PLATFORM LICENSING FOR ELECTRONIC COMMERCE ECOSYSTEMS

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ABSTRACT

Many e-commerce platform ecosystems have evolved around complementary products/services/technologies. In mobile commerce, smart phones (running on Android, iOS, or Windows) are platform products that have many complementary apps for each specific ecosystem. The complementary effects usually greatly enhance the value of owning both the platform product and the complements to a customer. Consequently, an e-commerce ecosystem that has independent firms making separate output decisions tends to under-produce both the platform and complementary products. In this paper we prove that licensing the platform products to independent licensees can be utilized as a mechanism to credibly signal a higher level of output of the platform products and induce improved availability of complementary products. Different forms of licensing arrangements are studied and compared in this work. The equilibrium licensing contract terms are solved and the results indicate that a platform product provider has incentives not to sell directly to the market, but to license the product / technology to independent licensees.

Keywords: Complementary effects; e-Commerce ecosystems; Fixed fee licensing; Royalty licensing

1. Introduction

The internet with its scalability and simplicity has created many e-commerce ecosystems that are powered by complementary effects. In such ecosystems, we usually observe supporting complementary products/services evolving with a central platform / technology standard. “A platform is a system with well-defined access points and rules on which other parties can build applications or service [Iansiti & Levien 2004].” In the m-commerce area, mobile technology is an excellent example of a platform ecosystem where apps as complements are developed for iOS, Android, or Windows operating system platforms. As different operating systems / platforms are not compatible to each other, the installed base, i.e., the number of active devices on each platform, determines the profitability of corresponding mobile apps. On the other hand, the variety and availability of apps for each platform have direct impacts on the demand for the platform products, i.e., smart devices.

In mobile payment area of e-commerce, the Apple Pay ecosystem has gained market shares quickly. The NFC based Apple mobile payment system with the addition of two-factor authentication is the platform technology in the ecosystem. The banks carry the load of the transaction service. The payment service provided by the banks and Apple Pay enabled smart devices are complementary to each other. The more devices with activated Apple Pay, the more transaction service financial institutions will be willing to make available. If Apple Pay service is accepted everywhere, more customers will be willing to buy an Apple device and activate Apply Pay.

In both examples, an increase in availability of one product or service enhances the sales of a complementary product or service, which can in turn increase the value of the original. A platform product in an ecosystem is usually considered more of a durable product/service than the complementary good. For example, smart phones are considered durable platform products because most customers purchase only one unit over certain period, while the apps and mobile payment services are considered non-durable complementary products because customers usually own multiple apps and use the payment services frequently in daily life.

It is well known that when such complementarities exist between the products of independent firms, both firms have an incentive to under-produce because they ignore the positive effects of their own outputs upon the profits of the other firm. Complementarities create a sort of prisoners’ dilemma in which both firms would benefit if they increased their outputs, but neither firm has an incentive to unilaterally increase its own production level. We propose that in an e-commerce ecosystem, a platform product manufacturer that has patent protection for its technology may use an appropriately designed licensing arrangement to provide a credible commitment to a higher level of output, thereby encouraging greater output of the complement from its ecosystem partners. When complementary effects are sufficiently strong, a well-designed licensing arrangement can allow the ecosystem to generate more platform and complementary products and make more profits. Note that when complementary effects are absent, a platform durable good manufacturer in the ecosystem has no incentive to license to other firms which have the same marginal costs as (or higher than) itself. This paper contributes to the body of knowledge by establishing the role of licensing arrangements as an ecosystem coordination mechanism when complementary effects are present.

Licensing is a common practice in e-commerce ecosystems that feature complementary interaction between the platform durable goods and complements. For example, Apple Inc., as the platform technology provider of Apple Pay, has entered loyalty licensing agreements with major banks and credit card providers. According to Financial Times [Fiveash 2014], banks and credit card providers as licensees pay Apple 0.15% of US Apple Pay transactions. Many believe this lower than market loyalty license charge and user-friendliness of the Apple's mobile payment system will continue to give Apple competitive advantage in the mobile payment industry.

In smart device war, Google's Android platform technology has reached 80% market share by licensing. Google licenses its Android operating system to HTC, Samsung, and several other OEMs. The OEMs seem to get the license rights for the Android platform technology for the price of air. However, nothing is free in business. With the Android platform technology comes the bundle of Google Search, Gmail, and Google Play. Instead of charging a licensing fee for Android technology, Google demands OEMs to make Google Search and other applications default on their devices. In February 2016 Oracle sued Google and claimed that Google reaped $21 billion in profit from Android technology, mostly from Google online advertising and the app store on Android devices [Rosenblatt 2016]. This shows that Google's Android licensing agreements with device OEMs are worth billions of dollars. Another piece of evidence to support our argument on the value of Android licensing contracts is that Google paid Apple $1 billion to have Google search as the default search engine on iOS devices. As a consequence, about 80% of advertising revenue on Apple devices goes to Apple. If Apple had to license Android technology from Google, Google would have not paid this considerable amount.

