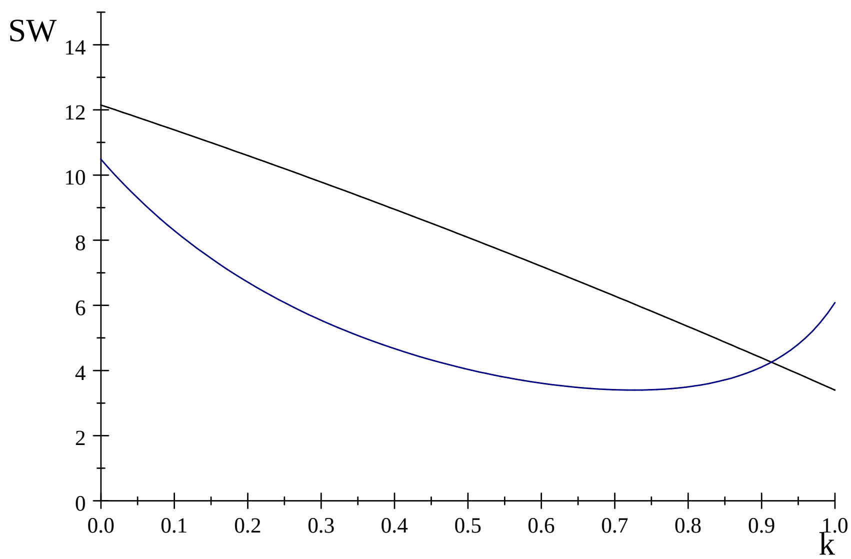

Figure 1. Welfare comparison.

We have already got a flavor of this result in Appendix B - with isoelastic demand and resulting constant markups, UL regime is welfare-inferior because of lower total output. For very high values of the royalty rate on product 2 ($k > 0.913$), the welfare ranking is reversed, because the royalty burden on product 2 is relatively lower under UL and this generates higher surplus on this product which is greater in value than surplus generated by production of product 1. Such outcome, however, requires either extracting almost all the rents from producer 2 by the PH, or extreme asymmetry in the demand for the two products. Moreover, allowing $\eta < 1$ will further reduce the scope for such result, because it would imply lower license rate. Overall, therefore, we believe this to be a very unrealistic situation.

Figure 2 illustrates that, in terms of PH's profits, DL is superior for the whole range of parameter k. This is, as discussed, because UL is more distortive and leads to lower total output.

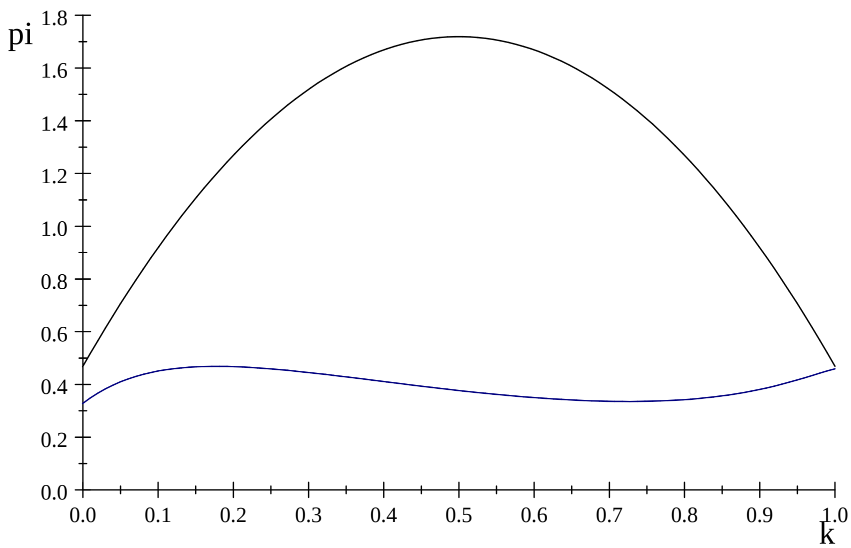

Figure 2. PH's profits.

