Endogenous Mode of Competition in a Platform Market

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Abstract

This research analyzes incompatible platforms' competition mode choices, specifically content quantity versus license fee, in a traditional competitive bottleneck set-up with single-homing users and multi-homing content developers. The main contribution of the paper to the literature is showing that license fee competition can be an equilibrium outcome even when competing platforms are incompatible, which sharply contrasts with the result in the existing literature that price competition can be an equilibrium outcome when the degree of network compatibility is sufficiently large. Regarding social desirability, we present the following two findings contrary to conventional wisdom. First, the market outcome with license fee competition could align with consumers' surplus optimum, but the market outcome cannot align with the social welfare optimum, regardless of whether the platforms compete in license fees or content quantities. Second, asymmetric competition could be optimal for consumers' surplus.

Keywords: Competition Mode, Content Quantity, License Fee, Pisoners' Dlemma, To-sided Maket

JEL Classification: D45, L11, L13

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1. Introduction

It is common to observe industries with demand interdependencies between agents on both sides, hardware users and content developers. The home video game industry is a typical example in which console users gain more utility from a technology platform with more game titles. At the same time, game designers earn more profits from a technology platform with more console users. From this viewpoint, the amount of supporting content plays a crucial role in hardware users' platform adoption decisions, which affects content developers' joining decisions. More often than not, platforms license content provision to independent developers rather than provide it themselves. Similar to the demonstrations presented by Singh and Vives (1984), which pioneered the research of competition mode decisions, platforms can use a license fee or a content quantity contract when licensing content provision to independent developers. For instance, if a console developer chooses the license fee contract in the home video game industry, it will have to offer a number of licensees that meet the content developers' demand. On the contrary, if the console developer chooses the content quantity contract, it must fulfill the committed number of licensees. The operating system (OS) market can serve as another example in which an OS developer can similarly use a license fee or a supporting software quantity contract in licensing. From the above demonstrations, in addition to competing in the console device or OS prices, the console (OS) developer can compete in license fees or content quantities. This leads us to examine platforms' competition mode decisions.

Singh and Vives (1984) show that competing in quantity (price) is a dominant strategy when competitive goods are substitutes (complements). This leads many economists to discuss the validity of the above results under different frameworks. Cheng (1985) provides insights into the results of Singh and Vices (1984) by presenting a geometric analysis. Miller and Pazgal (2001) find that price and quantity competition lead to the same outcome under delegation. Arya et al. (2008) show that the results of Singh and Vives (1984) can be reversed when the production of inputs is outsourced to retail rivals.

Choi et al. (2016) demonstrate that Bertrand competition can be a dominant strategy that makes firms face the Prisoners' Dilemma in international trade with oligopolistic competition. Nasser and Turcic (2016) consider a Hotelling model with differentiated firms and show that an asymmetric outcome in which some firms commit to a quantity and others choose not to can arise as an equilibrium outcome. Niu (2018) examines firms' decisions of competition mode in an asymmetric duopoly market with process innovation licensing, finding that both firms prefer quantity competition if the initial cost difference is slight or the goods are close substitutes. Meccheri and Fanti (2018) demonstrate that the result of Singh and Vives (1984) is generally reversed in a market with managerial delegation and unionized labor.

This paper is related to the literature on two-sided markets in which economists have taken different approaches to delineate network externalities across agents of two sides to investigate platform competition and related issues. Economides and Katsamakas (2006), Rasch and Wenzel (2014), Maruyama and Zennyo (2015), Choi and Jeon (2021), and Ishihara and Oki (2021) examine platforms' licensing behaviors. Rochet and Tirole (2003, 2006), Hagiu (2006, 2009), Bedre-Defolie and Calvano (2013), Reisinger (2014), and Roger and Vasconcelos (2014) study platforms' optimal pricing structures. Hagiu et al. (2022), Choi and Jeon (2023), and Hahn et al. (2023) investigate platforms' anti-competitive strategic tools. Belleflamme and Peitz (2019), Bakos and Halaburda (2020), and Teh et al. (2023) discuss the effect of multihoming. The main difference between our research and the existing literature is that we endogenize platforms' decisions of competition mode, specifically, license fee or content quantity in licensing. License fees can be regarded as the price of the source code of hardware technology. From this viewpoint, our study essentially discusses whether the dominance of quantity (price) competition in terms of firms' profits (consumers' surplus) obtained by Singh and Vives (1984) can be valid in a two-sided market. Our research is closely related to Hashizume and Nariu (2020), which address a similar issue. Different from Hashizume and Nariu (2020) which analyze firms' competition mode decisions in a one-sided market with network externalities, we investigate incompatible two-sided platforms' competition mode decisions in a traditional competitive bottleneck setup. Our research

presents that license fee competition could be an equilibrium outcome even with incompatible platforms which sharply contrasts with the results found in Hashizume and Nariu (2020) that price competition can be an equilibrium outcome when network compatibility is sufficiently large. To be specific, weakly differentiated platforms in a market with a substantial difference between per-user profit and pre-content benefit tend to adopt license fee competition with the property of a strategic complement as a dominant strategy. Conversely, platforms with significant differentiation tend to compete in content quantities with the property of a strategic substitute. Besides, due to toughening hardware price competition, platforms earn less profits under license fee competition than content quantity competition. It is worth mentioning that the equilibrium content quantity and license fee are independent of platforms' competition modes decisions which only affect the price of hardware prices and profits. Regarding consumers' surplus, owing to a lower hardware price or more content provision, symmetric license fee competition or asymmetric competition can be optimal for consumers' surplus. Finally, when the extent of differentiation between platforms is relatively small (significant), asymmetric (symmetric) competition optimizes social welfare. To sum up, the main contribution of this paper is showing that instead of competing in content quantities, two-sided platforms could end up competing in license fees, which leads to the Prisoners' Dilemma. License fee competition as a market outcome could optimize consumers' surplus, implying an alignment between the market outcome and the consumers' surplus optimum. However, the market outcome cannot be aligned with the social welfare optimum, no matter whether platforms compete in license fees or content quantities.

