Component Sharing Through Licensing (*)

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Abstract: In this paper, we consider products that are composed of distinct components that can be shared with rival firms through licensing agreements. In contrast to the standard licensing settings in which firms make binary choices (whether to license or not), the innovator decides on the set of product components to be licensed, i.e., on how much to license. The product components that are licensed out determines the degree of commonality in the competing products, which in turn affects post-licensing competition through the degree of product differentiation. In a duopoly setting we show that licensing occurs more often than what a binary choice setting predicts, while it does not necessarily imply more component-sharing between the firms. We also show that in a dynamic setting where the timing of entry depends on the components that are acquired through the license, the innovator may strategically grant a license for a smaller set of components to delay competition unless entry expands the market. Finally, we study a more general licensing scheme and show that a larger set of components are licensed out under a two-part scheme with a per-unit royalty than with a fixed fee scheme.
Key words: component sharing, licensing, commonality, product differentiation.

Many products are made of distinct product components that alone have no value to end consumers. When the interfaces among those product components are fairly standardized, the same set of components can be used to develop a variety of products. Such component-sharing between products can occur both within and between firms.

(*) An earlier version of this paper was circulated as "Partial Licensing of Modular Products." We would like to thank Claude Crampes, Jacques Crémer, Etienne De Villemeur, Bruno Jullien, Patrick Rey, and Dani Rodrik.

Within firm component-sharing occurs when a multi-product firm uses some of the components of its existing products in new product development. For instance, in the automobile industry, the same car engine is often used in a range of car models developed and produced by the same manufacturer. [1] Many software products come with different versions, and yet share a body of common software codes. [2] Between firms component-sharing can occur mainly through two channels: joint component development and licensing contracts. [3] Component-sharing through joint development is a widespread practice in the automobile industry. For example, a diesel automobile engine, DW10, which was jointly developed and manufactured by the PSA group (Peugeot and Citroën) and Ford was used in a variety of PSA passenger models (Citroën Xsara and Xantia, Peugeot 306 and 406) as well as Ford models (e.g., Ford Focus and C-Max, Mazda 5). Component sharing through licensing is mostly observed in software markets. For example, two video game producers, id Software and Epic Games, license their 3 Dimensional (3D) game engines [4] that provide real-time computing techniques for special effects to other game publishers with whom they compete in selling video games to end users. [5]

In this paper, we focus on the last of these arrangements and analyze the incentives for component sharing through licensing agreements. The traditional treatment of licensing agreements in the literature does not provide a good fit for studying component sharing between rivals as its underlying assumption is that firms' choices consist of a binary, zero-one decision: whether or not to license an innovation to their potential competitors. In contrast, we introduce a setting in which the innovator decides on the set of product components to be licensed, i.e., on how much to license. In circumstances where the innovator can undertake such partial

[1] For example, the automobile engine AJ25 developed and manufactured by Ford is used in both the Ford Mondeo and the Jaguar X-type.

[2] For example, MacKichan sells three distinct programs, Scientific Workplace, Scientific Word, and Scientific Notebook that share common software components.

[3] In this paper we focus on component sharing between rival firms. Note, however, that component sharing can also occur between firms that do not compete in the end product market.

[4] 3-D engines and game design are product components that are not sold separately at the retail level.

[5] Epic Games charges a fixed fee of $350,000 per platform (e.g., PC, PS2) and a royalty of 3% of revenues from the game for its Unreal Engine 2, whereas id Software charges a fixed fee of $250,000 for a single title plus a royalty of 5% of the wholesale price for its Quake III Arena Engine.

licensing,[6] as opposed to licensing the end product as a whole, it can also fine-tune the trade-off between licensing rents and potential competitive costs.

A potential competitive cost of sharing more product components with a rival firm is reduced differentiation, which is likely to intensify post-licensing competition. For example, in the video game case we have cited above, if the 3D engine is initially designed for 'first-person shooter' games, it is only suitable for games of the same genre and not for different classes of games such as 'soccer' or 'role-playing.' Therefore, although licensing generates additional revenues from the licensee, it also intensifies competition by leaving little room for differentiation. We first introduce a simple duopoly setting with a fixed licensing scheme that elucidates this trade-off and contrast our findings with the standard licensing settings in which firms make binary choices. We show that licensing occurs more often in this setting than what the binary decision setting predicts, while it does not necessarily imply more component-sharing between the firms.

We then extend our analysis to discuss possible implications of component sharing for timing of entry. When entrants have access to a larger set of product components through a licensing agreement, it may require less time to develop and introduce their own products to the market. When we introduce such dynamics into our basic framework, we find that the innovator may strategically license a smaller set of product components to delay entry unless entry expands the market.