Such licensing practices play an important role in growing e-commerce ecosystems. In this paper, we set up a model that excludes other incentives for having a licensing agreement (such as that licensees have technology or cost advantages) and focuses on the signaling effects of licensing contracts in ecosystem coordination. In this paper, we summarize the recent literature in section 2. Then, in section 3, a game theory model is set up and the optimal licensing contracts are derived. Finally, in section 4, the implications of findings are discussed and future research is recommended.

2. Related Literature

Complementary effects have long been a subject of interest in economics literature. Katz & Shapiro [1985a], [1994]; Farrell & Saloner [1985], [1986]; Choi [1994] and Liebowitz & Margolis [1994] discuss the innovation, competition, and compatibility issues in the context of the complementary effects. However, they usually take a pair of complements as a system and ignore the incentive conflicts among independent complementary industries. Many other issues involving complementary effects have been the topic of study. For example, Paulraj, Jayaraman, and Blome [2014] examine the complementary effects in regulatory environmental efforts. See-To, Jaisingh, and Tam [2007] discuss the critical mass in micro payment ecosystems, where two complementary markets interact with each other. Liu, Shang, and Lai [2015] suggest incentive mechanisms for e-commerce service supply chains under knowledge complementarities.

Recent work by Parker & VanAlstyne [2003a] and Parker & VanAlstyne [2003b] examines how to stimulate demand by subsidizing one of the complementary markets. Miao [2016] proposes to sell the complements through a decentralized marketplace to coordinate an ecosystem. Our paper studies how the complementary interactions between two markets can be coordinated, but we differ from theirs in that we assume that two complements are not produced by the same firm. Bhaskaran & Gilbert [2005] demonstrate that leasing may be better than direct selling for a durable good monopolist as leasing can serve as a commitment to a higher future output level and thus the complementary producer would increase the output accordingly. We focus on different signaling mechanisms other than leasing in our paper. D'Antoni & Rossi [2014] and Somaya, Kim, and Vonortas [2011] examine how to promote research and development of complementary technologies and ours study how to promote the whole ecosystem after the products / services have been introduced to market.

Our work is related to the literature on the role of intermediaries. In their seminar paper, McGuire & Staelin [1983] demonstrate that, by selling through intermediaries, competing manufacturers can dampen the effects of competition. Other papers, including Choi [1991], Gupta & Loulou [1998], etc. have extended this line of analysis. But most of this work focuses on how intermediaries affect competition between manufacturers of same products and assumes that linear wholesale pricing is used. This contrasts with our work, where we examine the role that intermediaries can play in improving coordination between complementary industries in an ecosystem and allow for non-linear wholesale pricing.

Extensive research has been done on capitalization of patented technology through licensing. Arrow [1962] compares the profit an inventor could realize by licensing an innovation to a perfectly competitive industry versus a monopoly, by means of a per-royalty. Kamien & Schwartz [1982] study the option of licensing to an oligopolistic industry by means of both a fixed fee and a royalty. Kamien & Tauman [1984] extend the work and analyze how much profit an inventor can obtain by using both a fixed fee and a royalty in a purely competitive industry. Katz & Shapiro [1984] and Katz & Shapiro [1985b] have studied licensing by means of auction. Fershtman & Kamien [1992] show that anticipated crossing licensing of two complementary technologies tends to retard each firm's development process. Shapiro [1985] and Kamien [1992] provide overviews of related work. Lin [2011] shows that double marginalization in a patent chain can be mitigated by using profit-based royalty or fixed fee licensing. Choi and Gerlach [2015] recommend using patent bundling to avoid uncertainty in product development. Bianchi, Frattini, Lejarraga, and Di Minin [2014] establish a model to combine the internal R&D and external licensing decisions. Kwok, Yang, and Tam [2004] show the use of watermarking to protect loyalty licensing payments of e-commerce applications. All this research overlooks the possible strategic interaction between a patented technology and its complementary products, which is the focus of this paper.

3. **The Model**

We consider an ecosystem that grows around two complementary technologies, A and B, which are owned by two separate firms. We assume that technology A is the platform product in the ecosystem and is durable in the sense that each consumer purchases at most one unit of it, while technology B is non-durable, i.e. consumers may purchase multiple units of product B. These assumptions are consistent with the relationship that exists between a smart phone and app downloads, an iOS device and frequent Apple Pay transactions, a Netflix streaming subscription and available titles of streaming content.

We refer to the manufacturer of the durable platform product A as "firm A" and assume that the non-durable technology is provided by "firm B." In most of the examples given above, the producer of the durable platform product frequently has the most market power. Often, many different firms compete to produce the non-durable complement in the ecosystem. Although for simplicity, we assume that product B is produced by a single firm, but most of our results can be obtained for situations in which we allow for free entry into the market for product B.

We assume that both firms have constant marginal costs and normalize them to zero. There are a total of M consumers, who will buy one unit of A or none. In the absence of complementary product B, a consumer's utility for product A is v_A, which is uniformly distributed over $[a_A - M, a_A]$, where $0 \leq a_A \leq M$. The assumption that some consumers have negative utility for product A implies that there will be some consumers who do not purchase the product at any price. Let δ be an indicator function that is equal to one if a consumer purchases product A, and is equal to zero otherwise.