The remainder of the paper is organized as follows. Section 2 presents the theoretical model. Section 3 analyzes platforms' competition mode decisions and the welfare implications. Section 4 concludes and provides intuitions about platforms' competition mode decisions under compatibility and quantity competition in the hardware-user market.

2. The Model

Following Armstrong (2006) and Rasch and Wenzel (2014), we consider a two-sided market with horizontally differentiated incompatible platforms that interconnect agents of two sides: hardware users and content developers in a competitive bottleneck setup with single-homing users and multi-homing content developers. Hardware users gain more utility from a platform with more content, and content developers earn more profits from a platform with more hardware users, implying network externalities among two-sided agents.

Platforms produce hardware devices, whereas independent developers support the content. An independent developer who provides content for platform i ($i = 1, 2$) earns the following profit.

$$\pi_i^c = \phi s_i - l_i - f. \tag{1}$$

Here, ϕ is per-user profit, s_i and l_i are the number of hardware users and license fee of platform i, respectively, and f is the investment cost for offering content which is uniformly distributed on the unit interval, [0, 1]. We assume developers can provide content for both platforms (multihoming) if it is profitable.

From the content developer's profit function stated as (1), the amount of supporting content for platform i can be expressed as follows.

$$n_i = \phi s_i - l_i. \tag{2}$$

Consumers are uniformly distributed on the interval [0, 1] with density 1. Platforms 1 and 2 reside at points 0 and 1, respectively. Let t denote consumers' location, which represents their subjective preferences for platforms. Specifically, consumers' utility function is given by the following expression.

$$u(t)=\begin{cases} v+\theta n_1-p_1-\tau t & \text{if he joins platform 1,} \\ v+\theta n_2-p_2-\tau(1-t) & \text{if he joins platform 2.} \end{cases} \tag{3}$$

Here, v is the standalone utility of the hardware device, which is assumed to be sufficiently large that the hardware-user market is fully covered, θ is per-content benefit to consumers, p_i is the price of platform i's hardware device, τ reflects platform differentiation. We assume platforms are sufficiently differentiated, i.e., $\tau > (\theta^2 + \phi^2 + 6\theta\phi) / 8$, which ensures the satisfaction of the second-order conditions.

We also assume that content developers and hardware users have rational (fulfilled) expectations about the network size.

The timing of the game is stated as follows. In the first stage, each platform chooses whether to compete in license fees (l_i, $i = 1, 2$) or content quantities (n_i). In the second stage, in addition to competing in hardware prices, each platform commits to a content quantity or a license fee according to its decision in the first stage. In the third stage, content developers and hardware users decide which platform to join. We use backward induction to characterize the subgame-perfect Nash equilibrium in the following analysis.

3. Equilibrium Analysis

From consumers' utility function, the consumer who is indifferent between joining platforms 1 and 2 can be derived as follows.

$$t=\frac{\tau+(p_2-p_1)+\theta(n_1-n_2)}{2\tau}. \tag{4}$$

Hence, given that platform i ($i = 1, 2$) sets the content quantity as n_i and the price of hardware device as p_i, the number of hardware users joining platform 1 under both platforms choosing content quantity as their competition modes which is a function of the hardware prices and the content quantities of both platforms is $s_1^{NN}(p_1, p_2, n_1, n_2) = [\tau + (p_2 - p_1) + \theta(n_1 - n_2)] / 2\tau$. Here, the superscript "*NN*" denotes that both platforms choose the content quantity as

their competition modes.

First, we analyze both platforms choosing to compete in content quantities. From (2) and (4), the content quantities of platforms 1 and 2 can be stated as follows.

$$n_1 = \phi \frac{\tau + (p_2 - p_1) + \theta(n_1 - n_2)}{2\tau} - l_1. \tag{5a}$$

$$n_2 = \phi \left[1 - \frac{\tau + (p_2 - p_1) + \theta(n_1 - n_2)}{2\tau} \right] - l_2. \tag{5b}$$

From (2), given that platform i ($i = 1, 2$) sets a quantity of content, n_i in the second stage, platforms 1′s and 2′s equilibrium license fees can be stated as follows.[1]

$$l_1(p_1, p_2, n_1, n_2) = \phi s_1^{NN}(p_1, p_2, n_1, n_2) - n_1. \tag{6a}$$

$$l_2(p_1, p_2, n_1, n_2) = \phi[1 - s_1^{NN}(p_1, p_2, n_1, n_2)] - n_2. \tag{6b}$$

$[\partial l_1(p_1, p_2, n_1, n_2)] / \partial n_1 = \phi[\partial s_1^{NN}(p_1, p_2, n_1, n_2)] / \partial n_1 - 1 = \theta\phi / 2\tau - 1 < 0$, implying that platform 1′s equilibrium license fee decreases in its committed content quantities. Platform 2′s equilibrium license fee similarly decreases in its committed content quantities. From the above demonstrations, platforms 1′s and 2′s profit functions can be written as follows respectively.

$$\pi_1(p_1, p_2, n_1, n_2) = p_1 s_1^{NN}(p_1, p_2, n_1, n_2) + l_1(p_1, p_2, n_1, n_2) n_1, \tag{7a}$$

$$\pi_2(p_1, p_2, n_1, n_2) = p_2(1 - s_1^{NN}(p_1, p_2, n_1, n_2)) + l_2(p_1, p_2, n_1, n_2) n_2. \tag{7b}$$

Solving the first-order conditions simultaneously yields the optimal

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1 Regarding the stability of the above hardware-device demaind functions, when $\tau > (\theta^2 + \phi^2 + 6\theta\phi) / 8$, $\partial / \partial n_1[\phi(\tau + (p_2 - p_1) + \theta(n_1 - n_2)) / 2\tau] = \theta\phi / 2\tau < 4\theta\phi / (\theta^2 + \phi^2 + 6\theta\phi) < 1$. The same result applies to platform 2′s hardware device demand function, implying that the satisfaction of the second-order conditions ensures the stability of the hardware device demand functions.