Figure 3 shows that, in the isoelastic case, the incentives of the upstream monopolist are largely aligned with those of the PH and the social planner, except for larger values of the royalty rate on product 2 ($k > 0.73$). For $0.73 < k < 0.913$, the upstream manufacturer prefers UL whereas socially optimal and preferred by PH is DL. This is also the result of trade-off between the disproportionately higher burden of the royalty on more valuable product 2 in DL (grows in k) and higher distortion of total output in UL (inverse U-shape in k). The former affects upstream profits stronger than welfare, that is why UL becomes superior for lower values of k than socially optimal.

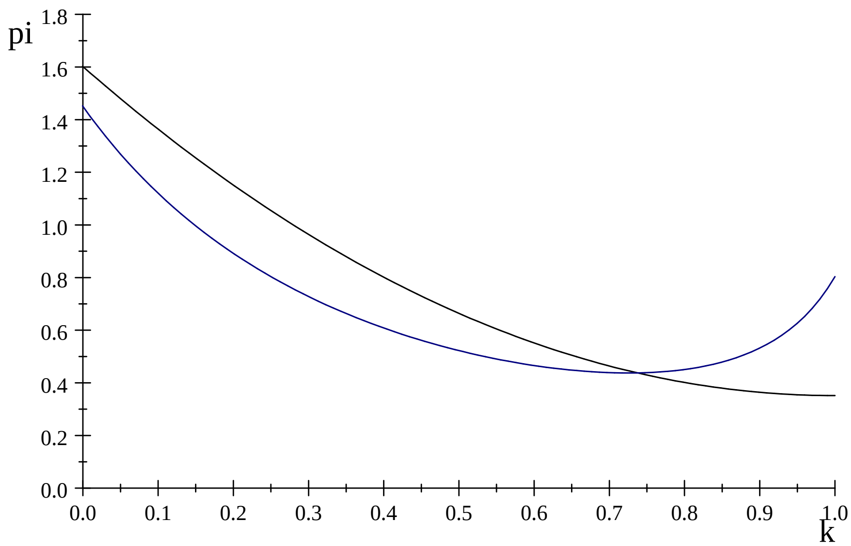

Figure 3. Profits of the upstream manufacturer.

Figure 4 shows the profits of downstream manufacturers whereby thicker curves correspond to product 2. We observe that the manufacturer of product 1 prefers DL unless k is small (in which case the output distortion is minimal and the manufacturer benefits from shifting the burden to the manufacturer of the other product as $\kappa_2 < \kappa_1$. The manufacturer of product 2 prefers DL for lower levels of k, but UL for higher values as the latter allows it to shift the burden to the other downstream producer.

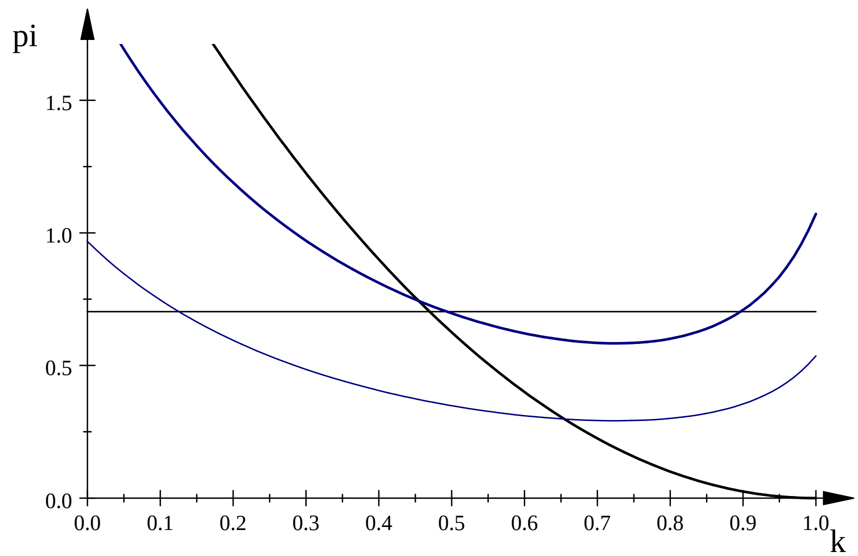

Figure 4. Profits of downstream manufacturers.

Overall, it is clear that the incentives of downstream manufacturers are not aligned with those of social planner.

Linear demand

Consider linear demand $a_i - bp$ with $b = 1$. In such formulation, corner solutions are possible in which good 1 (lower value) is not produced at all. This happens when the upstream producer quotes a component price that is too high for the downstream producer of good 1 to avoid running losses for any positive output level.

