

The Market for Consumption Devices - On Complementary Products and Seller-Side Revenue-Extraction

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**The Market for Consumption Devices
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by

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The Market for Consumption Devices; - On Complementary Products and Seller-Side Revenue-Extraction

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Abstract

Some products and services are perfect complements to technological devices, such as video games to video game consoles. We analyze how competition between two firms selling such devices is affected by the fact that they can retrieve revenue both from end-users and from firms selling complementary products. We show that non-exclusive complementary products weaken competition relative to when the products are exclusive. Furthermore, competition is less keen when the device producers have inefficient means for retrieving revenue from the seller side, compared to when they have efficient means. Finally, we show that from the set of feasible strategies, the firms will always choose the socially optimal one. A novel finding is that at the consumer side there are brand specific adoption externalities also when the complementary products are non-exclusive.

Keywords: System Economics, network effects, R&D investments

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1 Introduction

In order to play video games, you need a video game console. Also other devices, such as tablet computers, are often bought solely or primarily in order to consume complementary products. Consumers continuously demand new complementary products for their devices. Furthermore, these devices are usually proprietary systems. Thus, in sum, the consumers who have bought a given device represent an aftermarket for complementary products, for which the producer of the device is a gatekeeper. A device producer can exploit this role directly by developing and selling complementary products itself. However, inasmuch as there exist firms that specialize in serving aftermarkets, the device producers often choose to sell off the rights to develop and sell the complementary products. This is the starting point of our paper.

When the aftermarkets are served by an independent seller, the seller's willingness to pay for serving a consumer with complementary products will determine the device producers' incentive to capture consumers. Thus, when the value of a captive consumer is high, the competition in the device market is tough, and vice versa. In this paper we analyze how characteristics of the aftermarket, by determining the value of a captive consumer, affect the competition in the device market.

In order to do this, we build a two-stage model where two device producers compete à la Hotelling for the consumers by selling devices at stage 1. At stage 2, the device producers sell off the rights to serve their captive consumers to a firm which develops and sells complementary products. We impose the realistic assumption that the more the seller invests in R&D when a product is developed, the higher profit margin it obtains when it sells the product. We find that compared to when the products are exclusive, the competition is softer when the products are non-exclusive. Furthermore, we find that if there is an opportunity for the device producers to retrieve rents from the seller by the use of two-part tariffs, the competition is intensified compared to when rents can be retrieved by per-unit-sold royalty fees only. Our results are driven by how the value to a device producer of capturing a marginal consumer is affected by different product- and contract types.

When the complementary products are exclusive, the value increases in a device

producer's market share. The reason is that the more consumers that can buy a product, the higher is the demand for a given R&D level. This creates a positive relationship between the marginal revenue of R&D investments and the number of consumers that can buy a product. Taken together, this implies that a device producer can retrieve more revenues per captive consumer from the seller of complementary products the more captive consumers it can offer the product seller.

When the products are non-exclusive, the seller's R&D investments in the common products are determined by its average profit margin from selling the products. This reverses the relationship between revenue per consumer served and market share. In order to see the intuition, suppose that one device producer has a large customer base relative to the other producer. Then, most non-exclusive products will be sold to the customers of the first producer, such that the seller's average profit margin will also be most sensitive to the profit margin it obtains when selling products for the device which is owned by the most customers. Furthermore, the device producer which has sold the most devices will also be the one which benefits the most when the consumers demand for complementary products increases due to increased R&D. Taken together, this implies that it is optimal for a device producer to charge a lower royalty fee and thus incentiveze the seller more strongly to invest in R&D, the larger its market share. The flip-side is thus that the smaller the market share a device producer has, the more it can free-ride on its rival promoting high R&D investments. Thus, in equilibrium the device producer which has the smallest market share charges the highest per-unit-sold royalty fee and makes the most revenue per consumer.

Next we show that there is a positive relationship between the surplus which is competed away in the form of low device prices and the marginal revenue of increasing the sales. Thus, since the marginal value of increasing the sales is highest when the products are exclusive, most surplus is also competed away when the products are exclusive. Furthermore, compared to when the products are exclusive, less resources have to be spent on developing the complementary products when they are non-exclusive. Thus, it is when the products are non-exclusive that most surplus is generated. Both reasons contribute to the fact that the device producers

make the highest profit when the products are non-exclusive.

Both when the complementary products are exclusive and non-exclusive, the quality adjusted price that a consumer has to pay for complementary products is decreasing in the number of consumers who own the same device as him. This reinforces the utility boost which a consumer experiences when the price of a device is reduced, inasmuch as a lower price means that more consumers will buy the device. The fact that this is anticipated by the consumers strengthens the device producers' incentives to set low device prices in order to attract consumers. Interestingly, we find that the effect is more pronounced when the device producers retrieve revenue from the product seller by the use of two-part tariffs than when they use per-unit-sold royalty fees alone. The explanation is simply that it is most efficient to retrieve rents by two-part tariffs. This implies that the quality-adjusted price for the products that can be used on a given device becomes the most sensitive to the number of consumers who own the device when two-part tariffs are implantable. This intensifies the competition in the device market to such an extent that the device producers obtain lowest profit when two-part tariffs are implemented.

Next, we ask whether we will observe non-exclusive products and two-part tariffs in equilibrium. We find that we will do so whenever it is technologically feasible and the device producers are unable to commit to anything else. The explanation is that a device producer is able to retrieve the largest share of rents when it employs a two-part tariff, and that there will be more rents when the products are non-exclusive. Since product and contract type is determined after the consumers are captured, there is no incentive for a device producer to choose anything else than what maximizes its revenue at stage 2. Since these are non-exclusive products and two-part tariffs, this will be chosen whenever technologically feasible. Furthermore, we show that these choices are also the choices that maximize social surplus.

Together the devices and the complementary products form (virtual) systems. For an overview of literature on the economics of systems, see Katz & Shapiro (1994). This literature has in particular focused on lock-in effects (switching costs) (see Klemperer (1987a) and Klemperer (1987b)), indirect network effects/adoption externalities, (see Chou & Shy (1990) and Church *et al.* (1993)), and network com-

patibility, (see Katz & Shapiro (1985) and Farrell & Saloner (1992)). In our model, a consumer's utility at stage 2 is a function of the number of consumers with whom he is locked in together with (at stage 1). Thus, in our model, switching costs and network effects are present. Furthermore, we analyze the impacts of two extremes with respect to "compatibility", i.e. exclusive and non-exclusive complementary products. In the systems literature, the supply of complementary products is usually modeled like a "black box". We deviate from this, however, as we explicitly model the actions of a strategic seller of complementary products. Among other things, this approach allows us to show that adoption externalities may be brand specific also when complementary products are non-exclusive, which, as far as we know, we are the first to show.

Our approach is borrowed from the literature of two-sided platforms. This literature studies industries/situations where heterogeneous groups, that impose externalities on each other, interact across one platform. Early papers of this literature investigate how the prices should be set in order to internalize the externalities when all groups arrive at the market simultaneously. See for instance Rochet & Tirole (2003) or Caillaud & Jullien (2003). Hagiu (2006), however, deviates from the situation where agents from both groups arrive simultaneously. He considers a market where there are both sellers and buyers, but where the sellers arrive first. The timing is motivated by the fact that sellers often need time to adjust the products before the products can be used together with a given platform. We turn his timing upside-down. This we do in order to capture that most of the complementary products that a consumer buys, he buys quite a long time after he bought the device. Despite this, in spirit, Hagiu's paper is the paper which is closest to ours paper.

The remainder of the paper is organized into five sections. The next section describes the timing of the game and outlines its building blocks. In the third section we derive how the seller of complementary products acts for different contracts and for different product types, while in the fourth section we derive how the device producers set device prices. In the fifth section, we put together the findings and study how the interaction of contracts and product types affects the competition in the market for devices. The last section makes some concluding remarks.

2 Timing of the game and some preliminaries

We assume that there is a unity mass of consumers who need a technological device in order to derive utility from a class of products. These devices are sold by two producers that compete a la Hotelling, i.e. producer 0 and producer 1 sell devices that are horizontally differentiated. The products, which are perfect complements to the devices are sold by a monopolist. This firm is referred to as the product seller or simply the seller. In some device industries, there are several firms that are selling products for one device system. As long as a seller has a profit margin which can be increased by R&D investments, the number of sellers has no implication for our qualitative results. Thus, our choice of a monopoly seller is made in order to simplify the algebra.