hardware price and content quantity as follows.[2]

$$p_1^*(N,N) = p_2^*(N,N) = \frac{4\tau - \phi^2 - \theta\phi}{4}, \tag{8a}$$

$$n_1^*(N,N) = n_2^*(N,N) = \frac{\theta + \phi}{4}. \tag{8b}$$

Inserting the above optimal decisions into (6a) yields the equilibrium license fee.

$$l_1^*(N,N) = l_2^*(N,N) = \frac{\phi - \theta}{4}. \tag{9}$$

Therefore, platforms' profits under content quantity competition are stated as follows.

$$\pi_1^*(N,N) = \pi_2^*(N,N) = \frac{-(\theta + \phi)^2 + 8\tau}{16} > 0. \tag{10}$$

Next, we analyze asymmetric competition. Without loss of generality, we consider that platform 1 competes in license fees, whereas platform 2 competes in content quantities.

From (5a) and (5b), given that platform 1 sets a license fee, l_1, and platform 2 sets a content quantity, n_2, platforms 1′s content quantity and platform 2′s license fee are given by the following expressions respectively.

$$n_1(p_1, p_2, l_1, n_2) = \frac{n_2\theta\phi + (2l_1 - \phi)\tau + (p_1 - p_2)\phi}{\theta\phi - 2\tau}. \tag{11a}$$

$$l_2(p_1, p_2, l_1, n_2) = \frac{[\phi^2 - (2n_2 + l_1)\phi]\theta + (2n_2 - \phi)\tau + (p_2 - p_1)\phi}{\theta\phi - 2\tau}. \tag{11b}$$

Inserting (11a) into (4) yields the number of hardware users joining platform

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2 The proof of satisfaction of second-order conditions is provided in Appendix I.

1under asymmetric competition as follows given that platform 1′s license fee is l_1, platform 2′s content quantity is n_2, and the hardware prices of platform i ($i = 1, 2$) is p_i.

$$s_1^{LN}(p_1, p_2, l_1, n_2) = \frac{n_2\theta + l_1\theta - \tau - p_2 + p_1}{\theta\phi - 2\tau}. \tag{12}$$

The superscript "LN" denotes that platform 1 chooses the license fee as its competition mode, and platform 2 chooses the content quantity as its one. Hence, platform 1′s and 2′s profit functions can be written as follows, respectively.

$$\pi_1(p_1, p_2, l_1, n_2) = p_1 s_1^{LN}(p_1, p_2, l_1, n_2) + l_1 n_1(p_1, p_2, l_1, n_2), \tag{13a}$$

$$\pi_2(p_1, p_2, l_1, n_2) = p_2(1 - s_1^{LN}(p_1, p_2, l_1, n_2)) + l_2(p_1, p_2, l_1, n_2)n_2. \tag{13b}$$

Solving the first-order conditions simultaneously derives the optimal hardware prices, platform 1′s license fee and platform 2′s content quantity as follows.[3]

$$p_1^*(L, N) = \frac{(4\tau - \theta\phi - \phi^2)(\theta^2 + \phi^2 + 4\theta\phi - 6\tau)}{4(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)}. \tag{14a}$$

$$p_2^*(L, N) = \frac{(4\tau - 3\theta\phi - \phi^2)(\theta^2 + \phi^2 + 2\theta\phi - 6\tau)}{4(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)}. \tag{14b}$$

$$l_1^*(L, N) = -\frac{(\theta - \phi)(\theta^2 + \phi^2 + 4\theta\phi - 6\tau)}{4(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)}. \tag{14c}$$

$$n_2^*(L, N) = \frac{(\theta + \phi)(\theta^2 + \phi^2 + 2\theta\phi - 6\tau)}{4(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)} > 0 \text{ if } \tau < \frac{\theta^2 + \phi^2 + 2\theta\phi}{6} \text{ or } \tau > \frac{\theta^2 + \phi^2 + 3\theta\phi}{6}. \tag{14d}$$

Therefore, platform 2′s licens fee can be derived as follows.

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3 The proof of satisfaction of second-order conditions is provided in Appendix II.

$$l_2^*(L,N) = -\frac{(\theta-\phi)(\theta^2+\phi^2+2\theta\phi-6\tau)}{4(\theta^2+\phi^2+3\theta\phi-6\tau)}. \tag{14e}$$

Inserting the above results into (12) yields the number of hardware users joining platform 1 under asymmetric competition.

$$s_1^*(L,N) = \frac{(\theta^2+\phi^2+4\theta\phi-6\tau)}{2(\theta^2+\phi^2+3\theta\phi-6\tau)} > 0 \; if \; \tau > \frac{\theta^2+\phi^2+4\theta\phi}{6} \; or \; \tau < \frac{\theta^2+\phi^2+3\theta\phi}{6}. \tag{15}$$

From (15),

$$s_1^*(L,N) - \frac{1}{2} = \frac{\theta\phi}{2(\theta^2+\phi^2+3\theta\phi-6\tau)} \begin{cases} > 0 & if \; \tau < \dfrac{\theta^2+\phi^2+3\theta\phi}{6} \\ < 0 & if \; \tau < \dfrac{\theta^2+\phi^2+3\theta\phi}{6} \end{cases}. \tag{16a}$$

$$s_2^*(L,N) = 1 - s_1^*(L,N) = \frac{(\theta^2+\phi^2+2\theta\phi-6\tau)}{2(\theta^2+\phi^2+3\theta\phi-6\tau)} > 0 \; if \; and \; only \; if \; n_2^*(L,N) > 0. \tag{16b}$$

We compare the prices of hardware devices in a market with asymmetric competition.

$$p_1^*(L,N) = p_2^*(L,N) = \frac{\theta\phi(\theta^2+\theta\phi-2\tau)}{2(\theta^2+\phi^2+3\theta\phi-6\tau)}. \tag{17}$$

Inserting the above derivations into (11a) derives platform 1′s content quantity as follows.

$$n_1^*(L,N) = \frac{(\theta+\phi)(\theta^2+\phi^2+4\theta\phi-6\tau)}{4(\theta^2+\phi^2+3\theta\phi-6\tau)} > 0 \; if \; and \; only \; if \; s_1^*(L,N) > 0. \tag{18}$$

From (16b) and (18), $n_2^*(L,N) > 0$ and $s_1^*(L,N) > 0$ ensure that the content quantities and the numbers of hardware users of both platforms are positive

under asymmetric competition. Therefore, considering the satisfaction of the second-order conditions, the number of hardware users, and positive content quantities under asymmetric competition, our analysis is confined to the following two situations.