We also extend our analysis to consider a more general licensing scheme and show that a two-part scheme with per-unit royalty implies more component sharing compared to a fixed licensing scheme.

As its title suggests, our paper combines two distinct lines of research: component sharing across multiple products and strategic use of licensing. The literature on component sharing mostly focuses on within-firm component sharing, which is often cited as a cost-effective way of producing different varieties.[7] Component sharing can reduce the cost and time

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[6] In general, partial licensing may involve any restriction that prevents the licensee to derive the full commercial benefit from the original invention. Licensing a process or product innovation that is inferior to the original one, restricting the license to a limited partition of the original product innovation, and field-of-use restrictions can be considered as examples of partial licensing.

[7] Among others, see ROBERTSON & ULRICH (1998). See also FISHER *et al*. (1999) for other drivers of component sharing: quality and performance, and organizational structure.

required for new product development (as we underline in this paper), as well as manufacturing costs due to economies of scale in production. [8] The adverse impact of component sharing on product differentiation, which is the other factor in the main trade-off we present in this paper, has also been discussed within-firm component sharing settings. For example, DESAI *et al*. (2001) and KIM & CHHAJED (2000) put forward the following trade-off for within firm component sharing when quality differentiation matters: while commonality in products reduces manufacturing costs, it also reduces product differentiation, and hence component sharing may have a negative impact on a firm's profits. [9] Both papers consider a monopolist that produces two varieties and two consumer segments that differ in their valuation for quality. Profit maximizing prices are set so as to satisfy incentive compatibility and participation constraints. The negative impact of commonality is that it hinders the monopolist's ability to price discriminate by self-selection. As consumers perceive the two products to be closer substitutes, the price that can be charged for the high-end product is reduced. Since both papers focus on within-firm component sharing in a multi-product monopoly setting, competition (and hence any strategic interaction) is absent in the analysis. Furthermore, both models consider vertical (quality) differentiation models and as the example of video games suggests, component sharing may also have a significant impact on horizontal differentiation. [10]

To our knowledge, there is no paper that formally studies the incentives for component sharing between firms. At first glance, the trade-off between reduced manufacturing costs and reduced vertical product differentiation that has been studied in the monopolistic settings resembles the trade-off between reduced development costs (which implies higher licensing revenues) and reduced horizontal product differentiation that we present in our duopoly setting. The most significant difference is the presence of competition in our setting, which raises the question how component sharing through licensing can shape post-licensing competition.

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[8] Note, however, that although the reduction in development costs is a valid argument for both within and between firm component sharing, the economies of scale argument applies only to within firm component sharing, unless firms engage in joint production.

[9] See also ROBERTSON & ULRICH (1998) for a discussion on the tradeoff between distinctiveness and commonality.

[10] When video game developers share the same 3D engine, say, one designed for soccer games, they can not develop different genre of games, i.e., they can not differentiate their games much in the horizontal dimension. While any given genre of game is not a higher (or lower) quality game than other genres per se, there can be different quality games within the same genre.

Our paper also contributes to the literature that analyses the strategic use of licensing to alter competitors' R&D and entry decisions (GALLINI, 1984; GALLINI & WINTER, 1985; ROCKETT, 1990a, 1990b; YI, 1999). [11] Two closely related papers are GALLINI (1984) and ROCKETT (1990a). GALLINI (1984) considers a process innovation in an ex-ante licensing setting, and shows how an innovator may engage in strategic licensing to deter the R&D activity of the entrant, who might come up with a better technology. In our setting, the innovator has lower incentives to deter R&D, since the products are too similar when the entrant does not engage in product development. Component sharing with a partial license leads to partial R&D deterrence. In contrast to GALLINI (1984) the innovator does not face a threat to be eliminated from the market, and hence, the motive behind R&D deterrence is purely to extract the R&D cost savings of the entrant. Furthermore, since the entrant's R&D activity is directed to product innovation in our setting, it is not duplicative and is not necessarily socially wasteful. ROCKETT (1990a) analyses the incentives of an innovator to license a process innovation which is inferior to its own technology. The author considers a continuum of process innovations with different costs of production, and the innovator can decide to license any technology that entails a higher cost of production than its own technology. Therefore, the innovator's strategy can be interpreted as partial licensing in a process innovation setting. However, partial licensing of a process innovation puts the licensee at a cost disadvantage, whereas this is not true in our setting with a product innovation.