For product B, we assume that each consumer has a decreasing marginal utility for owning additional unit of B, and that this marginal utility is higher if he has the use of product A than if he does not. Specifically, each consumer has the following marginal utility for the y^{th} unit of product B: $(a_B + \delta k + \phi v_A - y)/\gamma$, where $a_B, k, \gamma \geq 0$, and $\phi \in (0, 2\gamma)$ are constants. The parameter a_B indicates the magnitude of consumers' utility for technology B relative to product A; k represents the strength of complementarity; γ is a measure of price sensitivity; and ϕ indicates the relationship between a consumer's valuation for product A and his marginal utility for product B. If ϕ is strictly positive, then consumers with the highest valuations for the use of A will have the highest marginal utilities for product B. If $\phi = 0$, then all consumers are homogeneous with respect to their marginal utilities for the complement.

A consumer's total utility can be expressed as the following function of whether he purchases product A, $\delta \in \{0, 1\}$, and the amount, y_i, of product B that he purchases:

$$U_i(y_i, \delta) = \delta(v_A - p_A) + \int_0^{y_i} \frac{(a_B + \delta k + \phi v_A - x)}{\gamma} d_x - y_i p_B \qquad (1)$$

where p_A, p_B are prices of product A and B. Note that by setting $k = 0$, we get the consumer's utility function when A and B are not complements. A larger k corresponds to a stronger complementary effect. The model we use is essentially the same as the one used by established literature, i.e. Bhaskaran & Gilbert [2005]. But our paper looks at completely different ecosystem coordination contracts.

It can be shown that at price p_B, a utility maximizing individual consumer with valuation v_A for product A would consume

$$y_i(p_B, v_A, \delta) = a_A + \delta k + \phi v_A - \gamma p_B \quad (2)$$

units of product B. Thus, at a given price p_B, access to product A increases the amount of product B that a consumer will purchase by k units.

To determine how product B affects a consumer's willingness to pay for product A, we must consider his total utility as a function of the price of product B. If the price of B is p_B, and the consumer's independent valuation for product A is v_A, then having product A increases his total utility by the following amount:

$$\begin{aligned} &U_i(y_i(p_B, v_A, 1), 1) - U_i(y_i(p_B, v_A, 0), 0) \\ &= v_A - p_A + \frac{(a_A + k + \emptyset v_A - \gamma p_B)^2}{2\gamma} - \frac{(a_A + \emptyset v_A - \gamma p_B)^2}{2\gamma} \\ &= v_A - p_A + \frac{k^2 + 2k(a_B + \emptyset v_A - \gamma p_B)}{2\gamma} \end{aligned} \quad (3)$$

Note that the last term in expression represents the amount by which the availability of product B increases a consumer's willingness to pay for product A. Thus, if the price charged for product A is p_A, then all consumers with an independent valuation of more than $p_A - \frac{k^2 + 2k(a_B + \emptyset v_A - \gamma p_B)}{2\gamma}$ will purchase product A, and the total number of consumers who pay to use the service of product A will be:

$$Q = [Min\left\{M, a_A + \frac{k^2 + 2k(a_B + \emptyset v_A - \gamma p_B)}{2\gamma} - p_A\right\}]^+ \quad (4)$$

To facilitate the analysis, we will introduce several restrictions upon our parameters:

$$a_B \leq \frac{2\gamma(M - a_A) - k^2}{2k} \quad (5)$$

$$a_B \geq \frac{k^3 + 2M\phi(\gamma + k\phi)(3M - 2a_A) + k^2\phi(5M - 2a_A) + 2k\gamma a_A}{2(k^2 + 2M\gamma + 2kM\phi)} \quad (6)$$

The first of these restrictions is sufficient to guarantee that at equilibrium, $Q \leq M$, i.e. some consumers will not purchase product A. This plays a major role in our results since it implies that a decrease in the price of product A leads to more consumers having access to the platform product A, which in turn increases demand for product B. Note that as $a_B \geq 0$, assumption (5) also implies that $k^2 \leq 2\gamma(M - a_d)$. The restriction shown in (6) implies that, at equilibrium, all consumers purchase a positive amount of product B, even those who lack access to product A. Although this restriction simplifies the mathematical analysis, our results do not depend upon it qualitatively. Note that as $\phi \geq 0$, the right-hand-side of (5) is greater than the right-hand-side of (6).

From equations (2) and (4), we can obtain the following inverse demand functions for product A and product B:

$$p_A(Q, y) = \frac{(k^2 + Mk\phi)(M - 2Q) + 2M(a_A - Q)\gamma + 2ky}{2M\gamma} \quad (7)$$

$$p_B(Q, y) = \frac{2Ma_B + 2kQ - 2y + M\phi(2a_A - M)}{2M\gamma} \quad (8)$$

where *Q* and *y* are the numbers of units of product A and B that are available for consumers.