We impose the standard assumption that the consumers have unit demand (for devices) and that the market for devices is covered in equilibrium. However, a consumer demands multiple complementary products for his device. Finally we assume that the devices are proprietary systems. Thus, in return for allowing the seller to develop and sell products that are compatible with its the device system, the device producer claims payments from the seller.

The timing of the game is as follows; at stage 1, the device producers sell devices to the consumers. The product seller enters into contracts with the device producers at stage 2. Since the consumers who are captured by a device producer represent a valuable market for the seller, we assume that the device producers can dictate the contract terms as long as the seller's participation constraint holds.¹ When the contracts are signed, the seller invests in R&D in order to develop the products. The more the seller invests in developing a product, the higher marginal utility a consumer obtains from consuming the product, all else equal. Finally, at the end of stage 2, the consumers buy the products. The game is solved by backward induction.

¹This may not be as unrealistic as it may sound. For instance, if there are more potential sellers of complementary products for its device than what the device producer prefers, the device producer will contract with only a subset of them, and that is the ones that offer the most favorable contracts from the device producers point of view. Thus, if the outside option has a low value for the sellers, the equilibrium will be as if the device producer could dictate the contract.

We assume that the consumers have preferences over devices. However, the utility which a consumer derives from consuming complementary products (on a device) is assumed to be independent of his preferences with respect to devices. Thus in our model, all consumers obtain the same utility from consuming a given complementary product.² In some device-based industries, the consumers have unit demand for different product varieties. For instance, a consumer may buy several video games, but he will never buy two copies of the same title. In order to capture this type of unit demand, we assume that the seller supplies a range of different product varieties, normalized to unity. Thus, a consumer can consume any number of varieties in the interval $[0, 1]$. Let a consumer's gross utility of consuming the n 'th product variety be given by $1 + q - n$, where q is the vertical quality of the product variety. This quality is a function of the R&D investments, and we assume that it is equal across all products that are sold for a device.³ If we now assume that the demand can be approximated by a continuous variable n , the gross utility of consuming n product varieties can be expressed as:

$$u = \int_0^n (1 + q - n) dn = n(1 + q - n/2). \quad (1)$$

Suppose now that the price of each product variety that is compatible with device i is p_i . If buying device i and consuming n_i different varieties, a representative consumer's net utility from the complementary products is then:⁴

$$U_i = u_i - n_i p_i. \quad (2)$$

By solving a representative consumer's F.O.C. ($\partial U / \partial p = 0$), we obtain his demand for product varieties as a function of the product price and the quality that he faces;

$$n_i = 1 + q_i - p_i. \quad (3)$$

²We assume that the preferences measure the utility from other properties of the devices, for instance design.

³Decreasing marginal utility can for instance stem from the consumers buying the product varieties they like the best first.

⁴Note, if the nature of the product is such that a consumer buys the same variety several times, n_i can simply be interpreted as the number of times the product is bought.

We assume that when the products are non-exclusive, there is a version for each device. Thus, consumers who own different devices can be charged different prices. This is in line with observations for instance from the video game market. Here one and the same game title may be released in several versions in order to be compatible with several consoles. Furthermore, the different versions are sometimes sold at different prices, such that consumers with different console brands have to pay different prices in order to play the same game. Total product demand from the consumers who own a given device is therefore:

$$\begin{aligned} D_0 &= N_0 n_0, \\ D_1 &= (1 - N_0) n_1, \end{aligned}$$

where n_i is given by Eq. (3) and N_0 is the number of consumers that own device 0. Since the number of consumers is normalized to unity and full market coverage is assumed, N_0 is also device producer 0's market share. The market share of distributor 1 is consequently $N_1 = 1 - N_0$.

At stage 2, each device producer offers the seller a contract $K_i = [F_i, f_i]$ where $F_i \geq 0$ is a lump sum element and $f_i \geq 0$ is a per-unit-sold royalty fee. After the contracts are signed, the product seller chooses the level of R&D investments. We assume that if no R&D investments are made, the vertical quality of the complementary products is 1. Furthermore, if the seller invests $q_i^2/2$ in R&D, the vertical quality of all product varieties compatible with device i is $1 + q_i$.⁵ Finally, we normalize the marginal cost of all products to zero. Thus, if the product seller in total invests $C(q_0, q_1)$, its profit (Γ) will be:

$$\Gamma = \sum_{i=0}^1 (p_i - f_i) D_i - F_i - C(q_0, q_1). \quad (4)$$

⁵In cases where the consumers have unit demand for different varieties, we assume that the investments benefit all varieties equally; for instance that a game developer builds up the capacity to publish games with 3D technology. Alternatively, that the investments are spread equally across the varieties, such that the vertical quality of each variety increases equally.

The optimal price (p_i^*) of the product varieties that are compatible with device i is given by the F.O.C. ($\partial\Gamma/\partial p_i = 0$) By solving this we obtain :

$$p_0^* = (1 + q_0 + f_0) / 2 \quad (5)$$

$$p_1^* = (1 + q_1 + f_1) / 2 \quad (6)$$

If the products have to be tailored for each device, we assume that there is no spillover in the R&D investments, i.e. $C(q_0, q_1) = (q_0^2 + q_1^2) / 2$. On the other hand, if the products are non-exclusive, we assume that there is full spillover. Thus, by investing $C(q_0, 0) = q_0^2/2$, products of quality $1 + q_0$ can be sold to all consumers, regardless of which device they own. In order to avoid confusion, we denote the non-exclusive products by q .⁶ By substituting into Eq. (4) for p_0^* and p_1^* , and then solving for the relevant F.O.C.(s), i.e. $\partial\Gamma/\partial q_0 = 0 = \partial\Gamma/\partial q_1$ when the products are exclusive and $\partial\Gamma/\partial q = 0$ when the products are non-exclusive, we obtain the quality levels. When the products are exclusive, this is:

$$q_i^* = \frac{N_i}{2 - N_i} (1 - f_i), \quad (7)$$

where $i = 0, 1$. The quality of non-exclusive products is in contrast:

$$q^* = 1 - N_0 f_0 - (1 - N_0) f_1, \quad (8)$$

We can now substitute for the equilibrium values p^* and q^* into Eq. (4), in order to obtain the seller's profit as a function of the contracts it has entered into and the device producers' market shares. When the products are exclusive, this is:⁷

$$\Gamma_{0,1}^E = \sum_{i=0}^1 \left(\frac{1}{2} N_i \frac{(1 - f_i)^2}{2 - N_i} - F_i \right). \quad (9)$$

Note, it is possible that the seller will develop and sell products for only one device. We therefore let the subscripts of Γ indicate which devices the seller serves. The seller's profit when both device producers allow it to develop and sell non-exclusive products is however:

⁶Since the products are non-exclusive, we assume that resources are spent on developing one set of product varieties, and each of these is thereafter released in two versions, one for each device.

⁷Obviously, this is its profit also if only one device producer accepts non-exclusive products.

$$\Gamma^N = \frac{1}{2} (1 - f_1 (2 - f_1) + N_0 f_0 f_1 (1 - N_0)) + \frac{N_0}{4} (f_1 (4 - f_1 (3 - N_0)) - f_0 (4 - f_0 (1 + N_0))) - F_0 - F_1.$$

3 Stage 2: Product sales

In the previous section we derived the seller's responses and profits, for the possible combinations of contracts and product types, as functions of the device producers' market shares. Since the seller by assumption accepts all contracts for which the participation condition holds, it will accept device producer 0's offer if $\Gamma_{0,1} \geq \Gamma_1$ and $\Gamma_{0,1} \geq 0$ hold simultaneously or $\Gamma_0 > 0$ holds separately, and vice versa for device producer 1.