(1) Platforms are substantially differentiated, i.e., $\tau > (\theta^2 + \phi^2 + 4\theta\phi) / 6$.

(2) The difference between per-user benefit and per-content benefit is sufficiently large and platforms are weakly differentiated and, i.e., $(\theta - \phi)^2 > 8\theta\phi$ and $(\theta^2 + \phi^2 + 6\theta\phi) / 8 < \tau < (\theta^2 + \phi^2 + 2\theta\phi) / 6$.[4]

From (14a) and (14b), in a market with asymmetric competition, whether platforms subsidize or charge hardware users depends on the extent of differentiation between platforms. If the extent of differentiation between platforms is very low, i.e., $\tau < (\theta\phi + \phi^2) / 4$, platforms compete for hardware users aggressively by offering a subsidy. If the extent of differentiation between platforms is sufficiently large, i.e., $\tau > (3\theta\phi + \phi^2) / 4$, platforms tend to act mildly in competing for hardware users, and charge hardware users. If the extent of differentiation between platforms is moderate, i.e., $(\theta\phi + \phi^2) / 4 < \tau < (3\theta\phi + \phi^2) / 4$, the platform that competes in license fees charges hardware users. In contrast, the one that competes in content quantities subsidizes hardware users.

From (14d) and (18), comparison of content quantities under asymmetric competition is given by

$$n_1^*(L,N) - n_2^*(L,N) = \frac{\theta\phi(\theta+\phi)}{2(\theta^2+\phi^2+3\theta\phi-6\tau)} \begin{cases} > 0 & if\ \tau < \dfrac{\theta^2+\phi^2+3\theta\phi}{6} \\ < 0 & if\ \tau < \dfrac{\theta^2+\phi^2+3\theta\phi}{6} \end{cases}. \quad (19)$$

From (16a) and (19), $n_1^*(L,N) > n_2^*(L,N)$ if and only if $s_1^*(L, N) > 1 / 2$. This means that in a market with asymmetric competition, which platform gains a larger market share in the hardware-user market is solely determined by the

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4 $(\theta - \phi)^2 > 8\theta\phi$ ensures $(\theta^2 + \phi^2 + 2\theta\phi) / 6 > (\theta^2 + \phi^2 + 6\theta\phi) / 8$.

content quantities. If the difference between per-user profit and per-content benefit is substantial, and platform differentiation is weak, i.e., $(\theta-\phi)^2 > 8\theta\phi$ and $(\theta^2+\phi^2+6\theta\phi)/8 < \tau < (\theta^2+\phi^2+2\theta\phi)/6$, the platform that competes in license fees attracts more content developers and gains a larger hardware-user market share, i.e., $n_1^*(L,N) > n_2^*(L,N)$ and $1/2 < s_1^*(L,N) < 1$.[5] It is worth noting that due to consumers' willingness to pay for the hardware device increasing in the amount of supporting content, comparisons of hardware prices are ambiguous.[6]

On the other hand, if platform differentiation is significant, i.e., $\tau > (\theta^2+\phi^2+4\theta\phi)/6$, the platform that competes in content quantities encourages more content provision and attracts more hardware users, i.e., $n_1^*(L,N) < n_2^*(L,N)$ and $0 < s_1^*(L,N) < 1/2$.[7] Comparisons of hardware prices are similarly ambiguous in this situation.

From the above derivations, platforms' profits under asymmetric competition are given by

$$\pi_1^*(L,N) = -\frac{(\theta^2+\phi^2+4\theta\phi-6\tau)^2(\theta^2+\phi^2+2\theta\phi-8\tau)}{16(\theta^2+\phi^2+3\theta\phi-6\tau)^2} > 0. \tag{20a}$$

$$\pi_2^*(L,N) = -\frac{(\theta^2+\phi^2+2\theta\phi-6\tau)^2(\theta^2+\phi^2+6\theta\phi-8\tau)}{16(\theta^2+\phi^2+3\theta\phi-6\tau)^2} > 0. \tag{20b}$$

Finally, if both platforms use a license fee strategy, as obtained in Rasch and Wenzel (2014), the price of hardware device, license fee, content quantity, and platforms' profits are stated as follows respectively.

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5 From (14d) and (18), if $\theta^2+\phi^2+2\theta\phi-6\tau > 0$, $n_1^*(L,N) > 0$ and $n_2^*(L,N) > 0$. Hence, from (15) and (16b), $s_1^*(L,N) > 0$ and $s_2^*(L,N) > 0$. Besides, from (20a) and (20b), $\pi_1^*(L,N) > 0$ and $\pi_2^*(L,N) > 0$.

6 From (17), if $\tau < \min[(\theta^2+\phi^2+3\theta\phi)/6, (\theta^2+\theta\phi)/2]$ or $\tau > \max[(\theta^2+\phi^2+3\theta\phi)/6, (\theta^2+\theta\phi)/2]$, then $p_1^*(L,N) > p_2^*(L,N)$. Conversely, if $(\theta^2+\theta\phi)/2 < \tau < (\theta^2+\phi^2+3\theta\phi)/6$ and $\phi > \sqrt{2}\theta$, then $p_1^*(L,N) < p_2^*(L,N)$. Similarly, if $(\theta^2+\phi^2+3\theta\phi)/6 < \tau < (\theta^2+\theta\phi)/2$ and $\phi < \sqrt{2}\theta$, then $p_1^*(L,N) < p_2^*(L,N)$.