The remainder of the paper is organized as follows. In the following section we set up the basic model with a fixed licensing scheme. In the next Section we solve for the equilibrium and analyze the licensing strategy of the innovator. We then compare our findings with those that would be predicted in a standard licensing setting with binary choices. In the 4th Section we analyze the licensing incentives when the timing of entry depends on the size of the license. Then we extend our analysis by considering a two-part tariff (with a per-unit royalty) for the license. Finally, we conclude.

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[11] In this literature, the innovator is assumed to have sunk its investments before it decides on its licensing strategy. In the present paper, we adopt the same approach. To our knowledge, few papers consider the impact of licensing on ex-ante R&D efforts. A notable exception is KATZ & SHAPIRO (1987), who study the impact of licensing on preemption incentives in a technology adoption race setting. The paper, however, does not address the optimal licensing strategy.

The model

We consider an innovator (Firm 1) and a potential entrant (Firm 2). The innovation is composed of a continuum of product components. [12] The innovator decides to license a partition $\alpha \in [0,1]$ of its innovation to the potential entrant. [13] We will refer to α as the size of the license. When $\alpha=0$, there is no licensing and when $\alpha=1$, there is full licensing (i.e., all product components are licensed). For all $\alpha \in (0,1)$, there is partial licensing (i.e., some, but not all components are licensed). If the entrant acquires the license, it decides on the components that it uses in its product development, $\hat{\alpha} \in [0,\alpha]$ and invests in the remaining $(1-\hat{\alpha})$ product components to develop the end product. Therefore, $\hat{\alpha}$ represents the degree of commonality in the two end products. If the innovator does not license its innovation, the entrant's sole possibility to enter in the market is by developing all the product components from scratch. [14]

Consumers

Following DIXIT (1979) and SINGH & VIVES (1984), we adopt the following demand function

$$p_i = a - q_i - (1-s)q_j,$$

where q_i and p_i denote the quantity and price of firm *i*, with *i,j*=1,2 and *i≠j*, and *s* denotes the degree of product differentiation, with $s \in [\underline{s},\bar{s}]$, $\underline{s} \in [0,\bar{s}]$ and $\bar{s} \leq 1$.

12 Considering discrete product components would be more realistic, however, it would not add much to our analysis.

13 In the paper, we look at markets where the innovator is also a manufacturer (like Apple), and we do not question if the upstream innovator (or the society) would be better off under a different market structure. However, we can notice that the vertically integrated firm can always replicate the separate structure, especially if it can commit to an internal (input) price.

14 We believe that this might be feasible in some product markets and not in others. Therefore, we also discuss the case when the entrant has no other entry option than acquiring a license.

Product differentiation

The degree of differentiation depends on the degree of commonality, i.e., $s = s(\hat{\alpha})$. We assume that $s(1) = \underline{s}$ and $s(0) = \overline{s}$, and that the degree of product differentiation decreases with the degree of commonality in the two end products, that is, $\partial s(\hat{\alpha})/\partial \hat{\alpha} < 0$.

Cost of product development

If the entrant acquires a license of *α* product components and uses $\hat{\alpha} \leq \alpha$ components of it, then it needs to develop the remaining components, which entails a development cost denoted by $d(\hat{\alpha})$. We assume that the higher the degree of commonality, the lower the cost of developing the end product, that is, $\partial d(\hat{\alpha})/\partial \hat{\alpha} < 0$. If the entrant develops its product from scratch, it has to invest $d(0)$.

Notice that we do not assume any economies or diseconomies of scope in developing product components since in this formulation the cost of developing the first $\hat{\alpha}$ components, $(d(0) - d(\hat{\alpha}))$, plus the cost of developing the remaining components, $d(\hat{\alpha})$, is equal to $d(0)$, that is, to the cost of developing the product from scratch.