We start by considering profits of upstream manufacturer in figure 5, because this manufacturer decides on the component price and therefore may effectively choose whether to serve both markets (not too high component price) or only the market for good 2 (high component price). In the figures, black (DL) and blue (UL) curves describe the situation when both markets are served; red (DL) and green (UL) curves describe the situation when only market for good 2 is served.

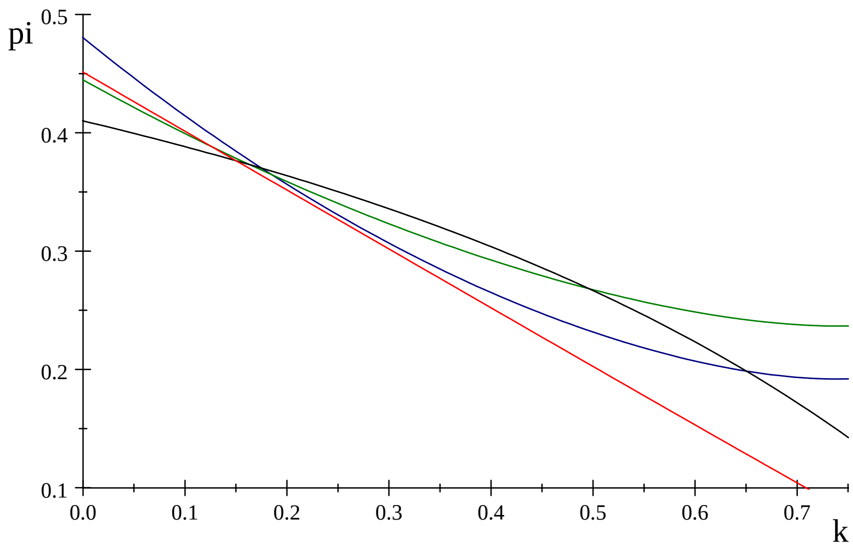

Figure 5. Upstream profits.

We note that for $k < 0.175$, UL is preferred and for $0.175 < k < 0.48$ the DL is preferred, always serving both markets. Finally, for $k > 0.48$, UL again is preferred and only market 2 is served.

The social planner, in contrast, would always prefer downstream licensing and both markets served, as apparent from figure 6.

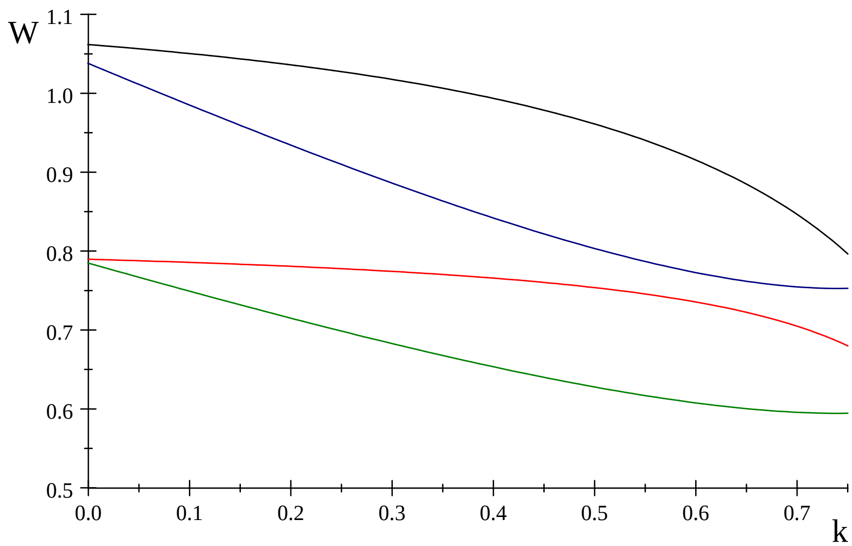

Figure 6. Welfare.

Moreover, for $k > 0.48$, the drop of welfare associated with the upstream manufacturer's preferred choice is huge (the distance between black and green curves in figure 6) due to the associated shutdown of market 1.

The earnings of the PH are plotted in figure 7. The PH prefers downstream regime for the whole range of the parameter k, and so its incentives are aligned with the ones of the social planner in linear formulation.