As should be expected for complementary products, the inverse demand function for each of products A and B is decreasing in its own quantity and increasing in the quantity of the other. As a result, firms A and B will have incentives to set quantities too low or prices too high. We will argue that a durable platform product manufacturer can license its technologies to intermediaries, instead of selling directly to consumers. The incentive behind the licensing is to stimulate greater output of product A and signal to firm B to increase the output of the complementary product.

3.1. Benchmark Profits

To define a benchmark, we first consider the situation under which firm A directly sells product A to market. We define the profit that firm A earns by producing and selling the product directly by herself as her *proprietary direct* (*PD*) profit. To obtain our benchmark monopoly profit, we define the profit functions of firm A and B by assuming that they set the quantities simultaneously and sell products directly to the market.

$$\pi_A^{PD}(Q, y) = Qp_A(Q, y) \quad (9)$$

$$\pi_B^{PD}(Q, y) = yp_B(Q, y) \quad (10)$$

where $p_A(Q,y)$ and $p_B(Q,y)$ are from equations (7) and (8).

In equilibrium, each firm determines its output in order to maximize its own profits. These equilibrium output quantities can be identified by simultaneously solving the first-order conditions for (9) and (10) with respect to Q and y respectively.

$$Q^{PD*} = \frac{M(2k(a_B+k)+kM\phi+2(2\gamma+k\phi)a_A)}{2(3k^2+4M\gamma+4kM\phi)}$$
$$y^{PD*} = \frac{M(k^3-M\phi k^2-2M^2\phi(\gamma+k\phi)+(4a_B+4\phi a_A)(k^2+M\gamma+kM\phi)+2a_Ak\gamma)}{2(3k^2+4M\gamma+4kM\phi)}$$

Substituting the resulting equilibrium output quantities back into (9) and (10), we have:

$$\pi_A^{PD*} = \frac{M(k^2+M\gamma+kM\phi)(2k(a_B+k)+kM\phi+2(2\gamma+k\phi)a_A)^2}{4\gamma(3k^2+4M\gamma+4kM\phi)^2}$$
$$\pi_B^{PD*} = \frac{M(k^3-M\phi k^2-2M^2\phi(\gamma+k\phi)+(4a_B+4\phi a_A)(k^2+M\gamma+kM\phi)+2a_Ak\gamma)^2}{4(3k^2+4M\gamma+4kM\phi)^2}$$

3.2. Technology Licensing

One way in which a firm can capitalize on a proprietary technology that interacts with a complement is to license it to other firms. In this section, we explore two different forms of technology licensing: fixed fee and royalty arrangements. Under a fixed fee arrangement, a licensee pays a one-time fee, which is independent of the amount produced, for the right to produce the durable good. Under a royalty arrangement, the licensee pays a royalty to the owner of the technology for each unit that is sold. Note that under a royalty arrangement, the royalty paid by the licensee is analogous to the wholesale price paid by an independent retailer. Thus, our analysis of the royalty arrangement can also be applied to situations in which firm A sells its technology through retailers.

3.2.1. Fixed-fee license

To consider the fixed-fee licensing arrangement, we assume that there are a large number of potential licensees that will participate as long as they can earn nonnegative profits. Of course, our analysis can easily be extended to require positive participation profits for the licensees. The products sold by the licensees are undifferentiated. The licensees have no production cost advantage or disadvantage relative to firm A. Recall that firm A's production cost has been normalized to zero.

Under a fixed-fee license arrangement, Firm A moves first by setting the one-time license fee, denoted by F, that a licensee must pay in order to participate in selling product A. In response to this fee, licensees enter the industry until each one earns his indifference profits, which we have assumed to be zero. Let n denote the number of licensees that pay the fixed fee of F in order to participate. For analytical tractability, we treat n as a continuous variable throughout the paper.

We assume that the license fee F is fully observable, so that firm B can anticipate the number of licensees. Therefore, following the licensees' entry, firm B and the licensees all make their output decisions simultaneously. Let q_{Ai} denote the output for product A from license $i=1,\cdots,n$, and let $Q_{AT}=q_{A1}+\cdots+q_{An}$. Recall that y represents the output of firm B. In the output setting stage of the game, each of the n licensees determines the level of output that will maximize its profits, which can be represented as follows:

$$\pi_{Ai}^{FF}(q_{A1},q_{A2},\cdots,q_{An},y,F) = q_{Ai}p_A(Q_{AT},y) - F \qquad (11)$$

for $i=1,\cdots,n$, while firm B sets its output to maximize:

$$\pi_B^{FF}(q_{A1},q_{A2},\cdots,q_{An},y,F) = yp_B(Q_{AT},y) \qquad (12)$$

By applying first-order conditions to (11) and (12), we can determine the output quantities of product A for any given number, n, of licensees. Denote these quantities as $q_{Ai}^*(n), i=1,\cdots,n$, and $y^*(n)$ respectively. However, because licensees enter until they anticipate that they cannot earn positive profits, in equilibrium we will also need to have:

$$\pi_{Ai}^{FF}(q_{A1}^*(n),q_{A2}^*(n),\cdots,q_{An}^*(n),y^*(n),F) = 0 \qquad (13)$$