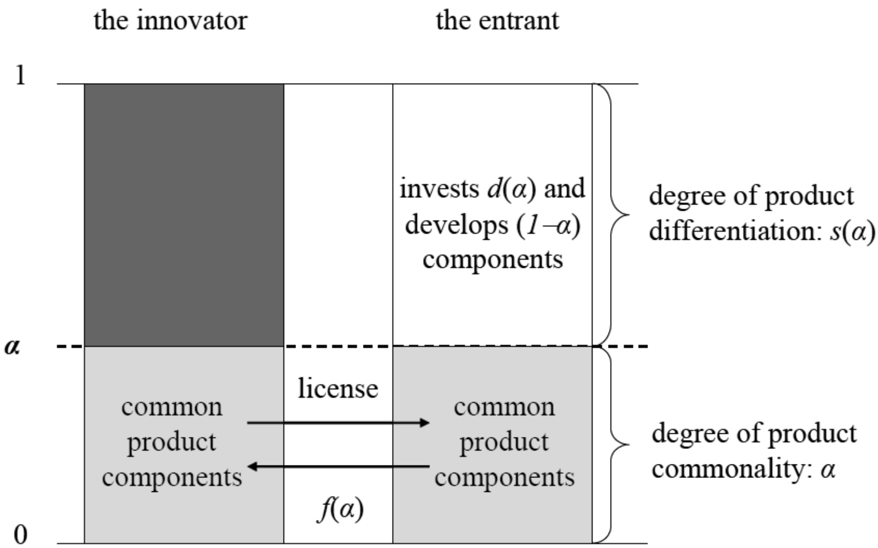
Finally, we assume that the product development cost for the innovator is sunk.

Cost of production

We assume that firms have symmetric unit costs of production, *c*.

Figure 1 below illustrates the entrant's product development when it acquires a license of size *α*, and uses all licensed product components for its product design.

Figure 1 - The entrant's product development when the entrant uses all licensed components for its product design (i.e., $\hat{\alpha} = \alpha$).



The timing

The timing of the game is as follows.

1. The innovator decides on α and sets a fixed licence fee $f \geq 0$ for it,[15] and makes a take-it-or-leave-it offer $\{\alpha, f\}$ to the entrant.[16]

2. The entrant decides whether or not to acquire the license.

3. If the entrant acquires the license, it decides on $\hat{\alpha} \in [0, \alpha]$, i.e., the product components it uses for its product, and it develops the remaining $(1 - \hat{\alpha})$ components. If it does not acquire the license, it develops its product from scratch.

4. Firms compete with prices, and profits are realized.

[15] Later in the text, we shall consider a per-unit royalty rate combined with a fixed licensing fee.

[16] We do not consider the possibility of subsidized entry.

Analysis

As usual, we solve the model proceeding backward, and start by the last stage. All proofs can be found in our working paper, BOURREAU & DOĞAN (2010).

Competition (Stage 4)

Let Π_i denote the net profit of firm *i*, with *i*=1,2, when the entrant acquires the license $\{\alpha, f\}$, and uses $\hat{\alpha}$ of the product components in its product development. The innovator obtains a profit of

$$\Pi_1(\hat{\alpha}, f) = \pi(s(\hat{\alpha})) + f,$$

whereas the entrant obtains a profit of

$$\Pi_2(\hat{\alpha}, f) = \pi(s(\hat{\alpha})) - d(\hat{\alpha}) - f,$$

with

$$\pi(s(\hat{\alpha})) = \frac{(a-c)^2 s(\hat{\alpha})}{(2 - s(\hat{\alpha}))(1 + s(\hat{\alpha}))^2}.$$

We assume that $\Pi_2(\hat{\alpha}, f)$ is strictly concave in $\hat{\alpha}$.[17]

Let $\overline{\Pi}_i$ denote the net profits of firm *i*, when the entrant does not acquire the license. Since the degree of commonality is zero ($\hat{\alpha} = 0$), firms obtain $\overline{\Pi}_1 = \pi(\overline{s})$, and $\overline{\Pi}_2 = \pi(\overline{s}) - d(0)$. Entry without acquiring the license is viable if and only if $\overline{\Pi}_2 \geq 0$, and we assume that this is the case.[18]

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[17] See Appendix A in BOURREAU & DOĞAN (2010), where we discuss the conditions for concavity.

[18] If $\overline{\Pi}_2 < 0$, the entrant has no outside option. We provide the analysis for this case at the end of this section.

Entrant's product development (Stage 3)

If the entrant acquires the license of a given size α, it uses $\hat{\alpha}^*(\alpha)$ product components, where $\hat{\alpha}^*(\alpha)$ maximizes its profit, $\Pi_2(\hat{\alpha}, f)$.[19] If the entrant does not acquire the license, the profits of the innovator and the entrant are $\overline{\Pi}_1$ and $\overline{\Pi}_2$, respectively.

Entrant's decision to acquire the license (Stage 2)

The entrant acquires the license if and only if it makes more profit by accepting it than by developing its product from scratch, that is,

$$\Pi_2(\hat{\alpha}^*(\alpha), f) \geq \overline{\Pi}_2.$$

Optimal licensing scheme $\{\alpha, f\}$ (Stage 1)

The innovator has the following problem

$$\max_{\alpha, f} \Pi_1(\alpha, f) = \max_{\alpha, f} \{\pi(s(\hat{\alpha}^*(\alpha))) + f\},$$

subject to $\Pi_2(\hat{\alpha}^*(\alpha), f) \geq \overline{\Pi}_2$. A larger size of license yields higher profits to the incumbent due to the entrant's higher willingness to pay for the license because of larger savings from development cost. At the same time it lowers profits due to the reduced degree of product differentiation which intensifies competition.

