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(Citation)
International Journal of Industrial Organization,70:102617

(Issue Date)
2020-05

(Resource Type)
journal article

(Version)
Accepted Manuscript

Platform Most-Favored-Customer Clauses and Investment Incentives*

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This version: March 31, 2020

Abstract

This paper examines the effects of platform most-favored-customer (PMFC) clauses on incentives for platforms to invest in demand-enhancing investments that might involve spillover effects. In a bilateral duopoly model incorporating competition between sellers and between platforms, we show that the industry-wide adoption of PMFC clauses raises the platforms' investment level and the resulting retail price if the substitution between platforms is large compared to the substitution between sellers. Additionally, we assess the respective effects of PMFC clauses on the demand, profit of sellers, profit of platforms, consumer surplus, and social welfare. The results suggest a possible conflict between platforms and competition authorities.

Keywords: *most-favored-customer clause, price parity clause, platform investment, spillover effect, vertical relation*

JEL Classification: L42, K21, L13, L11, L14

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*The authors are truly indebted to Julian Wright (co-editor) and two anonymous referees for their invaluable comments and suggestions. We would like to thank Tatsuhiko Nariu, Carlo Reggiani, and seminar participants at Nanzan University, participants at the 2018 EARIE annual conference in Athens, and those at the 2018 APIOC annual conference at Melbourne for very helpful comments. The work was partially supported by JSPS KAKENHI Grant Numbers 24330080, 26285098, 16H03670, 16K17126, 17H00959, and 19H01474.

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1 Introduction

Online platforms are usually serving their users in an effort to provide a better buying environment. For instance, online marketplaces (e.g., Amazon, eBay, iBookstore, and Kindle Store) and online travel agents (e.g., HRS, Booking.com, and Expedia) provide valuable services ranging from user-friendly search interface to on-target recommendation system. While investing in such demand-enhancing facilities, they earn commissions from the sale of goods.[1] Consequently, they strive to prevent sellers from charging lower prices on rival platforms. To do so, they typically impose a platform most-favored-customer (PMFC) clause in their contracts with sellers, which is a general promise by a seller to treat the platform as favorably as the seller's most-favored-customer related to price, availability, and the other terms of a transaction.[2] When related to prices, a PMFC clause is an agreement between a seller and a platform stipulating that the seller does not charge a higher price on the platform than it does on another.[3]

Recently, PMFC clauses have been the subject of several antitrust investigations.[4] For the PMFC clauses used by Amazon, Amazon offered commitments not to enforce the MFC clauses for e-book publishers in Europe. The European Commission announced its decision to make the commitments offered by Amazon legally binding on 4 May 2017. Also in Japan,

[1]This business model is called an agency model in which sellers set final retail prices, and sales revenue through a platform are split between sellers and a platform subject to a fixed revenue-sharing rule. By contrast, in a traditional brick-and-mortar business, the wholesale model is commonly used, where the retailer purchases goods from the seller at a given wholesale price and subsequently sets its own retail price and deals with final consumers.

[2]The PMFC clause, also designated as an across-platform parity agreement (APPA), is sometimes called rate parity in the hotel industry. Regarding parity clauses and competition law in the case of OTAs, one might refer to examples explained in the literature (e.g., Colangelo, 2017). In more recent studies of the parity clause, see Hunold et al. (2018) for empirical investigations of best price clauses imposed by OTAs.

[3]It is worth noting that a PMFC clause differs greatly from a traditional most-favored-*nation* (MFN) clause. A traditional MFN clause is an agreement between a seller and a buyer in which a seller commits to the buyer not to sell to other buyers at a lower price. In contrast, a PMFC clause is an agreement between a seller and a platform about prices charged by the seller to the buyer who is not a party to the agreement (Boik and Corts, 2016). Furthermore, they are distinct in the respect that the traditional MFN clause links prices between different customers of the same seller, but a PMFC links prices for the same customer buying from different platforms (Edelman and Wright, 2015; Akman, 2016; Akman and Sokol, 2017).

[4]Akman (2016) and Fletcher and Hviid (2016) provide overviews of the related issues and literature for PMFC clauses.

as a result of the review on the proposal by Amazon Japan G.K. not to enforce MFC clauses, the Japan Fair Trade Commission decided to close the antitrust investigation of this case on 1 June 2017.

There is an ongoing debate about how to assess the PMFC clause. There have been several arguments about its potential to harm competition. LEAR (2012) identified some possible *anti-competitive* effects of such across-platforms parity agreements (PMFC clauses): foreclosing entry of other platforms; softening competition among platforms; facilitating collusion among platforms; and signaling information about platforms' costs.[5] Parallel investigations by competition authorities revealed anti-competitive effects stemming from PMFC clauses. By contrast, LEAR (2012) also described the possible *pro-competitive* effects of the PMFC clauses to generate efficiencies that might protect investments by platform owners. Although PMFC clauses have received attention in the economics literature, analysis of their competitive effects remains limited in theoretical models. The aim of this paper is to build a model to elucidate effects of PMFC clauses on the incentives for platforms to invest in demand-enhancing investments.