By simultaneously solving (13) along with the first order conditions for (11) and (12), we can obtain the following expression for the equilibrium number of licensees that will participate in a fixed fee licensing arrangement when the fixed fee is set to F:

$$n^{FF}(F) = \frac{\sqrt{k^2M+M^2\gamma+kM^2\phi}\left(k(2a_B+2k+M\phi)+2a_A(2\gamma+k\phi)\right)-4\sqrt{F\gamma}(k^2+M\gamma+kM\phi)}{2\sqrt{F\gamma}(k^2+2M\gamma+2kM\phi)} \quad (14)$$

Thus, when firm A sets the licensing fee, it does so to maximize the following profit:

$$\pi_A^{FF}(q_{A1}^*(n), q_{A2}^*(n), \cdots, q_{An}^*(n), y^*(n), F) = Fn^{FF}(F) \quad (15)$$

It is easy to confirm that firm A's profits, as represented in (15), are maximized when the fixed fee is set as follows:

$$F^* = \frac{M(2k(a_B+k)+kM\phi+2(2\gamma+k\phi)a_A)^2}{64\gamma(k^2+M\gamma+kM\phi)}$$

In response to this fixed fee, the number of licensees and profits for firm A are shown below:

$$n^{FF*} = \frac{2(k^2+M\gamma+kM\phi)}{k^2+2M\gamma+2kM\phi} \quad (16)$$

$$\pi_A^{FF*} = \frac{M(2k(a_B+k)+kM\phi+2(2\gamma+k\phi)a_A)^2}{32\gamma(k^2+2M\gamma+2kM\phi)} \quad (17)$$

Proposition 1 *Under a fixed fee licensing arrangement, the equilibrium number of licensees has the following properties:*

i) $n^{FF*} = 1$ *when* $k = 0$.
ii) n^{FF*} *is increasing in* k.
iii) $\lim_{k\to\infty} n^{FF*} = 2$

This result has several important implications. First, part *i*) confirms that, in the absence of complementary effects, firm A will contract with exactly one licensee and set the fixed licensing fee at a level under which the licensee makes zero profit. Since firm A is able to extract all profits from the licensee, it earns exactly the same profit that it would by selling its product directly to the market.

Part *ii*) of the proposition confirms that as complementarity (k) increases, firm A will induce more licensees to participate in the fixed fee arrangement. Note that the number of licensees is treated as a real number. However, part *iii*) shows that firm A will never induce more than two licensees to enter. Recall that the equilibrium described in (16) and (17) is an approximation to the true equilibrium in which there must be an integer number of licensees. Therefore (17) represents an upper bound on the profit that firm A can earn under a fixed fee licensing arrangement.

Proposition 2 *There exists a threshold level of complementarity,* K, *such that if* $k^2 > K$, *then firm A can maximize its profits under a fixed fee licensing by inducing exactly two licensees to participate, and these profits will be greater than what firm A could earn by selling its product directly to the market. This threshold value of .*

$$K = (M\phi)^2 + \sqrt{2}M\gamma + M\phi\sqrt{M\left(2\sqrt{2}\gamma + M\phi^2\right)}$$

By inverting n^{FF*} as shown in (14) we can see that the fixed fee that is necessary to induce exactly $n = 2$ licensees to participate is equal to:

$$F^{FF}(2) = \frac{M(k^2+M\gamma+kM\phi)(2k(a_B+k)+kM\phi+2(2\gamma+k\phi)a_A)^2}{8\gamma(2k^2+3M\gamma+3kM\phi)^2}$$

and the total profit earned by firm A from licensing its product to two licensees at this fixed fee is:

$$\pi_A^{FF}(2) = \frac{M(k^2+M\gamma+kM\phi)(2k(a_B+k)+kM\phi+2(2\gamma+k\phi)a_A)^2}{4\gamma(2k^2+3M\gamma+3kM\phi)^2}$$

3.2.2. Royalty license

A common alternative to a fixed fee licensing arrangement is a royalty contract. Under a royalty arrangement, firm A announces a per-unit fee, denoted by L, which is common knowledge to all potential licensees and firm B. Note that this arrangement is similar to one in which firm A sells its product through intermediaries at a prearranged wholesale price of L. However, since licensing arrangements tend to be more formal, they tend to allow less flexibility for firm A to adjust its price and are therefore more credible as mechanisms for strategic commitments.

As before, we assume that, following the announcement of the royalty fee, L, potential licensees enter as long as they do not earn negative profits. Again, we denote the number of licensees by a real number n. Finally, firm B and the licensees simultaneously determine their quantities of output, denoted by q_B and q_{Ai}, for $i = 1, \cdots, n$, respectively.