In BOURREAU & DOĞAN (2010), we show that, if the entrant acquires a license, it uses all the product components provided with the license. Therefore, when the innovator decides on the size of the license, it also sets the degree of commonality. In the following Proposition, we characterize the equilibrium size of the license.

Proposition 1

The equilibrium size of the license is larger when

19 See BOURREAU & DOĞAN (2010) for a more detailed analysis.

(i) the marginal cost of component development is higher,

(ii) the marginal effect of the size of the license on the degree of product differentiation is lower.

Proof. See Appendix C in BOURREAU & DOĞAN (2010).

For a given sensitivity of industry profits to product differentiation, there are two factors that affect the equilibrium size of the license. Firstly, if the marginal cost of component development is higher, the innovator can extract more rents by granting a license of a larger size. Therefore, if the marginal cost of component development is sufficiently high, the innovator grants a full license. Secondly, the size of the license (which is also the degree of commonality in the two end products) determines the degree of competition. A higher negative marginal effect of the size of the license on the degree of differentiation yields a license of a smaller size, as a lower degree of product differentiation harms industry profits. If this marginal effect is sufficiently large there is no licensing, and hence no component sharing, at the equilibrium.

The first effect corresponds to the standard effect in the ex-ante licensing settings. Larger R&D costs imply higher incentives to license an existing innovation. The second effect is novel and works in the opposite direction. While a mild second effect may lead to deterrence of R&D activities as in GALLINI (1984), a strong second effect, combined with the first effect, may lead to partial licensing, and hence, partial deterrence.

Last but not least, the sensitivity of industry profits to the degree of differentiation affects the equilibrium size of the license. For example, in our setting the equilibrium size of the license is higher under quantity competition than under price competition, since firms' gross profits are more responsive to differentiation under price competition. Asymmetries in production costs can also affect the sensitivity of industry profits to the degree of differentiation. For example, in our competitive setting if the innovator has a production cost advantage over the entrant we find that the industry profits become less sensitive to product differentiation with larger cost asymmetries, and hence, a larger cost advantage implies a license of a larger size (i.e., more component sharing).

Component sharing when the entrant has no outside option

So far, we have assumed that the entrant can enter in the market if it does not acquire the license. If the entrant has no outside option (i.e., if $\overline{\Pi}_2 < 0$), the innovator's profit function is discontinuous at $\alpha = 0$. Therefore, the innovator compares its profit under optimal partial licensing to its profit with no licensing. As we state with the following proposition, the incentives for component sharing through licensing are lower when the entrant has no outside option.

Proposition 2

If the entrant has no outside option,

i. if the innovator grants a license, the size of the license is the same as in the presence of an outside option;

ii. no licensing is more likely to prevail at the equilibrium than when the entrant has an outside option.

Proof. See Appendix D in BOURREAU & DOĞAN (2010).

The optimal size of the license (given that the innovator grants a license), and hence the degree of commonality, is the same regardless of the presence of an outside option, simply because the entrant's opportunity cost of acquiring the license does not depend on the size of the license. The intuition for the second result is that the innovator's opportunity cost of granting a license is lower when the entrant has an outside option than when it has not. In the absence of an outside option, the innovator engages in component sharing through licensing only if entry expands the market, whereas this is not necessarily true when the entrant has an outside option.

Comparison to a binary licensing decision

In this section, we determine the optimal licensing strategy when the innovator makes a zero-one licensing decision, that is, to offer either a full license or no license. We show that when firms make binary decisions, licensing, and hence R&D deterrence is less likely to occur at the equilibrium. However, since our setting with partial licensing enables firms to share some (and not necessarily all) product components, the overall effect of component sharing between firms is ambiguous.

We find that licensing is more likely to occur at the equilibrium when the firm can engage in component sharing with a partial license. However, when there is licensing in both cases, licensing is full (complete R&D deterrence) with a binary decision, whereas, it may be partial (partial R&D deterrence) in our setting. Therefore, depending on the product development and differentiation technology, our setting may or may not predict more R&D deterrence. As an illustration, we provide functional forms for $s(\alpha)$ and $d(\alpha)$ that satisfy our modelling assumptions, and then revert to a numerical example.