At stage 2, device producer i will therefore choose the contract, from the set of feasible contracts, which maximizes:

$$\pi_i = N_i c_i f_i + F_i, \quad (10)$$

under the restrictions defined by the seller's participation constraint. Since we consider two types of contracts, both for when the products are exclusive and non-exclusive, we have in total four different cases:

Product / Contract	Two-part tariff	Linear fee
Exclusive	E/T	E/L
Non-Exclusive	N/T	N/L

Table 1; Product / Contract

In order to distinguish between the cases, we use the notation from Table 1 as superscripts. Hence $\pi_i^{E/T}$ is the revenue at stage 2 for device producer i when the products are exclusive and revenues are retrieved by the use of two-part tariffs. In this case, a device producer can use the lump sum element to extract all the net

revenues that the seller earns when it is given access to selling products for the device system. Thus, a device producer will set the royalty fee to zero, in order not to distort the seller's incentives with respect to pricing and investments. Device producer i 's stage 2 revenue is therefore the first term of Eq. (9). Furthermore, a consumer's net utility of consuming complementary products on the device system is obtained by substituting into Eq. (2) for the equilibrium values p_i^* and q_i^* . This gives, respectively:

$$\begin{aligned}\pi_i^{E/T} &= \frac{1}{2} \frac{N_i}{2 - N_i}, \\ U_i^{E/T} &= \frac{1}{2} \frac{1}{(2 - N_i)^2}.\end{aligned}$$

If the complementary products are exclusive, but it is not possible for the device producers to retrieve rents by lump-sum fees, a device producer will choose f_i in order to maximize:

$$\pi_i^{E/L} = N_i c_i f_i. \quad (11)$$

By solving $\partial \pi_i^{E/L} / \partial f_i = 0$, we obtain:

$$f_i^{E/L} = 1/2.$$

We can now substitute $f_i^{E/L} = 1/2$ back into p_i^* and q_i^* and then substitute it all back into a consumer's utility and device producer i 's stage 2 revenue, which are given by respectively Eq. (2) and Eq. (11). By doing so we obtain:

$$\begin{aligned}\pi_i^{E/L} &= \frac{1}{4} \frac{N_i}{2 - N_i}, \\ U_i^{E/L} &= \frac{1}{8} \frac{1}{(2 - N_i)^2}.\end{aligned}$$

If the complementary products are non-exclusive, we assume that the device producers announce their respective contract offers simultaneously. When two-part tariffs are implementable, the optimal lump sum in pure strategies is:

$$F_i^* \equiv N_i \left(\sum_{i=0}^1 (p_i^* - f_i) D_i - q^2/2 \right). \quad (12)$$

Thus, the optimal lump sum fee equals the device producer's market share multiplied by the seller's total net revenue. In order to see that this has to be the optimal lump sum, suppose that device producer j claims $F_j = F_j^*$. For any f_i , the seller's participation constraint holds if $F_i \leq F_i^*$ and is violated if $F_i > F_i^*$, inasmuch as the seller will obtain negative profit if it accepts one or both contracts in the latter case.⁸ Hence, device producer i maximizes its profit by setting $F_i = F_i^*$, given its royalty fee f_i . Thus, it is a Nash equilibrium in pure strategies that both device producers set f_i such that they maximize their respective stage 2 revenues when $F_i = F^*$. By solving $\partial \pi_i^{N/T} / \partial f_i = 0$ for f_i under the constraint given by Eq. (12), we obtain device producer i 's best response function:

$$f_i^{NN} = (1 - N_i) \frac{2 - (1 - N_i)f_j}{(1 + N_i)(2 - N_i)}. \quad (13)$$

It follows from Eq. (13) that when $N_i < 1$ we have $f_i^{N/T} \geq 0$ and $\partial f_i^{N/T} / \partial f_j < 0$.

Lemma 1: *When two-part tariffs are implementable, and the products are non-exclusive;*

- a) *the royalty fees are higher than when the products are exclusive, and;*
- b) *the royalty fees are strategic substitutes.*

The seller's marginal profit from R&D investments, and thus also the R&D investments, are highest when the products are non-exclusive. The intuition is that since all consumers are served with the same product varieties, the sales of a product variety are highest when the products are non-exclusive, for a given quality level. Hence, it is less necessary for a device producer to incentivize the seller to invest in R&D by giving the seller a high profit margin. Furthermore, for a given per-unit-sold royalty fee, the consumers' demand for complementary products is highest when the products are non-exclusive. The device producers will internalize both effects by setting the highest per-unit-sold royalty fees when products are non-exclusive.

When a device producer sets a higher royalty fee, the seller responds by investing less in R&D. This is due to the fact that the seller's R&D investments increase in

⁸See the appendix for details.

its average profit margin. Hence, when a device producer claims a higher royalty fee, a consumer's willingness to pay decreases irrespective of which device he owns. This makes it optimal for the other device producer to charge a lower royalty fee, inasmuch as the consumers will respond to lower R&D investments by buying fewer products, all else equal. Thus, when the products are non-exclusive, the royalty fees are strategic substitutes.

By solving the system of the two best response functions, defined by Eq. (13), we obtain the optimal royalty fees $f_0^{N/T}$ and $f_1^{N/T}$:

$$f_i^{N/T} = \frac{(1 - N_i)}{1 + N_i(1 - N_i)}. \quad (14)$$

The equilibrium lump sums are then derived by substituting for the equilibrium values into Eq. (12):⁹

$$F_i^{N/T} = N_i(2 - N_i)(N_i + 1) \frac{1 - 2N_i(1 - N_i)}{4(1 + N_i(1 - N_i))^2}. \quad (15)$$

It follows from Eq. (14) that, in contrast to when the products are exclusive, it is optimal to set $f_i > 0$ also when two-part tariffs are implementable. In order to see the intuition, note that when the products are exclusive, a device producer retrieves by the lump sum all the net revenue which the seller earns when it is given access to sell products for the device. In contrast, when the products are non-exclusive, a device producer retrieves a weighted share of the total net revenues that the seller makes. Thus, when the products are non-exclusive, a device producer has, all else equal, the weakest incentives to boost the net revenue of the seller by setting a low royalty fee. Nonetheless, the larger the market share, the larger share of the net revenue a device producer can retrieve by the lump sum. Thus, the larger the market share a device produce has, the more it will rely on using the lump sum for retrieving revenue from the seller, and as a consequence it will set a lower royalty fee in order to boost the seller's net revenue. This is clear from Eq. (14) which shows that $f_i \approx 0$ if $N_i \approx 1$. Nonetheless, since the device producers free-ride on each other's efforts to incentivize the seller to invest in R&D, a device producer which has a fairly small

⁹We drop the asterisk.

market share will set $f_i^{N/T} > f_i^{E/L} = 1/2$, even though it can now retrieve revenues by the lump sum. By substituting the equilibrium values into a consumer's utility and device producer i 's stage 2 revenue, still given by respectively Eq. (2) and Eq. (10), we obtain:

$$\begin{aligned}\pi_i^{N/T} &= N_i(1 + N_i) \frac{4 - N_i(7 - N_i(6 - 2N_i))}{4(1 + N_i(1 - N_i))^2}, \\ U_i^{N/T} &= \frac{1}{2} \frac{N_i^2(N_i - 2)^2}{(1 + N_i(1 - N_i))^2}.\end{aligned}$$

If the complementary products are non-exclusive and only linear royalty fees can be used to extract rents, a device producer will maximize Eq. (11). By solving the system of F.O.C.s defined by $\partial\pi_0^{N/L}/\partial f_0 = 0 = \partial\pi_1^{N/L}/\partial f_1$ we obtain:

$$f_i^{N/L} = \frac{2(3 - N_i)}{8 + 3N_i(1 - N_i)}. \quad (16)$$

We can now compare the royalty fee when rents can be retrieved by two-part tariffs to when the rents can only be retrieved by per-unit-sold royalty fees, i.e. compare Eq. (14) to Eq. (16). By doing this, we observe that a device producer which has a large market share sets the highest royalty fee when it cannot use a lump sum, and vice versa for a device producer which has a fairly small market share. The explanation is that since a device producer cannot retrieve any of the seller's net revenue without the use of a lump sum, it has no incentives to set a low royalty fee with the aim of boosting the seller's net revenue. Thus, the device producer which has the largest market share always sets highest royalty fee when two-part tariffs are not available. Inasmuch as this implies that the seller invests less in R&D, compared to when two-part tariffs are available, it also implies that the scope for free-riding is smallest when two part tariffs are not available. For the device producer which has the smallest market share, a smaller scope for free-riding decreases its incentive to set a high royalty fee. This effect counters that a device producer, all else equal, has incentives to set a higher royalty fee when it two-part tariffs are not available. Thus, if a device producer has a sufficiently small market share, it will set the lowest royalty fee when two-part tariffs are not available.¹⁰

¹⁰Recall that royalty fees are strategic substitutes.