7 From (14d) and (18), if $\theta^2+\phi^2+4\theta\phi-6\tau < 0$, $n_1^*(L,N) > 0$ and $n_2^*(L,N) > 0$. Hence, from (15) and (16b), $s_1^*(L,N) > 0$ and $s_2^*(L,N) > 0$. Besides, from (20a) and (20b), $\pi_1^*(L,N) > 0$ and $\pi_2^*(L,N) > 0$.

$$p_1^*(L,L) = p_2^*(L,L) = \frac{4\tau - \phi^2 - 3\theta\phi}{4}. \tag{21a}$$

$$l_1^*(L,L) = l_2^*(L,L) = \frac{\phi - \theta}{4}. \tag{21b}$$

$$n_1^*(L,L) = n_2^*(L,L) = \frac{\theta + \phi}{4}. \tag{21c}$$

$$\pi_1^*(L,L) = \pi_2^*(L,L) = \frac{8\tau - \theta^2 - \phi^2 - 6\theta\phi}{16} > 0. \tag{21d}$$

From the above derivations, we compare the equilibrium outcomes of two types of symmetric competition.

$$p_1^*(L,L) - p_1^*(N,N) = -\frac{\theta\phi}{2} < 0. \tag{22a}$$

$$n_1^*(L,L) = n_1^*(N,N). \tag{22b}$$

$$l_1^*(L,L) = l_1^*(N,N). \tag{22c}$$

$$\pi_1^*(L,L) - \pi_1^*(N,N) = -\frac{\theta\phi}{4} < 0. \tag{22d}$$

The above results indicate that license fee competition toughens hardware price competition and yields the same content quantity as content quantity competition. This leads to the following two results. First, platforms earn less profit under license fee competition than content quantity competition. Second, due to the lower price of the hardware device, license fee competition enhances consumers' surplus.

From the above analysis, platforms' decisions of competition mode can be reduced to the following normal form game.

Table I Platforms' Competition Mode Decisions.

	Content Quantity (N)	License Fee (L)
Content Quantity (N)	$\pi_1^*(N, N)$, $\pi_2^*(N, N)$	$\pi_1^*(N, L)$, $\pi_2^*(N, L)$
License Fee (L)	$\pi_1^*(L, N)$, $\pi_2^*(L, N)$	$\pi_1^*(L, L)$, $\pi_2^*(L, L)$

Proposition 1.
Given the coexistence of both platforms under asymmetric competition, i.e., $\tau > (\theta^2 + \phi^2 + 6\theta\phi) / 8$,

(1) If the difference between per-user profit and per-content benefit is substantial and platform differentiation is weak, i.e., $(\theta - \phi)^2 > 8\theta\phi$ *and* $(\theta^2 + \phi^2 + 6\theta\phi) / 8 < \tau < (\theta^2 + \phi^2 + 2\theta\phi) / 6$, *competing in license fees is a dominant strategy.*

(2) If platform differentiation is significant, i.e., $\tau > (\theta^2 + \phi^2 + 4\theta\phi) / 6$, *competing in content quantities is a dominant strategy.*

Proof. See Appendix III.

□

If platform differentiation is substantial, it implies that platforms need to set a sufficiently low license fee to encourage a content quantity that is large enough to attract hardware users, severely reducing their profits when they compete in license fees. In other words, the license fee is a relatively inefficient strategic tool in attracting hardware users in terms of platforms' profits. Platforms, expecting this, choose to compete in content quantities. Conversely, if platform differentiation is weak, implying that platforms tend to commit to a larger content quantity to attract hardware users, which leads to a lower license fee when competing in content quantities. In other words, content quantity is a strategic tool that induces platforms to act aggressively in content provision competition. Platforms, expecting this, choose to compete in license fees. As obtained above, the equilibrium content quantity and license fee are independent of platforms' competition mode decisions, which only affect the hardware price and platforms' profits.

Singh and Vives (1984) show that if competing goods are substitutes (complements), competing in quantities (prices) is a dominant strategy that has the property of a strategic substitute (complement) which increases firms' profits. From (7a) and (7b), if platforms compete in content quantities, the slope of platform 1's reaction function can be derived as follows.

$$\frac{\mathrm{d}n_2}{\mathrm{d}n_1} = \frac{2(\theta\phi - 2\tau)}{\theta\phi} < 0. \tag{23}$$

If platforms compete in license fees, the slope of platform 1′s reaction function is given by

$$\frac{\mathrm{d}l_2}{\mathrm{d}l_1} = \frac{2(2\tau - \theta\phi)}{\theta\phi} > 0. \tag{24}$$

As in the literature, license fees (content quantities) exhibit strategic complements (substitutes) in a two-sided market. From this viewpoint, contrary to the standard result, in a two-sided market, substitutive platforms could choose a license fee strategy that has a property of strategic complements in equilibrium.

From the market outcome derived above, we discuss the welfare implications of the competition mode. Consumers' surplus under content quantity competition can be derived as follows.

$$cs(N,N) = 2\int_0^{\frac{1}{2}} [v + \theta n_1^*(N,N) - p_1^*(N,N) - \tau t]dt = v + \frac{(\theta+\phi)^2 - 5\tau}{4}. \tag{25a}$$

If platforms compete in license fees, as obtained in Maruyama and Zennyo (2015), consumers' surplus is stated as follows.

$$cs(L,L) = 2\int_0^{\frac{1}{2}} [v + \theta n_1^*(L,L) - p_1^*(L,L) - \tau t]dt = v + \frac{\theta^2 + 4\theta\phi + \phi^2 - 5\tau}{4}. \tag{25b}$$

Third, the following expression states consumers' surplus under asymmetric competition.

$$\begin{aligned} cs(L,N) &= \int_0^{s_1^*(L,N)} [v + \theta n_1^*(L,N) - p_1^*(L,N) - \tau t]dt + \int_{s_1^*(L,N)}^1 [v + \theta n_2^*(L,N) \\ &\quad - p_2^*(L,N) - \tau(1-t)]dt \\ &= v + \frac{\Gamma_1(\theta,\phi,\tau)}{4(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)^2}. \end{aligned} \tag{25c}$$

Here,

$$\Gamma_1(\theta,\phi,\tau) = (\theta+\phi)^2(\theta^2+3\theta\phi+\phi^2)(\theta^2+4\theta\phi+\phi^2) - \tau(17\theta^4+102\phi\theta^3 + 180\phi^2\theta^2+102\phi^3\theta+17\phi^4) + 96\tau^2(\theta^2+3\theta\phi+\phi^2) - 180\tau^3.$$

Proposition 2.