An Example

Let the differentiation technology and development cost be defined as $s(\alpha) = \underline{s}\alpha + \overline{s}(1-\alpha)$, and $d(\alpha) = \delta\left(1-\alpha^{1/n}\right)$, with $n \geq 2$. Our concavity assumption is satisfied under price competition with $\overline{s} \in (0, 0.64)$.[20]

Let $\Delta s = \overline{s} - \underline{s}$. As it represents the (absolute) marginal effect of the size of the license on product differentiation. Furthermore, as for all α, the marginal cost of component development increases with δ, we use δ as a proxy for the marginal cost of component development.

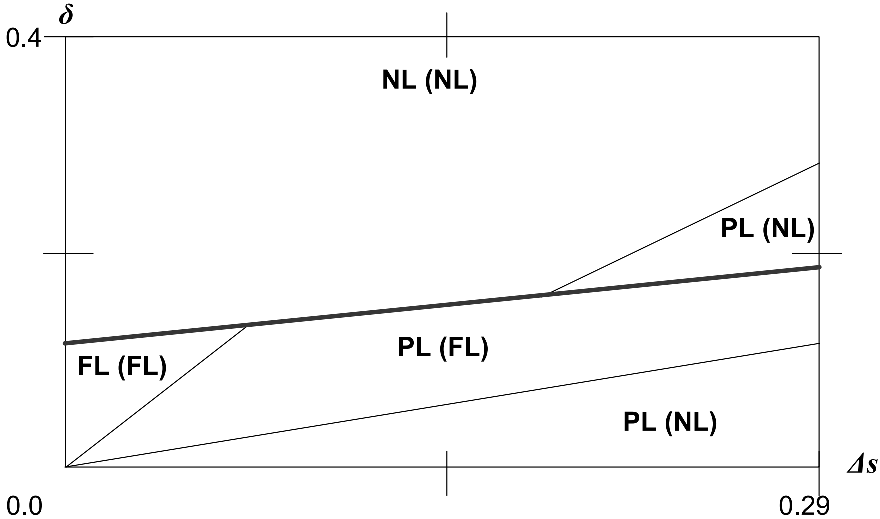
In Figure 2, NL, PL, and FL stand for no licensing, partial licensing and full licensing, respectively. The equilibrium strategy of the innovator when it makes a binary decision is indicated in parenthesis. The thick line represents the threshold values of δ above which the entrant has no outside option.

If δ is sufficiently high, the entrant has no outside option. For the parameter values we use in this example, there is no licensing with a binary decision. On the contrary, as it can be seen from the figure, there is partial licensing, and hence component sharing in our setting, for Δs is sufficiently large. To understand the intuition, consider the extreme case where $\underline{s} = 0$; if the product is integrated there will be no licensing since it leads to price competition with identical products ($0 = 2\pi(0) < \pi_1^m$). When the innovator sets the size of the license, partial licensing may occur if $2\pi\left(s\left(\alpha^*\right)\right) - d\left(\alpha^*\right) \geq \pi_1^m$, which is the case if $\overline{s}$ is sufficiently high (i.e., if

[20] See Appendix E in BOURREAU & DOĞAN (2010).

Δs is sufficiently high). Component sharing with partial licensing does not increase the industry profits if the maximum degree of differentiation is sufficiently small, and hence, no licensing may prevail regardless of the setting.

Figure 2 - The Innovator's Equilibrium Licensing Strategy, for $a=1$, $c=0$, $\underline{s}=0.35$, $\overline{s}\in(0.35,0.65)$, $n=4$



If δ is sufficiently low, the entrant has an outside option. With a binary decision, for a given δ, the innovator prefers no licensing if Δs is sufficiently large, and grants a full license otherwise. When the innovator decides on the size of the license, no licensing does not occur at the equilibrium.

To sum up, our setting may or may not predict more R&D deterrence through licensing. For a given Δs, our setting predicts more R&D deterrence for high or low values of δ, and less R&D deterrence for intermediate values of δ. Provided that there is an outside option (low and intermediate values of δ), and for a given Δs, when δ increases, the incentives to license increase. In the standard licensing setting when the innovator makes a binary decision, the size of the license jumps from zero to one, whereas it increases smoothly in our setting.