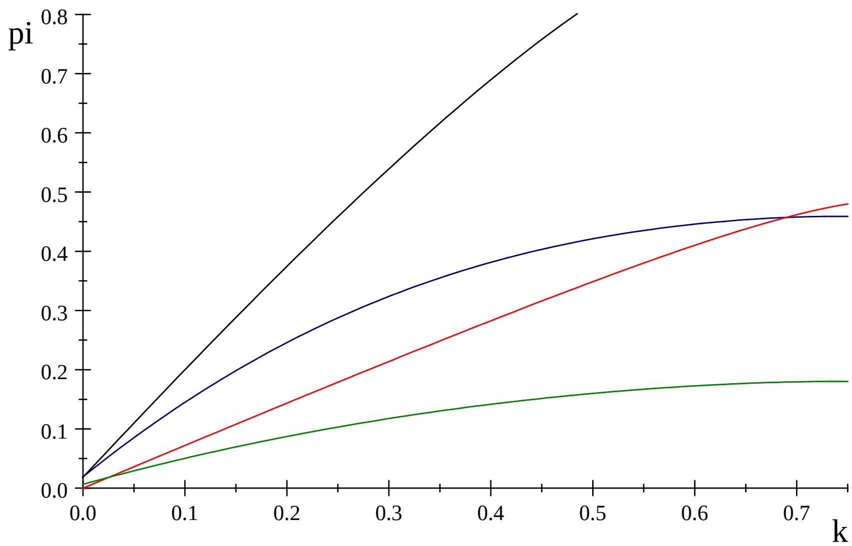

Figure 7. The payoff of the PH.

Figures 8a and 8b show us profits of the downstream manufacturers. We have shown that in general that the incentives of downstream producers may only by accident correspond to the incentives of the social planner. We note that, in the linear example, producer of good 1 prefer UL for $k < 0.18$; producer of good 2 prefers UL for $k > 0.08$ so that its interest directly contradicts the interest of social planner for most of the range of the parameter k.

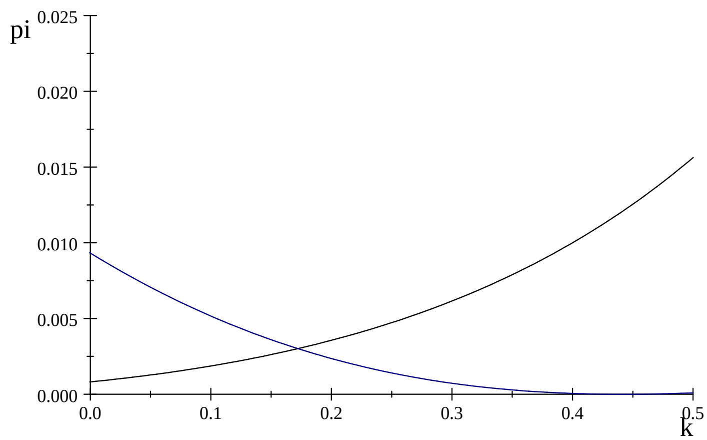

Figure 8a. Profits of the producer of product 1.

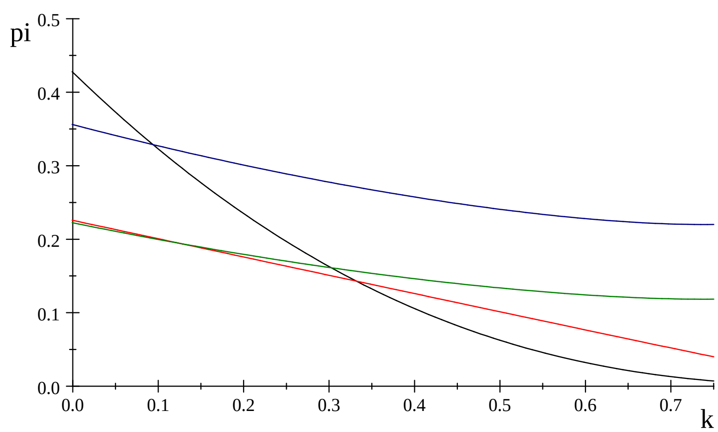

Figure 8b. Profits of the producer of product 2.

Overall, we note that in linear formulation only incentives of the PH and social planner are aligned. Downstream producer in the larger market has the opposite interest and upstream producer would choose to serve one market only that would lead to a significant welfare loss.