(1) License fee competition optimizes consumers' surplus under the following two situations.

(i) The difference between per-user profit and per-content benefit is substantial, and platform differentiation is sufficiently weak, i.e., $(\theta-\phi)^2 > 8\theta\phi$ *and* $(\theta^2+\phi^2+6\theta\phi)/8 < \tau < \Sigma_1(\theta,\phi)$.

(ii) Platform differentiation is sufficiently large, i.e., $\tau > \Sigma_2(\theta,\phi)$.

(2) Asymmetric competition optimizes consumers' surplus under the following two situations.

(i) The difference between per-user profit and per-content benefit is substantial, and platform differentiation is sufficiently large, i.e., $(\theta-\phi)^2 > 8\theta\phi$ *and* $\Sigma_1(\theta,\phi) < \tau < (\theta^2+\phi^2+2\theta\phi)/6$.

(ii) Platform differentiation is relatively small, i.e. $(\theta^2+\phi^2+4\theta\phi)/6 < \tau < \Sigma_2(\theta,\phi)$.

$\Sigma_1(\theta,\phi) = (12\theta^2+12\phi^2+43\theta\phi - \sqrt{\theta\phi(24\theta^2+121\theta\phi+24\phi^2)})/72$, $\Sigma_2(\theta,\phi) = (12\theta^2+12\phi^2+43\theta\phi + \sqrt{\theta\phi(24\theta^2+121\theta\phi+24\phi^2)})/72$.

Proof. See Appendix IV.

□

First, due to content quantity competition relaxing hardware price competition and yielding the same content quantity as license fee competition, in terms of consumers' surplus, license fee competition dominates content quantity competition. Second, if platforms are weakly (significantly) differentiated, the platform that commits to a license fee (a content quantity) owns more content under asymmetric competition than

symmetric competition.[8] Hence, asymmetric competition could optimize consumers' surplus. Third, the critical value of license fee competition optimizing consumers' surplus is lower than the upper bound of license fee competing being a market outcome, i.e. $\Sigma_1(\theta, \phi, \tau) < (\theta^2 + \phi^2 + 2\theta\phi) / 6$. From (4a), $[dp_1^*(L, L)] / d\tau = \tau > 0$. Hence, license fee competition as a market outcome is aligned with the consumers' surplus optimum when the extent of differentiation between platforms is sufficiently small in which platforms tend to act more aggressively in hardware price competition. The above results converse with those obtained in the existing literature that symmetric price competition is optimal for consumers' surplus, and the market outcome cannot be aligned with the consumers' surplus optimum.

Finally, social welfare, defined as the sum of consumers' and producers' surplus under three possible scenarios, can be derived as follows.

$$sw(N,N) = cs(N,N) + 2\pi_1^*(N,N) + 2\int_0^{n_1^*(N,N)} \left[\frac{\phi}{2} - l_1^*(N,N) - f\right] df$$
$$= v + \frac{3(\theta+\phi)^2 - 4\tau}{16}. \tag{26a}$$

$$sw(L,L) = cs(L,L) + 2\pi_1^*(L,L) + 2\int_0^{n_1^*(L,L)} \left[\frac{\phi}{2} - l_1^*(L,L) - f\right] df$$
$$= v + \frac{3(\theta+\phi)^2 - 4\tau}{16}. \tag{26b}$$

$$sw(L,N) = cs(L,N) + \sum_{i=1}^{2} \left\{\pi_i^*(L,N) + \int_0^{n_i^*(L,N)} [\phi s_i^*(L,N) - l_i^*(L,N) - f]df\right\}$$
$$= v + \frac{\Gamma_2(\theta,\phi,\tau)}{16(\theta^2+\phi^2+3\theta\phi-6\tau)^2}. \tag{26c}$$

Here, $\Gamma_2(\theta,\phi,\tau) = [3(\theta+\phi)^2 - 4\tau][(\theta^4 + 6\theta^3\phi + 12\theta^2\phi^2 + 6\theta\phi^3 + \phi^4) - 12(\theta^2 + \phi^2 + 3\theta\phi)\tau + 36\tau^2]$.

---

8 From (14d), (18), and (21c),
$n_1^*(L, N) - n_1^*(L, L) = [\theta\phi(\theta + \phi)] / [4(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)]$, $n_2^*(L, N) - n_2^*(L, L) = [\theta\phi(\theta + \phi)] / [4(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)]$.
Hence, if $\tau < (\theta^2 + \phi^2 + 3\theta\phi) / 6$, $n_1^*(L, N) > n_1^*(L, L)$; conversely, if $\tau > (\theta^2 + \phi^2 + 3\theta\phi) / 6$, $n_2^*(L, N) < n_2^*(L, L)$.

Proposition 3.
If the extent of differentiation between platforms is relatively small, i.e., $(\theta^2 + \phi^2 + 6\theta\phi) / 8 < \tau < (3(\theta + \phi)^2) / 4$*, then asymmetric competition is optimal for social welfare; conversely, if the extent of differentiation between platforms is sufficiently large, i.e.,* $\tau > (3(\theta + \phi)^2) / 4$*, then symmetric competition is optimal for social welfare.*

Proof. Appendix V.