Finally, note that the analysis provided in this section can also be read as follows. Consider an innovator that can only make a binary licensing decision (license or do not license) because of its integrated product design. Our analysis shows that such a firm would be slightly worse off than a firm that can decide on how many components it would share with a rival firm. Since the latter also has the options of the firm with an integrated product (license all product components or license none), any difference in the licensing strategies (areas denoted with PL(NL) and PL(FL)) in the figure implies that the firm with an integrated design obtains strictly lower profits. [21]

In the next two sections, we provide extensions to our basic model. We first analyze the licensing incentives when the timing of entry depends on the size of the license. Then, we then extend our analysis by considering a two-part tariff (with a per-unit royalty) for the license.

Component sharing and time-to-market

Time-to-market for new products is another important factor that characterizes competition. For example, in the 3D video games market, acquiring a license of a 3D engine accelerates the development of a new game.

In this section we introduce a timing game for the entrant and investigate how the timing of entry influences the innovator's licensing strategy. We assume that the innovator launches its product at the beginning of the game, and that it takes time for the entrant to develop its product. A higher degree of commonality obtained through licensing accelerates the introduction of the entrant's product, since it has to develop less product components.

Formally, we assume that if the entrant uses α product components of the innovator's product, it introduces its product at $T(\alpha)$, with $T(\alpha) \geq 0$ and $T'(\alpha) \leq 0$. At the beginning of the game, the entrant decides whether or not to acquire the license, and pays the up-front license fee if it does. It also incurs the product development cost at the beginning of time. Finally, we denote the discount factor by λ.

[21] One interesting question would then be whether the innovator chooses a modular or a non-modular design for its innovation. The optimal innovation strategy will depend on a cost-benefit analysis, that is, whether the higher profits obtained through a modular design offset the fixed cost of a modular design.

Similar to the static setting, we find that if the entrant acquires the license it uses all the product components for its product design (see Appendix F in Bourreau and Doğan (2010) for the proof), therefore, we replace $\hat{\alpha}$ (degree of commonality) with α (size of the license) in the remaining of the analysis.

When the innovator licenses α components, it obtains a discounted profit of

$$\Pi_1(\alpha) = \int_0^{T(\alpha)} \pi_1^m e^{-\lambda t} dt + \int_{T(\alpha)}^{\infty} \pi(s(\alpha)) e^{-\lambda t} dt + f,$$

where π_1^m denotes the monopoly profit flows. If the entrant acquires the license, it enters in the market at $T(\alpha)$, and obtains

$$\Pi_2(\alpha) = \int_{T(\alpha)}^{\infty} \pi(s(\alpha)) e^{-\lambda t} dt - d(\alpha) - f,$$

whereas when it develops its product from scratch it enters in the market at $T(0)$, and obtains

$$\overline{\Pi}_2(\alpha) = \int_{T(0)}^{\infty} \pi(\bar{s}) e^{-\lambda t} dt - d(0).$$

The innovator maximizes its discounted profits, $\Pi_1(\alpha)$, with respect to α and f, subject to $\Pi_2(\alpha) \geq \overline{\Pi}_2(\alpha)$.

The marginal effect of α on the innovator's profit is composed of two terms:

$$\left\{ \frac{e^{-\lambda T(\alpha)}}{\lambda} \frac{\partial(2\pi)}{\partial s} \frac{\partial s}{\partial \alpha} - \frac{\partial d}{\partial \alpha} \right\} + \left\{ \left(\pi_1^m - 2\pi(s(\alpha)) \right) e^{-\lambda T(\alpha)} T'(\alpha) \right\}.$$

The first term represents the variation of profit with respect to α when there is no time-to-market effect, i.e., when $T'(\alpha) = 0$. This term is similar to the one in the static model except that $\partial(2\pi)/\partial s$ is multiplied by $e^{-\lambda T(\alpha)}/\lambda$, which depends on α. The higher the discount rate, λ, the lower $e^{-\lambda T(\alpha)}/\lambda$, hence the higher $\partial \Pi_1(\alpha)/\partial \alpha$ (as $\partial(2\pi)/\partial s \times \partial s/\partial \alpha$ is negative). This means that a higher discount rate implies higher incentives to license. Indeed, while the innovator obtains the license fee at the beginning of time, entry has a negligible effect on discounted profits.

The second term represents the time-to-market effect. It has the sign of $\pi_1^m - 2\pi(s(\alpha))$. When $\pi_1^m < 2\pi(s(\alpha))$, this effect tends to increase the optimal α, the degree of commonality. Indeed, as entry increases industry profits, the innovator is willing to accelerate entry by sharing more product components. When $\pi_1^m > 2\pi(s(\alpha))$, this effect works in the opposite direction; the time-to-market effect tends to decrease the optimal α. This is because entry decreases industry profits, which provides the innovator with incentives to delay entry by sharing fewer product components. In our setting, depending on $s(\alpha)$, either of the two effects can be present. The following Proposition summarizes this analysis.