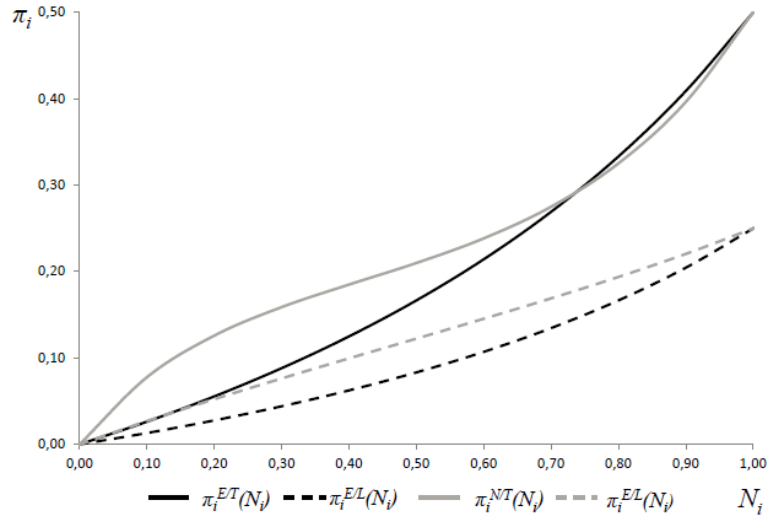


Figure 1; Rents per Consumer/Market Share

If we now substitute for the equilibrium values into the stage 2 revenue for device producer i and into the utility of a consumer who owns device i , we obtain:

$$\pi_i^{N/L} = (3 - N_i)^2 \frac{2N_i(1 + N_i)}{(8 + 3N_i(1 - N_i))^2},$$

$$U_i^{N/L} = \frac{1}{2} (3N_i + 1)^2 \frac{(N_i - 2)^2}{(8 + 3N_i(1 - N_i))^2}.$$

In the figure below, we have plotted device producer i 's revenue at stage 2 as a function of its market share, for all four cases. The solid lines are the revenue when the device producers employ two-part tariffs to shift rents from the seller, while the dashed lines are the revenue when they employ only royalty fees. Furthermore, the black lines are the revenue when the complementary products are exclusive, while the grey lines are the revenue when the products are non-exclusive.

From Figure 1 we observe that the stage 2 revenue of a device producer always increases in its market share. However, the type of contract and type of product together determine the levels of revenue, and how sensitive the revenue is to a device producer's market shares.

Lemma 2: *Around symmetric market shares, device producer's stage 2 revenue;*

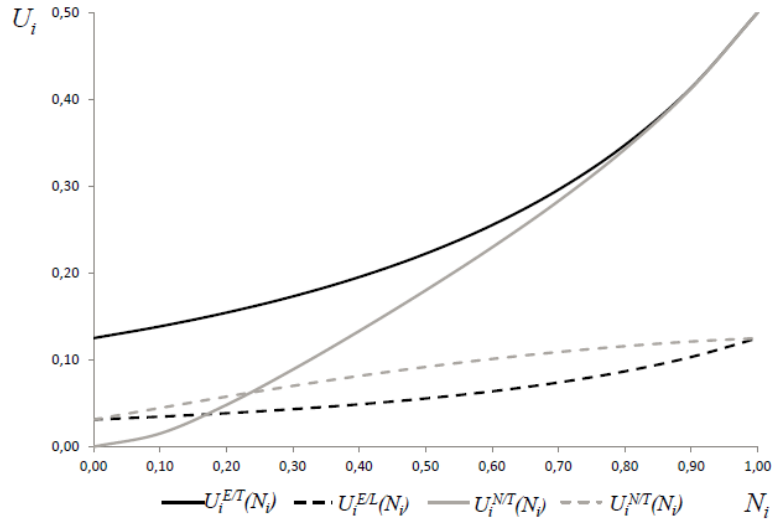


Figure 2; Utility/Market Share

a) *increases most in its market share when two-part tariffs are implementable., and;*

b) *is least sensitive to its market share when the products are non-exclusive.*

A device producer receives most revenue from the seller, per consumer served, when it can retrieve rents by two part tariffs. Thus, all else equal, it is when two-part tariffs are available that a device producer increases its revenue most when it is increasing its market share. When the complementary products are non-exclusive, the device producers free-ride on each other with respect to inducing the seller to invest in R&D. However, a device producer can free-ride less, the larger its market. Thus, when products are non-exclusive, a device producer's revenue from the seller is least sensitive to its market share.

If we now plot the stage 2 utility of a device owner as a function of the number of consumers that own the device, we obtain:

Lemma 3: *In the neighborhood of symmetric market shares, the utility of owning a given device;*

a) *increases most in the market share of the device when two-part tariffs are implementable., and;*

b) *is most sensitive to the market share of the device when the products are*

non-exclusive.¹¹

When one more consumer buys a device, the utility of owning the device increases most when two-part tariffs are implementable. However, the mechanisms that lead to this are different when the products are exclusive and non-exclusive. In the former case, the R&D investments increase most in the market share of a device when two-part tariffs are implementable. Since higher R&D investments mean lower quality-adjusted product prices, it follows that the utility increases most when only per-unit-sold royalty fees are used by the device producers to retrieve rents.

When the products are non-exclusive however, the explanation is that the larger market share a device producer has, the lower royalty fee it claims. This implies that the version of the non-exclusive complementary products that are made for the device which is owned by most consumers is the cheapest. Furthermore, the royalty fee which a device producer charges decreases most in its share when two-part tariffs are implementable. This effect in fact creates stronger adoption externalities than what the quality effect does when the products are exclusive. Thus, somewhat surprisingly, the utility from consuming complementary products is most sensitive to the device producers' market shares when the products are non-exclusive.

It is interesting to note from Figure 2 that when two-part tariffs are available, the consumers are better off when the products are exclusive than when they are non-exclusive, and vice versa if solely per-unit sold royalty fees can be used for retrieving rents. The explanation is that relative to exclusive products, non-exclusive products have two opposing effects on the quality-adjusted prices. All else equal, the seller invests more in R&D when products are non-exclusive. This benefits the consumers, inasmuch as more R&D investments mean lower quality-adjusted product prices. On the other hand, the device producers exploit this by charging the highest royalty fees when the products are non-exclusive. This increases the quality-adjusted product prices, all else equal. When two-part tariffs are available, the effect of higher per-unit sold royalty fees dominates the effect of more R&D investments. The quality

¹¹ *When only linear royalty fees are implementable, this result holds if the market share increases from less than 50% of the market .*

effect dominates however when only per-unit sold royalty fees can be used to shift rents.

In this section we have showed how the market share of a device producer impacts the per consumer revenue which the device producer retrieves from the seller, and the utility which a consumer obtains if it buys the device, i.e. we have derived the network effects. This is done for all four combinations of contract and product type. In the next section we will derive how stage 2 network effects in general affect the price of devices at stage 1.

4 Stage 1: Sales of devices

At this stage, the device producers compete for the consumers by selling devices. We assume that the unity mass of consumers is uniformly distributed over a Hotelling line (of length 1), where device producer 0 is located to the far left and device producer 1 is located to the far right. A consumer's location on the line determines his preferences for the devices. The net utility for a consumer located at a point $x \in [0, 1]$, before he consumes any complementary products is; $v - xt$ if he buys the device brand 0 and $v - (1 - x)t$ if he buys the device brand 1. t is the transportation costs parameter. In order to ensure that all consumers buy one and only one device and to avoid local monopolies, we assume that $v > t > \bar{t}$.¹² Suppose now that P_i is the price of device i , such that the consumer's net utility of the two devices can be expressed as:

$$V_0(x) = U_0 + v - xt - P_0, \quad (17)$$

$$V_1(x) = U_1 + v - (1 - x)t - P_1 \quad (18)$$

A consumer chooses the device which gives him the highest net utility. However, as shown in the previous section, the net utility of owning a device (U_i) is determined by the market share of the device. When the consumers buy devices, the market shares are obviously not yet determined. Thus, we assume that the consumers form

¹²If $t < 0.96222$, then under some conditions we will have negative device prices. If $v < t$ there will be some conditions under which the market will not be covered.

(correct) expectations about market shares, when they observe device prices and have complete information about each other's preferences. Suppose that for any given pair of device prices, there exists a unique expectation $0 \leq N_0^*(P_0, P_1) \leq 1$. When this holds with equality, there exists a consumer who is indifferent between the two devices. We define the location of this consumer as \hat{x} . By setting $V_0(\hat{x}) = V_1(\hat{x})$ and solving for \hat{x} , we obtain:

$$\hat{x} = \frac{1}{2} + \frac{U_A(N_0^*) - U_1(N_0^*) - P_0 + P_1}{2t}.$$

Since all consumers who are located to the left of this consumer will choose device 0, we know that device producer 0's sales, and thus its market share, will be $\hat{x} = N_0$. The market share of device 1 is then simply $N_1 = 1 - \hat{x}$.