□

The critical value of license fee competition optimizing social welfare is higher than the upper bound of license fee competition being a market outcome, i.e. $(3(\theta + \phi)^2) / 4 > (\theta^2 + \phi^2 + 2\theta\phi) / 6$. This suggests that even though license fee competition is aligned with the consumers' surplus when the extent of differentiation between platforms is sufficiently small, compared with the asymmetric competition, it reduces the industry profits which offsets the gains in consumers' surplus. Hence, license fee competition as a market outcome cannot be aligned with the social welfare optimum. On the other hand, asymmetric competition cannot be an equilibrium outcome despite possibly being the social welfare optimum. The above results imply a misalignment between the market outcome and social welfare optimum, regardless of whether platforms compete in license fees or content quantities.

4. Conclusion and Discussions

This paper considers a two-sided market with a traditional competitive bottleneck to endogenize incompatible platforms' decisions of competition mode and analyze the welfare implications. Our research contributes to the relevant literature by presenting the following results. First, license fee competition can be an equilibrium outcome in a two-sided market even with incompatible platforms. Second, license fee competition as a market outcome could be optimal for consumers' surplus due to the lower price of the hardware device. In other words, the market outcome with license fee competition could be aligned with the consumers' surplus optimum.

Nevertheless, regardless of license fee or content quantity competition, the market outcome cannot be aligned with the social welfare optimum. Third, asymmetric competition could be optimal for consumers' surplus.

Finally, it is worthwhile to discuss the platforms' decisions of competition mode under the relaxation of the assumptions in this paper. The first one is compatibility between platforms. As Rasch and Wenzel (2014) indicated, license fees are competed to zero in a market with compatible platforms. From this viewpoint, we expect that compatible platforms have an incentive to compete in content quantities to prevent cut-throat license fee competition. The second one regards price competition in the hardware-user market. It is well believed that quantity competition leads to a shrinkage in the industry output level, which induces platforms to act more aggressively in license fee competition. Hence, platforms are expected to compete in content quantities when they compete in quantities in the hardware-user market.

Appendix I: The Proof of Satisfaction of Second-Order Conditions under (*N*, *N*)

From (7a),

$$\frac{\partial^2 \pi_1(p_1(N,N), p_2(N,N), n_1(N,N), n_2(L,N))}{\partial p_1^2} = -\frac{1}{\tau} < 0.$$

$$\frac{\partial^2 \pi_1(p_1(N,\boldsymbol{N}), p_2(N,N), n_1(N,N), n_2(L,N))}{\partial n_1^2} = \frac{\theta\phi - 2\tau}{\tau} < 0.$$

$$\frac{\partial^2 \pi_1(p_1(N,N), p_2(\boldsymbol{N},N), n_1(N,N), n_2(N,N))}{\partial p_1^2} \frac{\partial^2 \pi_2(p_1(N,N), p_2(N,N), n_1(N,N), n_2(\boldsymbol{N},N))}{\partial n_2^2} -$$

$$\frac{\partial^2 \pi_2(p_1(N,N), p_2(N,N), n_1(N,N), n_2(N,N))}{\partial p_1 \partial n_1} \frac{\partial^2 \pi_1(p_1(N,N), p_2(N,N), n_1(N,N), n_2(N,N))}{\partial n_1 \partial p_1}$$

$$= -\frac{(\theta+\phi)^2 - 8\tau}{4\tau^2} > 0.$$

Hence, the second-order conditions are satisfied if τ is sufficiently large, i.e., $\tau > (\theta^2 + \phi^2 + 6\theta\phi) / 8$.

This completes the proof.

□

Appendix II: The Proof of Satisfaction of Second-Order Conditions under (*L*, *N*)

From (13a),

$$\frac{\partial^2 \pi_1(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial p_1^2} = \frac{2}{\theta\phi - 2\tau} < 0.$$

$$\frac{\partial^2 \pi_1(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial n_1^2} = \frac{4\tau}{\theta\phi - 2\tau} < 0.$$

$$\frac{\partial^2 \pi_1(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial p_1^2} \frac{\partial^2 \pi_1(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial l_1^2} -$$

$$\frac{\partial^2 \pi_1(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial p_1 \partial l_1} \frac{\partial^2 \pi_1(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial l_1 \partial p_1}$$

$$= -\frac{(\theta+\phi)^2 - 8\tau}{(\theta\phi - 2\tau)^2} > 0.$$

From (13b),

$$\frac{\partial^2 \pi_2(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial p_2^2} = \frac{2}{\theta\phi - 2\tau} < 0.$$

$$\frac{\partial^2 \pi_2(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial n_2^2} = -\frac{4(\theta\phi - \tau)}{\theta\phi - 2\tau} < 0.$$

$$\frac{\partial^2 \pi_2(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial p_2^2} \frac{\partial^2 \pi_2(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial n_2^2} -$$

$$\frac{\partial^2 \pi_2(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial p_2 \partial n_2} \frac{\partial^2 \pi_2(p_1(L,N), p_2(L,N), l_1(L,N), n_2(L,N))}{\partial n_2 \partial p_2}$$

$$= -\frac{\theta^2 + \phi^2 + 6\theta\phi - 8\tau}{(\theta\phi - 2\tau)^2} > 0.$$

Hence, the second-order conditions are satisfied if τ is sufficiently large, i.e., $\tau > (\theta^2 + \phi^2 + 6\theta\phi) / 8$.

This completes the proof.

□

Appendix III: Proof of Proposition 1

From (10) and (19a),

$$\pi_1^*(L,N) - \pi_1^*(N,N) = -\frac{\theta\phi(\theta^2 + \phi^2 + 2\theta\phi - 8\tau)(2\theta^2 + 2\phi^2 + 7\theta\phi - 12\tau)}{16(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)^2}.$$

From (19b) and (20d),

$$\pi_1^*(N,L) - \pi_1^*(L,L) = \pi_2^*(L,N) - \pi_2^*(L,L)$$

$$= \frac{\theta\phi(\theta^2 + \phi^2 + 6\theta\phi - 8\tau)(2\theta^2 + 2\phi^2 + 5\theta\phi - 12\tau)}{16(\theta^2 + \phi^2 + 3\theta\phi - 6\tau)^2}.$$

There are two possibilities.