Proposition 3

The higher the time-to-market effect, i.e., the higher $T'(\alpha)$ in absolute terms,

i. the larger the size of the license, if entry leads to market expansion ($2\pi(s(\alpha^*)) > \pi_1^m$),

ii. the smaller the size of the license, otherwise.

■ Per-unit royalty and fixed licensing fee

In this section we introduce a per-unit royalty rate, *r*, to the analysis, and hence consider a tow-part licensing scheme. The timing is similar to the basic setting, except that the innovator makes a take-it-or-leave-it offer, $\{\alpha, r, f\}$. The analysis with a per-unit royalty rate proves to be more complex than the analysis with a fixed licensing fee. This is because the entrant may use fewer product components than what is offered with the licensing scheme. To simplify the analysis, we assume that the entrant uses all components that are provided with the license. The equilibrium analysis can be found in Appendix G in BOURREAU & DOĞAN (2010).

A per-unit royalty rate has two effects on the innovator's profit. Firstly, it increases the perceived marginal cost of the entrant and hence enables the innovator to compete less aggressively. Therefore, it is as if the incumbent had a cost advantage in production. Secondly, the innovator receives royalty revenues. Due to these two effects, we find that the equilibrium size of the license is larger with a two-part tariff.

Proposition 4

The equilibrium size of the license is larger when the innovator charges a two-part tariff than when it charges a fixed licensing fee.

Proof. See Appendix H in BOURREAU & DOĞAN (2010).

■ Conclusions

We have shown that to the extent that component sharing affects the degree of product differentiation, partial licensing can be used to shape post-entry competition. Our basic model with a fixed licensing fee predicts that the size of license, and hence the degree of commonality in competing products is higher when the marginal cost of component development is higher and/or the marginal effect of the size of the license on the degree of product differentiation is sufficiently low. Similar results apply if the entrant has no outside option; however, in that case incentives for licensing are lower. We also compare our findings to those with the standard binary choice setting, and we show that our setting may or may not predict more R&D deterrence. This is because our setting considers a more flexible licensing strategy, which implies that both full licensing and no licensing are less likely to occur.

Factors that alter the sensitivity of the industry profits to the degree of product differentiation, e.g., the type of competition (price or quantity) and cost asymmetries in production, affect the size of the license, and hence component sharing. A higher sensitivity implies less component sharing between rival firms' products through licensing. Component sharing may also have implications in terms of timing of entry. When entrants have access to a larger partition of a product innovation, it may require less time to develop and introduce their own product to the market. In such a case, the innovator may strategically share fewer product components to delay entry, unless entry expands the market. Finally, the licensing scheme also has an impact on component sharing; we find that the innovator grants a license of a larger size with a two-part scheme with per-unit royalty than with a fixed licensing fee.

Our framework adopts the simplest setting possible. We ignored any uncertainty that product development process may involve. We also assumed away the possibility of imitation. Component sharing through licensing might facilitate imitation compared to no licensing, since it transfers the end product information partially to the entrant, which may reveal some information about the product components that are not subject to the license. The entrant who infers this additional information may use it for imitating other components of the innovator's product, instead of developing them independently. Our analysis shows that the entrant would have such an incentive (given that imitation is less costly than development), since it prefers a higher degree of commonality than can be obtained with the license. Hence, the innovator's strategy for partial licensing would be altered in the presence of imitation, in particular if the imitation cost depends on the size of the license.

We have also restricted our attention to a duopoly setting. With a larger number of entrants the innovator is likely to license fewer product components, to soften competition through a higher degree of product differentiation. Other interesting dynamics can arise with multiple entrants. For example, the innovator can adopt an exclusive licensing strategy and license out a larger set of components than it would under non-exclusivity, and deter entry if the development cost of the next potential entrant in line is sufficiently high.

Instead of sharing components with a competitor, the innovator could also decide to share components across a line of differentiated products. Different motivations might lead to intra-firm sharing. First, a modular design might make it easier to introduce different quality versions of the same product. Different quality versions of varied quality could serve at creating a network in the presence of network effects (firms can provide lower-quality versions to build a customer base, which would increase the willingness to pay for the higher-quality version) or at building customer awareness (lower quality or restricted versions can be provided at marginal cost, so that potential customers can test out the higher quality version). Second, in the presence of an entry threat, a modular design might lower the cost of a product proliferation strategy aimed at deterring entry. Our theoretical framework can be relatively easily extended to address these and similar questions.

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