We normalize the marginal cost of producing devices to zero. Furthermore, we define $R_i(N_i) = \pi_i/N_i$, such that $R_i(N_i)$ is device producer i 's revenue from the seller side per consumer served, when it serves N_i consumers. Thus, R_i can be interpreted as a negative marginal cost. The profit expression of device producer i then becomes:

$$\Pi_i = N_i(P_i + R_i). \quad (19)$$

The F.O.C. of device producer i ($\partial\Pi_i/\partial P_i = 0$), with respect to its device price, can now be expressed as:

$$\frac{\partial\Pi_i}{\partial P_i} = N_i + \frac{dN_i}{dP_i}(P_i + R_i) + \frac{\partial R_i}{\partial N_i} \frac{dN_i}{dP_i} N_i = 0, \quad (20)$$

where:

$$\frac{dN_i}{dP_i} = -\frac{1}{2t - \frac{\partial U_i}{\partial N_i} + \frac{\partial U_j}{\partial N_i}} < 0. \quad (21)$$

Definition 1: If $\partial U_i/\partial N_i \neq 0$, there is a consumer level network effect and if $R_i/\partial N_i \neq 0$, there is a firm level network effect.

Eq. (20) shows how device producer i 's profit changes if it increases the device price marginally. The two first terms of the equation capture the standard effects

of a price increase, i.e. higher mark-up but lower sales. The magnitude of the sales decrease is given by Eq. (21). From this we can conclude that the smaller t , and the stronger the positive consumer level network effect, the more the sales decrease.¹³ The former is straight forward, inasmuch as the consumers are less loyal when t is low. The explanation for the network effect's impact is that the consumers anticipate that the utility of owning the device is lower the higher the device price, inasmuch as a higher price means a lower market share of the device.

The third term of Eq. (20) captures the effect which a higher device price has on the device producer's revenue from the seller side. Since a higher price will lead to less device sales, the sign on this effect is determined by the sign on the firm level network effect, i.e. $R_i/\partial N_i$. Hence, compared to when $\partial R_i/\partial N_i = 0$, a positive firm level network effect ($\partial R_i/\partial N_i > 0$) decreases the marginal revenue of an increase in the device price, while a negative firm level network effect ($\partial R_i/\partial N_i < 0$) increases the marginal revenue. The intuition is simply that when $R_i/\partial N_i \neq 0$, the marginal consumer has an effect on the revenue to which the inframarginal consumers contribute. If this effect is positive, it increases the loss of revenue associated with less sales, and vice versa if the effect is negative. We can therefore conclude that:

Lemma 4: *The optimal device price is;*

- a) *lower the more positive the consumer level network effect is, and;*
- b) *lower the more positive the firm level network effect is, and vice versa when the firm level network effect is negative.*

From Lemma 4 it follows that a consumer- and a firm level network effect impact the device producers' business stealing incentives in the same direction. Positive effects increase the incentives, and negative network effects decrease them. The underlying mechanisms are not equal however. A (positive) consumer level network effect impacts the business stealing incentive in the sense that it makes it less costly to increase the market share. Hence, all else equal, the device price needs to be reduced less in order to increase the sales with a given amount when there is a

¹³Due to the market coverage assumption $|\Delta N_i| = -|\Delta N_j|$ which implies that $\partial U_i/\partial N_i$ will always have the opposite sign of $\partial U_j/\partial N_i$.

positive consumer level network effect. The firm level network effect impacts the profitability of increasing the market share. Thus, it is more profitable to increase the sales with a given amount when there is a positive firm level network effect. We can therefore sum up the discussion in a proposition:

Proposition 1: *Compared to when there are no network effects;*

a) a positive consumer level network effect makes the device sales more responsive to a decrease in the device price, while;

b) a positive firm level network effect makes it more profitable to serve a large market share, and vice versa when the firm level effect is negative.

In the appendix we use Eqs (20) and (21) to show that the device price in the symmetric equilibrium can be expressed as:¹⁴

$$P_i = t - R_i - N_i \left(\frac{\partial R_i}{\partial N_i} + \frac{\partial U_i}{\partial N_i} - \frac{\partial U_j}{\partial N_i} \right) \quad (22)$$

As expected, Eq. (22) shows that the device price is higher the more loyal the consumers are (higher t), and the less revenue the device producers receive from the seller side per consumer served (lower R). The former is simply because the more loyal the consumers are, the weaker is the incentive to reduce the device price in order to attract consumers. The latter is due to the fact that the more revenues that the device producers receive from the seller per consumer served, the stronger their incentives are to reduce the device price in order to increase the sales.

The last term of Eq. (22) captures the impact of the network effects, i.e. how the device producer's revenue per consumer served, and a consumer's utility of owning the devices, change as the market shares change. If the sum of this term is positive, we can interpret it as a network effect discount. Thus, inasmuch as the net adoption externalities are positive, and these are internalized by the device producers, the consumers are charged a low device price. On the other hand, if the term is negative,

¹⁴If the network effects are very strong, one device producer will corner the market. However, if the effects are sufficiently weak such that no device producer can profitably corner the market, it seems reasonable to consider the symmetric equilibrium.

the consumers are charged a higher device price due to the fact that the sum of adoption externalities that are internalized by the device producers is negative. If so, we can interpret it as a network effect premium.

By substituting Eq. (22) back into Eq. (19) we obtain:

$$\Pi_i = \frac{t}{2} - \frac{1}{4} \left(\frac{\partial R_i}{\partial N_i} + \frac{\partial U_i}{\partial N_i} - \frac{\partial U_j}{N_i} \right) \quad (23)$$

The last term of Eq. (23) shows that the larger the network effect discount, the lower the profit of the device producers. Hence, if the presence of a seller side implies that the device producers have to offer network effect discounts when they compete for the consumers, the device producers would have been better off if there was no aftermarket associated to the devices (and they were still able to sell their devices). This result applies irrespective of the magnitude of the revenue which can be retrieved from the seller side.

An interesting implication of this is that it may not necessarily be profitable for an industry as a whole that a product category becomes a sales platform for other products and services, mobile phones may serve as an example. This may be so despite the fact that the device producers are gaining a new source of revenue and a likely increase in the consumers' valuation of their products. Hence, if there are network effects associated to the market for smart phone applications, the handset producers' profit may actually decrease when such applications become more important to the consumers.

Having said that, it will of course always be privately optimal for a producer to develop a well-functioning application market for its handsets. Thus, the result can be a prisoner's dilemma situation. All device producers do their best to increase the revenues from the seller side, but the result is intensified competition in the device market and lower profit for the device producers.

Proposition 2: *Compared to a device type where there is no aftermarket for complementary products, the profit prospective of an industry with an aftermarket is;*

- a) *lower if the aftermarket creates positive network effects, and;*

b) *higher if the aftermarket creates negative network effects.*

In this section we have analyzed how network effects in general impact the competition for the consumers in device markets. In the next section we will look at this together with the results from the third section, in order to analyze how contract types (linear royalty fee/two-part tariff) and product types (exclusive/non-exclusive) are likely to affect the competition for consumers when the seller can increase the value of its products by R&D investments.

5 The competitive effects of product and contract types

From Eq. (23) we know that the more positive the sum of the consumer- and the firm level network effect is in the neighborhood of symmetric market shares, the tougher is the competition and the lower the profit of the device producers. Furthermore, this result applies regardless of the magnitude of the revenue which the device producers collect from the seller side. Hence, by evaluating the network effects in the neighbourhood of symmetric market shares, we can infer how the product and contract types affect the device producers' profit.

In the appendix we show that the consumer level network effects, in the neighbourhood of symmetric of market shares, can be ranked as follows:¹⁵

$$0 < \frac{\partial U_i^{N/L}}{\partial N_i} \Big|_{N_i=1/2} < \frac{\partial U_i^{E/L}}{\partial N_i} \Big|_{N_i=1/2} < \frac{\partial U_i^{E/T}}{\partial N_i} \Big|_{N_i=1/2} < \frac{\partial U_i^{N/T}}{\partial N_i} \Big|_{N_i=1/2}. \quad (24)$$

The consumers' responsiveness to a decrease in a device price is determined by the strength of the consumer level network effect. Inequality (24) shows how product types and contract types affect the consumer level network effect. Thus, from this inequality, we can deduce how responsive the consumers are to a price

¹⁵Our aim is not to derive the exact prices, but to analyze the qualitative effects that different contract types and product types may have on the competition. We consider the effects in the neighbourhood of symmetric market shares to be approximations for the effects we are interested in.

decrease. As expected, we observe that the consumer level network effects are most pronounced when two-part tariffs are available. We can therefore conclude that when only linear royalty fees can be used to retrieve revenue from the seller side, then the device price has to be reduced the most in order to increase the sales by a given amount. Furthermore, when two-part tariffs are available, the consumers will be most sensitive to device price differences when the products are non-exclusive. It is, however, the other way around when the device producers can use only linear royalty fees. Then the consumers are least sensitive to differences in prices when the products are non-exclusive.