(i) If $(\theta - \phi)^2 > 8\theta\phi$ and $\frac{\theta^2 + \phi^2 + 6\theta\phi}{8} < \tau < \frac{\theta^2 + \phi^2 + 2\theta\phi}{6}$,

$\pi_1^*(L,N) - \pi_1^*(N,N) > 0$ and $\pi_2^*(L,N) - \pi_2^*(L,L) < 0$.

This implies that competing in license fees is a dominant strategy.

(ii) If $\tau > (\theta^2 + \phi^2 + 4\theta\phi) / 6$, then $\pi_1^*(L,N) - \pi_1^*(N,N) < 0$ and $\pi_2^*(L,N) - \pi_2^*(L,L) > 0$.

This implies that competing in content quantities is a dominant strategy.

This completes the proof.

□

Appendix IV: Proof of Proposition 2

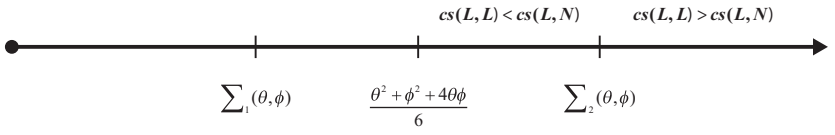
From (25a) and (25b), $cs(L, L) - cs(N, N) = \theta\phi / 2 > 0$.

From (25b) and (25c),

$$cs(L,L) - cs(L,N) = \frac{\theta\phi[(\theta^2+\phi^2+3\theta\phi)(\theta^2+\phi^2+4\theta\phi) - \tau(12\theta^2+12\phi^2+43\theta\phi)+36\tau^2]}{4(\theta^2+\phi^2+3\theta\phi-6\tau)^2} \begin{cases} >0 & if\ \tau < \Sigma_1(\theta,\phi) \text{ or } \tau > \Sigma_2(\theta,\phi) \\ <0 & if\ \Sigma_1(\theta,\phi) < \tau < \Sigma_2(\theta,\phi) \end{cases}.$$

Here, $\Sigma_1(\theta, \phi) = [12\theta^2 + 12\phi^2 + 43\theta\phi - \sqrt{\theta\phi(24\theta^2 + 121\theta\phi + 24\phi^2)}] / 6$,
$\Sigma_2(\theta, \phi) = (12\theta^2 + 12\phi^2 + 43\theta\phi + \sqrt{\theta\phi(24\theta^2 + 121\theta\phi + 24\phi^2)}) / 6$.
$\Sigma_2(\theta, \phi) > \Sigma_1(\theta, \phi) > (\theta^2 + \phi^2 + 4\theta\phi) / 6$.
If $(\theta - \phi)^2 > 8\theta\phi$, then $(\theta^2 + \phi^2 + 6\theta\phi) / 8 < \Sigma_1(\theta, \phi) < (\theta^2 + \phi^2 + 2\theta\phi) / 6 < \Sigma_2(\theta, \phi)$.

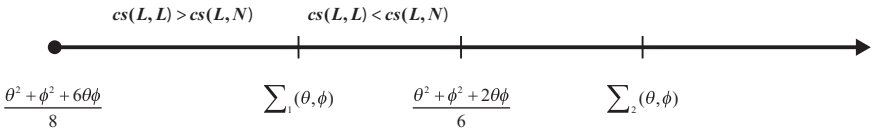
(1) Consider $\tau > (\theta^2 + \phi^2 + 4\theta\phi) / 6$ under which competing in content quantities is a dominant strategy, and $\Sigma_1(\theta, \phi) < (\theta^2 + \phi^2 + 4\theta\phi) / 6 < \Sigma_2(\theta, \phi)$.



(1.1) If $(\theta^2 + \phi^2 + 4\theta\phi) / 6 < \tau < \Sigma_2(\theta, \phi)$, then asymmetric competition is optimal for consumers' surplus.

(1.2) If $\tau > \Sigma_2(\theta,\phi)$, then license fee competition is optimal for consumers' surplus.

(2) Consider $(\theta-\phi)^2 > 8\theta\phi$ and $(\theta^2+\phi^2+6\theta\phi)/8 < \tau < (\theta^2+\phi^2+2\theta\phi)/6$ under which competeing in license fees is a dominant strategy and $(\theta^2+\phi^2+6\theta\phi)/8 < \Sigma_1(\theta,\phi) < (\theta^2+\phi^2+2\theta\phi)/6 < \Sigma_2(\theta,\phi)$.



(2.1) If $(\theta^2+\phi^2+6\theta\phi)/8 < \tau < \Sigma_1(\theta,\phi)$, then license fee competition is optimal for consumers' surplus.

(2.2) If $\Sigma_1(\theta,\phi) < \tau < (\theta^2+\phi^2+2\theta\phi)/6$, then asymmetric competition is optimal for consumers' surplus.

This completes the proof.

□

Appendix V: Proof of [Proposition 3]

From (26a) and (26c),

$$sw(L,N)-sw(L,L)=\frac{\theta^2\phi^2[3(\theta+\phi)^2-4\tau]}{16(\theta^2+\phi^2+3\theta\phi-6\tau)^2}\begin{cases}>0 & if\ \tau<\dfrac{3(\theta+\phi)^2}{4}\\ <0 & if\ \tau>\dfrac{3(\theta+\phi)^2}{4}\end{cases}.$$

It is worth noting $3(\theta+\phi)^2/4-(\theta^2+\phi^2+6\theta\phi)/8=(5\theta^2+5\phi^2+6\theta\phi)/8>0$.

This completes the proof.

□

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雙邊平台競爭策略工具探討

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摘　要

本文探討雙邊平台之競爭策略工具。本研究與既有文獻之差異在於發現不相容雙邊平台進行授權費競爭可能為一均衡結果。此外，市場均衡結果可能為消費者福利最適，但必不為社會福利最適。

關鍵詞：競爭策略、雙邊平台、授權費、囚犯兩難、雙邊市場
JEL分類代號：D45, L11, L13

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