Recall that, for fixed license fee agreements, the fixed fee has little effect upon the output decision of an individual licensee, but has a direct impact on the number of licensees that agree to participate. In contrast, a royalty fee has a direct impact on a licensee's output decision. Under a royalty arrangement, at the final stage of the game where quantities of output are being determined, the profit function for each licensee is as follows:

$$\pi_{Ai}^{R}(q_{A1}, q_{A2}, \cdots, q_{An}, y, L) = q_{Ai}(p_A(Q_{AT}, y) - L) \quad (18)$$

for $i = 1, \cdots, n$. While the profits for firm B and firm A are:

$$\pi_{B}^{R}(q_{A1}, q_{A2}, \cdots, q_{An}, y, L) = y p_B(Q_{AT}, y) \quad (19)$$

$$\pi_{A}^{R}(q_{A1}, q_{A2}, \cdots, q_{An}, y, L) = L Q_{AT} \quad (20)$$

By simultaneously solving the first-order conditions for (18) with respect to q_{Ai}, and (19) with respect to q_B, we can identify the equilibrium output quantities conditional upon the number n of licensees.

$$q_{Ai}^{R*}(n) = \frac{M\big(2k(a_B + k) - 4L\gamma + kM\phi + 2a_A(2\gamma + k\phi)\big)}{2\big(k^2(2+n) + 2M\gamma(1+n) + 2kM\phi(1+n)\big)}$$

$$y^{R*}(n) = \frac{M\left(k^3 n - 2kn\gamma(L-1) - M\phi\big(k^2 + G(1+n)\big) + (2a_B + 2a_A\phi)(1+n)(k^2+G)\right)}{2\big(k^2(2+n) + 2M\gamma(1+n) + 2kM\phi(1+n)\big)}$$

where $G = M\gamma + kM\phi$. However, it can be observed that, for any finite value of n, each licensee earns a positive profit.

Proposition 3 *Under a royalty fee licensing arrangement, the optimal royalty fee, L^{R*} is independent of the number n of licensees, where:*

$$L^{R*} = \frac{2k(a_B + k) + kM\phi + 2(2\gamma + k\phi)a_A}{8\gamma}$$

The profits of firm A are increasing in n and approach the following limiting value as $n \to \infty$:

$$\pi_A^{R*} = \pi_A^{FF*} = \frac{M(2k(a_B + k)kM\phi + 2(2\gamma + k\phi)a_A)^2}{32\gamma(k^2 + 2M\gamma + 2kM\phi)}$$

For firm A, the focus is to find as many as possible potential licensees under loyalty arrangements. Its profits increase with the number of licensees and the royalty rate is independent of the expected number of licensing participants.

It is easy to confirm that the optimal royalty rate, L^{R*}, is strictly increasing with the complementary effect parameter, k. For a given number, n, of licensees, the profits of firm A, firm B, and each licensee are increasing in complementarity, k. If the number of potential licensees is large, and their participation profits / fixed costs are truly negligible, then a royalty licensing arrangement could potentially deliver a larger total profit to firm A than could a fixed fee arrangement. Recall that when complementary effects are strong, i.e., $k^2 > K$, firm A can earn greater profits by using a fixed fee licensing arrangement with two licensees than by selling directly to the market. On the other hand, if $k^2 < K$, then having one licensee is the optimal solution under a fixed-fee license, and firm A earns the same profit as it would by selling its product directly. The following proposition identifies the conditions under which a royalty licensing arrangement is preferable to a fixed-fee arrangement.

Proposition 4 *Royalty licensing can bring firm A greater profits than fixed fee licensing if a sufficiently large number of potential licensees will participate. The critical number of licensees depends upon k. If $k^2 < K$, then the critical number of licensees is:*

$$n_1 = \frac{16}{k^4}\left((k^2 + M\gamma)^2 + \phi k(2Mk^2 + 2M^2\gamma + M^2\phi k)\right)$$

If the complementary effects are strong, i.e., $k^2 \geq K$ then the critical number of licensees is:

$$n_2 = \frac{8\left((k^2 + M\gamma)^2 + \phi k(2Mk^2 + 2M^2\gamma + M^2\phi k)\right)}{M^2(\gamma + k\phi)^2}$$

Recall from Proposition 2 that $K = (M\phi)^2 + \sqrt{2}M\gamma + M\phi\sqrt{M(2\sqrt{2}\gamma + M\phi^2)}$. Note that when there is no complementary interaction, i.e. $k = 0$, the threshold number of licensees, n_1 becomes infinite. In this case, double marginalization makes licensing unattractive.

For relatively low values of complementarity, i.e. $k^2 < K$, firm A's optimal fixed-fee licensing arrangement induces only one licensee to pay the fixed-fee and results in the same profits for firm A as when selling directly to market. However, the royalty licensing may enable firm A to make greater profits if enough number of licensees enter into the game.

For larger values of complementarity, $k^2 \geq K$, firm A can make a greater profit than selling directly by either fixed fee or loyalty arrangements. And when there are adequate number of licensees participating, loyalty licensing is better than fixed fee arrangements for firm A.