The ranking of the firm level network effect is in the appendix shown to be as follows:

$$\frac{\partial R_i^{N/T}}{\partial N_i} \Big|_{N_i=1/2} < \frac{\partial R_i^{N/L}}{\partial N_i} \Big|_{N_i=1/2} < 0 < \frac{\partial R_i^{E/L}}{\partial N_i} \Big|_{N_i=1/2} < \frac{\partial R_i^{E/T}}{\partial N_i} \Big|_{N_i=1/2}. \quad (25)$$

Inequality (25) shows how the per consumer revenue that a device producer retrieves from the seller changes if the device producer increases its market share marginally. From the inequality we observe that the per consumer revenue decreases if the products are non-exclusive, and increases vice versa if the products are exclusive. Thus, the firm level network effects are diametrically different for the two product types. The explanation is that when the products are exclusive, the seller will respond by increasing R&D investments when the market share of a device increases. This implies that there is more revenue to be shared between the device producer and the seller at stage 2. When the products are non-exclusive, however, it is the other way around. A device producer which increases its market share will to a lesser degree be able to free-ride on its rival. Thus, after having increased its market share, a device producer chooses to provide the seller with a higher profit margin in order to induce the seller to more eagerly invest in R&D (for the common products).

Compared to when only linear royalty fees can be implemented, the effects are reinforced when two-part tariffs are implementable. The explanation is simply that retrieving revenues by two-part tariffs is the most efficient method. It allows a device producer to retrieve a larger share of the seller's total revenues, while distorting the

seller's incentives to a smaller degree than linear royalty fees only. Thus, when the products are exclusive, the option of retrieving rents by a lump sum increases the value to a device producer of serving a large market. When the products are non-exclusive however, the option increases the value of being a free-rider.

In the appendix we show that if we substitute for the marginal effects into Eq. (23), the profit of a device producer can be ranked as follows¹⁶:

$$\Pi^{E/T} < \Pi^{N/T} < \Pi^{E/L} < \Pi^{N/L}. \quad (26)$$

Proposition 3: *The profit of a device producer is higher;*

a) *when the products are non-exclusive, compared to when they are exclusive, and;*

b) *when revenue from the seller is retrieved only by royalty fees, compared to when two-part tariffs are employed.*

Since tougher competition means lower equilibrium profit, we can use inequality (26) to draw some conclusions about how different characteristics of device markets affect the competition. First, we observe that the profit is higher when the products are non-exclusive than when the products are exclusive, all else equal. This is also true when two-part tariffs are implementable. Thus, we can conclude that the softening effect on the competition from the fact that non-exclusive products make it less profitable to serve large market shares dominates the intensifying effect on the competition due to the fact that non-exclusive products make the consumers more concerned about the popularity of the devices.

The profits of the device producers are always lowest when two-part tariffs are implemented. This may sound counterintuitive inasmuch as the device producers always retrieve most revenue from the seller when the two-part tariffs are implemented. However it is exactly because two-part tariffs are so efficient in retrieving revenues from the seller side that they hurt the device producers. Two-part tariffs create the strongest adoption externalities, and, thus, the strongest network effect discounts.

¹⁶Since all equilibria are symmetric, we drop the subscript.

We can now study how the consumers are affected by the combination of product and contract types. Since all equilibria are symmetric and there is a unity mass of consumers, the consumer surplus is given by $CS = U + v - t/4 - P$.¹⁷

$$CS^{E/L} < CS^{N/L} < CS^{N/T} < CS^{E/T}. \quad (27)$$

Lemma 5: *The consumers always obtain highest utility when the device producers can retrieve revenue by two-part tariffs, and they prefer;*

a) non-exclusive products to exclusive products, when the seller pays only linear royalty fees, and;

b) exclusive products to non-exclusive products, when the seller has to pay lump sums as well to the device producers.

The consumers are always better off when the device producers retrieve rents by two-part tariffs than when they only use royalty fees. The intuition is that two-part tariffs, due to no or low royalty fees, distort the seller's pricing and investments incentives to the lowest degree. This benefits the consumers in the form of low quality-adjusted product prices, but also in the form of low device prices. The former is because the royalty fees are lowest when two-part tariffs are employed, and the latter due to the fact that two-part tariffs intensify the competition in the device market.

If the device producers retrieve revenue from the seller by two-part tariffs, the consumers benefit from the products being exclusive. However, if only per-unit-sold royalty fees are used, the consumers are better off when the products are non-exclusive. The explanation is that when the products are non-exclusive, the seller invest more in R&D. Thus, the consumers obtain higher utility from the non-exclusive products than from the exclusive products. The flip side is that they also have to pay more, both for devices and for complementary products. When rents are retrieved by per-unit sold royalty fees only, the positive R&D effect dominates such that the consumers' utility is highest when the products are non-exclusive. The

¹⁷The average transportation cost is $t/4$.

effect of higher prices dominates, however, when revenue from the seller is retrieved by two-part tariffs, such that the consumers' utility is then lower when the products are non-exclusive than when they are exclusive.

The social surplus is given by $SS = \sum_i \Pi_i + CS + \Gamma$. In the appendix we substitute into this expression and derive the following ranking:

$$SS^{E/L} < SS^{N/L} < SS^{E/T} < SS^{N/T} \quad (28)$$

For any given contract type, the social surplus is highest when the products are non-exclusive. This implies that the positive scale effect in the R&D investments caused by the products being non-exclusive, dominates the efficiency gain from the fact that royalty fees are lowest when the products are exclusive. Furthermore, we observe that the social surplus is always highest when two-part tariffs are implementable. The explanation is simply that a two-part tariff is the most efficient instrument by which revenue can be retrieved.

Suppose now that we are at stage 2, i.e. that the consumers are captured. Since the seller, all else equal, invests more in the products when the products are non-exclusive, both device producers will at this stage be better off when the products are non-exclusive than when they are exclusive. In the appendix we show that also the seller is (weakly) better off when it is selling non-exclusive products. Thus, at stage 2, no firm has any interest in promoting exclusive products. We therefore conclude that the products will be non-exclusive whenever this is technologically feasible. Since this is anticipated by the active agents at stage 1, both the consumers and the device producers take it into account when they make their decisions at this stage. In other words, from the set of feasible products, the product type which occurs in equilibrium will be the socially efficient one.¹⁸

We can do the same analysis for contract types. Here, our results suggest that both the device producers and the seller prefer that two-part tariffs are not employed. However, since the device producers choose the contracts by which they should retrieve revenues from the seller at stage 2, it is at this stage that it is determined whether or not two-part tariffs will be employed in equilibrium. When the

¹⁸Non-exclusive products may for instance be restricted by technological conditions.

consumers are captured, the coalition of the seller and a device producer maximizes total revenue exactly by the use of two-part tariffs. Thus, at stage 2, both parties of a coalition can be made better off if two-part tariffs are employed, relative to when solely per-unit sold royalty fees are used. We can therefore conclude that whenever two-part tariffs are feasible, the device producers will charge the sellers lump sums. Again, this will be anticipated by the active agents at stage 1, and they will therefore take this into account. Hence, from the set of technologically feasible contracts, the socially most efficient contract occurs in equilibrium. In other words, if, in an industry which shares properties with the industry analyzed in this paper, we observe that the products are exclusive and that rents are retrieved by royalty fees only, we should not expect that non-exclusive products and two-part tariffs are not technologically feasible.

Proposition 4: *In a consumption device market where the seller can increase the value of its products by R&D investments, the social surplus for the feasible technologies is maximized without intervention from a social planner.*

6 Concluding Remarks

In this paper we have analyzed an industry where competing firms sell products which are (primarily) bought because they enable for consumption of complementary products. We refer to these products as consumption devices and examples may be coffee machines, tablet computers and video game consoles. Device-based industries differ, however, with respect to whether the same complementary products can be sold for several devices or the products have to be tailored for each device. For instance, the more advanced the technologies are, the more difficult it might be to make the same applications run at different devices. Conditions at the seller side may also determine which instruments the device producers may employ to extract revenue from the sellers. For instance, since video games are more advanced than most smart phone applications, it might be easier to develop non-exclusive smart phone applications than video games. Furthermore, since the video game developers

are large professional organizations, it might be easier to charge up-front payments from them than from individuals who develop smart phone applications as a hobby. This is the starting point of our study which aims at analyzing how such differences affect the competition in the device market.