3.2.3. Hybrid license

After analysing both pure fixed-fee and pure royalty licensing arrangements, we will now consider a hybrid form of licensing agreement that includes both a fixed-fee and a per-unit fee. As before, we assume that firm A moves first to announce both a one-time fixed licensing fee (F) paid by each licensee and a royalty fee (L) that is assessed on each unit that a licensee sells. Potential licensees respond to this announcement by entering until it is anticipated that further entry would result in negative profits (or profits that are below some minimum participation level). Finally, following the entry of the licensees, firm B and the licensees determine their output quantities simultaneously. As before, q_{Ai} denotes the output of licensee $i = 1, \cdots, n$. Q_{AT} denotes the combined output of all of the licensees, and y denotes the output of firm B. At the final stage of the game, where quantities of output are determined, the profit function for each licensee is as follows:

$$\pi_{Ai}^R(q_{A1}, q_{A2}, \cdots, q_{An}, y, L) = q_{Ai}(p_A(Q_{AT}, y) - L) - F \qquad (21)$$

for $i = 1, \cdots, n$, while the profit for firm B and firm A are:

$$\pi_B^R(q_{A1}, q_{A2}, \cdots, q_{An}, y, L) = yp_B(Q_{AT}, y) \qquad (22)$$

$$\pi_A^R(q_{A1}, q_{A2}, \cdots, q_{An}, y, L) = nF + LQ_{AT} \qquad (23)$$

By simultaneously solving the first-order conditions for (21) with respect to q_{Ai} for $i = 1, \cdots, n$, and (22) with respect to y, we can identify the following output quantities for a given number (n) of licensees and royalty payment (L).

$$q_{Ai}^H(n, L) = \frac{M\left(2k(a_B + k) - 4L\gamma + kM\phi + 2a_A(2\gamma + k\phi)\right)}{2\left(k^2(2+n) + 2M\gamma(1+n) + 2kM\phi(1+n)\right)} \qquad (24)$$

$$y^H(n, L) = \frac{M\left(k^3 n - 2kn\gamma(L-1) - M\phi\left(k^2 + G(1+n)\right) + (2a_B + 2a_A\phi(1+n)(k^2 + G)\right)}{2\left(k^2(2+n) + 2M\gamma(1+n) + 2kM\phi(1+n)\right)} \qquad (25)$$

where $G = M\gamma + kM\phi$. Note that neither of these quantities depends upon the fixed-fee, F. Recall that at the entry stage of the game, licensees enter until they earn zero profit. To determine the magnitude of the fixed-fee that, together with the royalty fee of L, would induce exactly n licensees to enter, we substitute (24) and (25) into (21) and solve for the fixed fee that gives each licensee zero profit. By doing this, we obtain the following expression for the fixed-fee that will induce the entry of n licensees when the royalty rate is L:

$$F^H(n,L) = \frac{M(k^2 + M\gamma + kM\phi)(2k(a_B + k) - 4L\gamma + kM\phi + 2a_A(2\gamma + k\phi))^2}{4\gamma(k^2(2+n) + 2M\gamma(1+n) + 2k\big(M\phi(1+n)\big)^2}$$

By substituting this function into (23), firm A's profits can be represented as a function of n and L. Note that even though firm A's direct decisions are F and L, she is implicitly determining the value of n when she designs the licensing arrangement. We have simply introduced a change of variables to facilitate the analysis.

From the first order conditions for firm A's profit, as a function of n and L, it can be confirmed that the hybrid licensing arrangement that maximizes the profits of firm A satisfies the following:

$$L^* = \frac{\big(k^2(n-2) + 2M\gamma(n-1) + 2kM\phi(n-1)\big)(2k(a_B + k) + kM\phi + 2(2\gamma + k\phi)a_A)}{8n\gamma(k^2 + 2M\gamma + 2kM\phi)}$$

In addition, firm A's profits are increasing in F, so for any number of licensees, she sets the fixed fee just high enough to allow them to make zero profits:

$$F^* = \frac{M(k^2 + M\gamma + kM\phi)(2k(a_B + k) + kM\phi + 2(2\gamma + k\phi)a_A)^2}{16n^2\gamma(k^2 + 2M\gamma + 2kM\phi)^2}$$

Proposition 5 *Under a hybrid licensing arrangement, firm A's optimal profits are equal to* π_A^{FF*} *and can be obtained for any number,* n, *of licensees.*

The optimal royalty license fee is concavely increasing in the number of licensees (n) and bounded above by $\frac{2k(a_B+k)+kM\phi+2(2\gamma+k\phi)a_A}{8\gamma}$. As firm A decreases the fixed-fee to induce more licensees to enter, it will also increase the royalty rate.

The royalty fee L plays an important role in the effort to trade off between the complementary effects and the competition. Firm A uses L to induce the right quantity from each licensee such that the total output level is above the monopoly output yet not as high as the output that would be produced by two or more licensees in a pure fixed-fee arrangement. After observing the royalty rate of the licensing contract, firm B anticipates that a larger quantity of A will be produced and thus increases his output level correspondingly. Our result shows that, for any number of licensees, with the help of fixed fee to squeeze the licensees, firm A can use an appropriate royalty rate L to perfectly balance the complementary effects and competition.

The case when $n = 1$ is of special interest. From the expression of royalty rate L^*, it is clear that when $n = 1$, $L^* < 0$ and when $n > 1$, $L^* > 0$. Recall that under a pure fixed-fee arrangement, with one licensee ($n = 1$), firm A earns exactly the same profits as it does by selling directly by collecting a fixed licensing fee. Under a pure royalty arrangement, with one licensee, double marginalization prevents firm A from making more profits than selling directly. However, under a hybrid arrangement, when $n = 1$, the variable licensing fee is negative, which means firm A subsidizes the only licensee at a per unit basis but charges a positive fixed fee. The purpose of negative announced royalty rate is to assure to firm B that the only licensee will produce more than monopoly output.

This raises an interesting question: Why firm A does not produce more to induce more output of B to earn more profit? This is because it is not credible to firm B that firm A would produce more than the monopoly output, thus firm B would not increase the quantity by himself. The licensing arrangement here becomes a credible commitment to future output. By doing so, firm A exploits the complementary effects by stimulating the demand for B. However, it is possible that this single licensee has incentives to inflate the actual sales in order to obtain extra subsidy from firm A. Thus, the optimal hybrid licensing arrangement with a single licensee should be implemented only when the actual sales can be easily monitored.

If firm A could squeeze every penny out of the licensees, a hybrid licensing structure as proposed above would lead to the maximum possible profit for firm A. In reality, firm A may have to share the gains with the licensees to make the ecosystem self-sustainable. With the profit sharing, firm A still has a chance to earn a profit greater than monopoly level.

4. Concluding Remarks

In this paper, we show that a platform product manufacturer operating under the complementary effects behaves differently from a firm that does not interact with a complementary market. These differences stem from the nature of the market dynamics that call for coordination across interrelated industries within an e-commerce ecosystem.

In the context of complementary interactions, licensing arrangements may deliver a profit that is better than selling the platform product directly to the market. Inserting intermediaries into ecosystems using carefully designed regulatory contracts can best balance the complementary effects and competition among licensees. The competition among licensees leads to higher output levels, which could encourage the complementary industry to produce more and stimulate the demand in both markets. An appropriate licensing arrangement can bring better profits to the platform product manufacturer.

Three different licensing arrangements are considered in this paper. First of all, if the complementary effect is strong, we can utilize a fixed fee licensing contract with two licensees. Furthermore, we show that if there are enough potential licensees available, then royalty licensing is always better than a fixed fee arrangement. Finally, if a hybrid licensing involving both a fixed fee and a royalty can be used, then the optimal profit for the platform product manufacturer can be achieved regardless of the number of participating licensees. Under the hybrid licensing, the announced royalty fee induces greater output levels of both the platform product and the complement. Note that when there is only one licensee, the platform product manufacturer subsidies the licensee's production at per unit basis in order to convince the complementary product producer to keep up the production.

Under our assumption that licensees have no cost nor technology advantages, the hybrid licensing is no better than selling directly to the market for the durable platform manufacturer in the absence of the complementary effects. Thus this paper establishes that licensing arrangements can serve as an ecosystem coordination mechanism when complementary effects are present. Note that most current research articles assume the motivation for licensing is the cost or other advantages licensees have over the technology owner. Our paper is among the first to study the signalling effects of licensing contracts in an e-commerce ecosystem.

Finally, the optimal licensing arrangement can be implemented internally. For instance, the platform product manufacturer can set up subordinate facilities and impose fixed fee and per unit transferring price. However, often the internal arrangement is not as transparent as an open licensing arrangement, and thus lacks credibility to the complementary product producer.

In this paper, we have derived the threshold levels of the strength of complementary effects for the pure royalty or fixed fee licensing to work when only the durable platform technology owner enters the licensing agreements. If both the durable and non-durable products are distributed through licensing contracts, then the threshold levels of complementary effects would be expected to be lower. Future research is recommended to establish these thresholds and compare to what we have in this paper. Our paper is to examine the signalling effects of licensing contracts in e-commerce ecosystems and the results we have achieved are adequate to support our arguments.

In practice, most complementary interaction involves a durable product and a non-durable complement. Recently, there is a trend in the e-commerce world to "de-durablize" durable platform products / technologies. For example, Apple offers subscription plans to iPhone users for them to receive a new phone every year. SaaS (Software as a Service) and PaaS (Platform as a Service) convert durable technology platforms into non-durable consumables. Thus there will be more examples of complementary interactions involving only the non-durable products / technologies. Future research is recommended to study e-commerce ecosystems that grow around a pair of non-durable complements. We believe that as long as the complementary effects are present in an ecosystem, the licensing agreements can be utilized in a similar fashion to coordinate the output levels and improve the system level performance.

In many situations, licensees enjoy a lower marginal production cost and the licensing arrangements are a way for a platform technology owner to take advantage of licensees' efficiency. In this paper, we assume licensees do not have cost advantage and demonstrate the usage of licensing in a signalling game. However, it may be of interest to study the optimal licensing structure when the platform product manufacturer and the potential licensees have different variable costs. In addition, the platform product manufacturer may use a mixed strategy of selling directly while licensing to other firms. All these scenarios may be worth exploring in the future. Most of our arguments can be applied to situations outside the e-commerce world and studies may be carried out to extend the research into general business settings. Finally, empirical evidences on the signalling effect of licensing in the context of complementary interactions are certainly needed.

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