We show that relative to exclusive products, non-exclusive products have a softening effect on the competition in the device market. The explanation is that when the products are exclusive, the seller will create "better" products for a device, i.e. invest more in R&D, the more consumers that own the device. This is beneficial to the consumers as well as to the coalition consisting of the seller and the device producer, which creates fierce competition to capture consumers. However, when the products are non-exclusive, the device producers have weaker incentives to capture large market shares. This is due to the fact that they can free-ride on each other when it comes to inducing the product seller to invest in R&D. Furthermore, we show that when rents can be extracted from the seller side by two-part tariffs, the competition in the device market is tougher relative to when revenue can only be retrieved by linear royalty fees. Roughly speaking, we can say that it is the fact that royalty fees create inefficiencies that decreases the positive adoption externalities, which in turn soften the competition in the device market. The more the product seller's incentives will be distorted by royalty fees, the less a device producer gains from capturing one more consumer and the less sensitive the quality-adjusted price of complementary products is to the market shares of the devices.

Relative to when the products are exclusive, the social surplus is higher when the products are non-exclusive. Furthermore, for given product types, the social surplus is always highest when two-part tariffs are employed to extract revenues from the seller side. An interesting finding is that due to the firms' incentives, it is not necessary for a social planner to intervene in the market in order to achieve the socially best solution. The explanation is that after the consumers have been captured, it is in the interest of all firms that the products are non-exclusive. The same argument applies to why two-part tariffs will always be employed when it is technologically feasible. After the consumers have been captured, it is always optimal to employ two-part tariffs. This will be anticipated by both consumers and

device producers. Thus, if two-part tariffs are technologically feasible, these will always occur in equilibrium.

Even though the industry maximizes (the feasible) social surplus, consumer surplus is not always maximized. When the products are exclusive, the competition for the consumers is toughest. From the consumers' point of view, lower device prices when the products are exclusive dominate over the quality-adjusted complementary product prices being lower when the products are non-exclusive. Hence, the consumers prefer exclusive products to non-exclusive products when two-part tariffs are feasible. It is the other way around, however, when linear fees are employed to extract revenue from the consumer side.

Our results may explain why Corts & Lederman (2009) find an increasing number of non-exclusive game titles in the video game industry. Furthermore, since Evans et al., 2006, report that linear royalty fees are the main instrument for rent extraction in the video game industry, our results indicate that this development should be welcomed by the consumers. It therefore seems like the Federal Trade Commission did consumers a favour when in 1987 they forced Nintendo to drop an exclusivity clause from its standard contract with game developers. On the other hand, our results suggest that Nintendo would probably have done so in any case when non-exclusive products became technologically feasible.

Some words about a couple of our assumptions. The driving mechanism of our results is that the seller of complementary products can invest in R&D in order to increase the profit margin of its products. Inasmuch as technological devices are often used to consume information goods that are produced at a very low marginal cost, we have modeled the R&D investments as investments in product quality. It should be noted, however, that all results are analogous if the seller of complementary products can decrease its marginal costs by investing in R&D.

We also assume that there is only one active seller of complementary products at each point of time. This may seem like a restrictive assumption, since we for instance observe that there are many firms that sell games for each video game console. However, the crucial property we aim to capture is that the seller has a profit margin, which can be increased by R&D investments. Thus, as long as this

holds, the number of sellers should have no implications for our qualitative results.

7 Appendix

Appendix A1: Optimal lump sum when products are non-exclusive.

Suppose that the device producers try to capture their incremental contribution: If the seller accepts the contract of device producer 1 it will obtain:

$$\Gamma_1 = \frac{1}{2}(1 - N_0) \frac{(1 - f_1)^2}{2 - (1 - N_0)} - F_1,$$

so it will accept a contract offered by device producer 0 if $\Gamma_{0,1} - \Gamma_1 > 0$ which can be expressed as:

$$\begin{aligned} & \frac{1}{2}(1 - f_1(2 - f_1) + N_0 f_0 f_1(1 - N_0)) + \\ & \frac{N_0}{4}(f_1(4 - f_1(3 - N_0)) - f_0(4 - f_0(1 + N_0))) - F_0 - F_1 - \Gamma_1^E > 0 \end{aligned} \quad (29)$$

by solving this for F_0 we obtain:

$$F_0 = \frac{1}{4} N_0 \frac{(f_0 + f_1 + N_0 f_0 - N_0 f_1 - 2)^2}{N_0 + 1} \quad (30)$$

When device producer 0 tries to appropriate its incremental contribution it will maximize $\pi_0 = n_0 f_0 N_0 + F_0$ for f_0 , under the restriction that F_0 is given by Eq. (30). This gives:

$$f_0 = \frac{1}{1 - N_0} (3f_0 - N_0 f_0)$$

However, as distributor 1 will do the same, we have that:

$$f_1 = \frac{1}{1 - (1 - N_0)} (3f_1 - (1 - N_0)f_1)$$

By solving the two best response functions we obtain:

$$f_0 = f_1 = 0$$

Due to symmetry, we know that:

$$F_1 = \frac{1}{4}(1 - N_0) \frac{(f_0 + f_1 + (1 - N_0)f_1 - (1 - N_0)f_0 - 2)^2}{N_0 + 1}$$

By substituting it all back into Γ^N we obtain:

$$\Gamma_{0,1} = -\frac{1}{2} \frac{1 - N_0}{1 + N_0} < 0$$

and by substituting back into Γ_0 and Γ_1 we obtain:

$$\begin{aligned} \Gamma_0 &= -\frac{3}{2} N_0 \frac{1 - N_0}{N_0 - N_0^2 + 2} < 0 \\ \Gamma_1 &= -\frac{1}{2} \frac{1 - N_0}{N_0 + 1} < 0 \end{aligned}$$

Hence, the device producers cannot capture their incremental contribution, since if they both try to do this, the seller will accept none of the contracts. Q.E.D.

Appendix A2: Deriving demand elasticity for devices

The expression for the indifferent consumer is:

$$\hat{x} = \frac{1}{2} + \frac{U_A(\hat{x}) - U_B(\hat{x}) - P_A + P_B}{2t} \quad (31)$$

If we differentiate equation (31) with respect to P_i , we obtain:

$$\frac{dN_i}{dP_i} = \frac{1}{2t} \left(-1 + \left(\frac{\partial U_i}{\partial N_i} - \frac{\partial U_j}{\partial N_i} \right) \frac{dN_i}{dP_i} \right) \quad (32)$$

By solving equation (32) for dN_i/dP_i we obtain:

$$\frac{dN_i}{dP_i} = -\frac{1}{2t - \frac{\partial u_i}{\partial N_i} + \frac{\partial u_j}{\partial N_i}}$$

Q.E.D.

Appendix A3: Deriving device price for the symmetric equilibrium

For convenience, we write equation (20) below:

$$\frac{\partial \Pi_i}{\partial P_i} = N_i + \frac{dN_i}{dP_i} (P_i + R_i) + \frac{\partial R_i}{\partial N_i} \frac{dN_i}{dP_i} N_i = 0$$

This can be rewritten as:

$$\begin{aligned}
 -\frac{dN_i}{dP_i}P_i &= N_i + \frac{dN_i}{dP_i}R_i + \frac{\partial R_i}{\partial N_i} \frac{dN_i}{dP_i}N_i \\
 P_i &= \left(-\frac{dN_i}{dP_i}\right)^{-1} N_i - R_i - \frac{\partial R_i}{\partial N_i}N_i \\
 P_i &= \left(2t - \frac{\partial U_i}{\partial N_i} + \frac{\partial U_j}{\partial N_i}\right) N_i - R_i - \frac{\partial R_i}{\partial N_i}N_i \\
 P_i &= \left(2t - \frac{\partial U_i}{\partial N_i} + \frac{\partial U_j}{\partial N_i}\right) N_i - R_i - \frac{\partial R_i}{\partial N_i}N_i \\
 P_i &= 2tN_i - R_i - N_i \left(\frac{\partial R_i}{\partial N_i} + \frac{\partial U_i}{\partial N_i} - \frac{\partial U_j}{\partial N_i}\right)
 \end{aligned}$$

where $N_i = \hat{x}$ and P_j is given by a symmetric expression.

Since $R_i, \partial R_i / \partial N_i$ and $\partial U_i / \partial N_i$ are functions of N_i we have a system of two equations and three unknowns. This cannot be solved, but since we are interested in the symmetric market shares, we can evaluate the expressions for $N_i = 1/2$. By doing so, it follows immediately that P_i is given by equation (22).

The profit is given by total revenues per device sold times the number of devices sold, i.e. $\Pi = (P_i + R_i) N_i$. If we evaluate this for $N_i = N_j = 1/2$ we obtain Eq (23). Q.E.D.

Appendix A4: Calibrating the adoption externalities that determine the consumers' demand

The expressions for the utility of consuming complementary products at device i are:

$$\begin{aligned}
 U_i^{E/T} &= \frac{1}{2} \frac{1}{(2 - N_i)^2} \\
 U_i^{E/L} &= \frac{1}{8} \frac{1}{(2 - N_i)^2} \\
 U_i^{N/T} &= \frac{1}{2} \frac{N_i^2 (N_i - 2)^2}{(1 + N_i(1 - N_i))^2} \\
 U_i^{N/L} &= \frac{1}{2} (3N_i + 1)^2 \frac{(N_i - 2)^2}{(8 + 3N_i(1 - N_i))^2}
 \end{aligned}$$

If we take derivatives with respect to N_i and then evaluate the expressions for

$N_i = 1/2$ we obtain:

$$\begin{aligned}
 \frac{\partial U_i^{E/T}}{\partial N_i} &= -\frac{1}{(N_i - 2)^3} & \Rightarrow \frac{\partial U_i^{E/T}}{\partial N_i} \Big|_{N_i=1/2} &= 0.296\ 30 \\
 \frac{\partial U_i^{E/L}}{\partial N_i} &= -\frac{1}{4(N_i - 2)^3} & \Rightarrow \frac{\partial U_i^{E/L}}{\partial N_i} \Big|_{N_i=1/2} &= 7.407\ 4 \times 10^{-2} \\
 \frac{\partial U_i^{N/T}}{\partial N_i} &= N_i(N_i - 2) \frac{-2N_i + N_i^2 + 2}{(-N_i + N_i^2 - 1)^3} & \Rightarrow \frac{\partial U_i^{N/T}}{\partial N_i} \Big|_{N_i=1/2} &= 0.48 \\
 \frac{\partial U_i^{N/L}}{\partial N_i} &= (N_1 - 3)(N_1 + 1) \frac{2N_1 + 3N_1^2 + 7}{(-3N_1 + 3N_1^2 - 8)^3} & \Rightarrow \frac{\partial U_i^{N/L}}{\partial N_i} \Big|_{N_i=1/2} &= 4.898\ 0 \times 10^{-2}
 \end{aligned}$$

Q.E.D.

Appendix A5: Calibrating the adoption externalities that determine the per consumer served revenue for the device producers

The expressions for the stage 2 revenues per consumer ($R_i = \pi_i/N_i$) are:

$$\begin{aligned}
 R_i^{E/T} &= \frac{1}{2} \frac{1}{2 - N_i} & \Rightarrow R_i^{E/T} \Big|_{N_i=0.5} &= 0.333\ 33 \\
 R_i^{E/L} &= \frac{1}{4} \frac{1}{2 - N_i} & \Rightarrow R_i^{E/L} \Big|_{N_i=0.5} &= 0.166\ 67 \\
 R_i^{N/T} &= (1 + N_i) \frac{4 - N_i(7 - N_i(6 - 2N_i))}{4(1 + N_i(1 - N_i))^2} & \Rightarrow R_i^{N/T} \Big|_{N_i=0.5} &= 0.42 \\
 R_i^{N/L} &= (3 - N_i)^2 \frac{2(1 + N_i)}{(8 + 3N_i(1 - N_i))^2} & \Rightarrow R_i^{N/L} \Big|_{N_i=0.5} &= 0.244\ 90
 \end{aligned}$$

If we take derivatives with respect to N_i and then evaluate the expressions for $N_i = 1/2$ we obtain:

$$\begin{aligned}
 \frac{\partial R_i^{E/T}}{\partial N_i} &= \frac{1}{2(N_i - 2)^2} & \Rightarrow \frac{\partial R_i^{E/T}}{\partial N_i} \Big|_{N_i=1/2} &= 0.222\ 22 \\
 \frac{\partial R_i^{E/L}}{\partial N_i} &= \frac{1}{4(N_i - 2)^2} & \Rightarrow \frac{\partial R_i^{E/L}}{\partial N_i} \Big|_{N_i=1/2} &= 0.111\ 11 \\
 \frac{\partial R_i^{N/T}}{\partial N_i} &= \frac{1 - 17N_i - 3N_i^2 + 6N_i^3 + 11}{4(N_i - N_i^2 + 1)^3} & \Rightarrow \frac{\partial R_i^{N/T}}{\partial N_i} \Big|_{N_i=1/2} &= -0.32 \\
 \frac{\partial R_i^{N/L}}{\partial N_i} &= -2(3 - N_i) \frac{10 - 3N_i(1 + 6N_i - N_i^2)}{(8 + 3N_i(1 - N_i))^3} & \Rightarrow \frac{\partial R_i^{N/L}}{\partial N_i} \Big|_{N_i=1/2} &= -3.265\ 3 \times 10^{-2}
 \end{aligned}$$

Q.E.D.

Appendix A6: Equilibrium values (Symmetric equilibrium)

When one device producer increases its market share, the stage 2 utility of both devices changes. Since we focus on effect around symmetric markets shares we know that change in the difference must be $\partial U_i/\partial N_i - \partial U_j/\partial N_i = 2(\partial U_i/\partial N_i) = \partial \Delta/\partial N_i$. We can now find the equilibrium prices by substituting into the Eq. (22) for the respective expressions, $\partial \Delta/\partial N_i$ and $R_i/\partial N_i$ and R_i , all evaluated for the symmetric equilibrium. This gives:

$$\begin{aligned} P_i^{E/T} &= t - 0.74074 \\ P_i^{E/L} &= t - 0.29630 \\ P_i^{N/T} &= t - 0.74 \\ P_i^{N/L} &= t - 0.27755 \end{aligned}$$

The equilibrium profit for the device producers is; $\Pi = \left(P_{|N_i=1/2} + R_{|N_i=1/2} \right) N_{i|N_i=1/2}$, which gives:

$$\begin{aligned} \Pi^{E/T} &= t/2 - 0.20371 \\ \Pi^{E/L} &= t/2 - 0.06482 \\ \Pi^{N/T} &= t/2 - 0.16 \\ \Pi^{N/L} &= t/2 - 1.6325 \times 10^{-2} \end{aligned}$$

The net utility of buying a device is determined by v , U_i , P and $x_i t$ where the last element is constant for all cases, but varies over the consumers. However, the transportation costs for a given consumer is equal across all cases. By substituting into Eq. (2) for the average consumer, we obtain:

$$\begin{aligned} CS_{i|N_i=0.5}^{E/T} &= v - t + 0.96296 - t/4 \\ CS_{i|N_i=0.5}^{E/L} &= v - t + 0.35186 - t/4 \\ CS_{i|N_i=0.5}^{N/T} &= v - t + 0.92 - t/4 \\ CS_{i|N_i=0.5}^{N/L} &= v - t + 0.36939 - t/4 \end{aligned}$$

The profit of the seller of complementary products is (Γ):

$$\begin{aligned}\Gamma^{E/T} &= 0 \\ \Gamma^{E/L} &= 8.3334 \times 10^{-2} \\ \Gamma^{N/T} &= 0 \\ \Gamma^{N/L} &= 9.1837 \times 10^{-2}\end{aligned}$$

The social surplus is given by the sum of the profit of the device producers, (Π), the profit of the seller of complementary products (Γ) and the total consumer surplus. Since there are a unity mass of consumers, we can therefore write $\Pi + \Gamma + CS$, this gives:

$$\begin{aligned}SS^{E/T} &= v - \frac{1}{4}t + 0.55555 \\ SS^{E/L} &= v - \frac{1}{4}t + 0.30555 \\ SS^{N/T} &= v - \frac{1}{4}t + 0.6 \\ SS^{N/L} &= v - \frac{1}{4}t + 0.42858\end{aligned}$$

Q.E.D.

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Some products and services are perfect complements to technological devices, such as video games to video game consoles. We analyze how competition between two firms selling such devices is affected by the fact that they can retrieve revenue both from end-users and from firms selling complementary products. We show that non-exclusive complementary products weaken competition relative to when the products are exclusive. Furthermore, competition is less keen when the device producers have inefficient means for retrieving revenue from the seller side, compared to when they have efficient means. Finally, we show that from the set of feasible strategies, the firms will always choose the socially optimal one. A novel finding is that at the consumer side there are brand specific adoption externalities also when the complementary products are non-exclusive.



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