This paper studies a bilateral duopoly model that incorporates both competition between two platforms and competition between two sellers. Sellers make their differentiated goods available on both platforms. Platforms adopt an agency model for their dealings with sellers, where retail pricing is delegated to sellers and the revenues earned from selling each good is allocated between the parties according to a fixed sharing rule. Instead of retail pricing, platforms invest in demand-enhancing investments that might involve spillover effects. Our central research question is whether the industry-wide adoption of PMFC clauses encourages competing platforms to invest more. To this end, we compare the case in which both platforms use PMFC clauses with the case in which neither platform uses a PMFC clause.

Our main result is that industry-wide PMFC clauses engender greater investment if platform competition (i.e. intrabrand competition) is fiercer than seller competition (i.e.

[5]LEAR (2012) is a report for practitioners, as extrapolated from the literature on vertical constraints on possible effects of MFN clauses.

interbrand competition). We emphasize that the mechanism underlying this result is not a simple story such that the clauses resolve an underinvestment problem stemming from externalities of investments (i.e., spillover effects) that increase the demand for goods sold on the rival platform. In the present paper, by contrast, whether industry-wide PMFC clauses increase investment incentives, or not, depends on the degree of competition in the vertically related market, not on the extent of spillover effects of investments.

The intuition underlying the main result can be explained as shown below. The presence of PMFC clauses has two effects. First, investments by a platform increase consumers' willingness to pay, which induces sellers to charge a higher price for goods sold on that platform. Without PMFC clauses, however, sellers need not raise their prices for the rival platform as well. This outcome is expected to make the platforms reluctant to invest. By contrast, the PMFC clause can resolve this underinvestment problem by requiring that sellers raise their prices for the rival platform by the same amount. The fiercer platform competition becomes, the greater this positive effect becomes. Second, the presence of PMFC clauses mitigates price competition between sellers. Less competition shrinks the total quantities demanded, which discourages the platforms from additional investment. The fiercer the seller competition becomes, the stronger this negative effect becomes. Overall, when platform competition is fierce compared to seller competition, the positive effect dominates the negative one, implying that the industry-wide adoption of PMFC clauses can heighten the platforms' investment incentives.

Additionally, we show that whenever the presence of industry-wide PMFC clauses increases the platform investment, it engenders higher prices but expands the resulting demand eventually, thereby yielding greater seller profits and consumer surplus. In other words, sellers and consumers share the same preference for the clauses. By contrast, the platforms would not necessarily do so. They can earn greater profits with PMFC clauses, which can nevertheless be harmful to sellers and consumers. Our results support an earlier theory that PMFC clauses can be harmful, but with important caveats.

2 Literature

The competitive effects of PMFC clauses have been studied only recently using theoretical models. Existing papers fundamentally address consideration of PMFC clause effects through pricing decisions. Boik and Corts (2016) examine competition between two platforms that carry a common supplier's product. They show that PMFC clauses, when adopted by both platforms, engender higher platform fees and retail prices than those obtained when no platform has a PMFC clause. Johnson (2017) incorporates competition between sellers into the model along with competition between platforms. He demonstrates that PMFC clauses raise retail prices and harm consumers. Foros et al. (2017) consider that platforms simultaneously and independently choose between agency and wholesale models. Moreover, if a platform chooses the agency model, then it additionally determines whether to have an MFN clause or not. They demonstrate that MFN clauses do not directly engender higher retail prices, but they can facilitate the adoption of an agency model, which leads to high retail prices.

The papers described above do not consider that sellers can sell directly to consumers. Other studies do allow for a direct channel. Gans (2012) assesses the pricing of mobile applications when a single application provider (seller) can reach consumers either directly or through a single monopoly platform. He demonstrates that a PMFC clause might allow the platform to charge a higher access price. Wang and Wright (2020) develop a consumer search model to investigate showrooming effects, by which consumers search on a platform but complete their purchase at a lower price through a direct channel. They demonstrate that imposing a price parity clause enables the platform to increase its commission fee, leading to a higher price and lower (total) consumer surplus.

The prevailing theories indicate that PMFC clauses are harmful because they increase retail prices through elimination of intrabrand competition and raising of their commissions. Johansen and Vergé (2017) instead show that one should be more careful when evaluating the welfare effects of PMFC clauses. They present a model in which two differentiated platforms compete by offering commissions to multiple sellers, where each seller has an outside option to delist from a platform and sell directly to consumers through its own direct channel. Thus, if the platforms adopt PMFC clauses, sellers' participation constraints on platforms become restrictive, which prevents them from increasing commissions too much or which might even force them to reduce their commissions. They show that PMFC clauses do not always engender higher commissions and retail prices. Additionally, PMFC clauses might simultaneously benefit all the platforms, sellers, and consumers.

All of these models consider the effect of PMFC clauses through pricing decisions. As might be readily apparent in the actual market, platforms make various decisions that affect demand (e.g., investment in providing presale services and promotions).[6] There has been an informal discussion of the pro-competitive effects of PMFC clauses in the policy-oriented literature with regard to the efficiency benefits of protecting investments by platform owners (LEAR, 2012). However, the literature on formal theoretical analysis is quite limited. Edelman and Wright (2015) allow for platform investments that increase consumers' willingness to pay for joining the platform. The investments differ from those investments considered herein, which increase potential demands for products sold by the platform. They show that platforms have an excessive incentive to induce consumers to use their intermediating services rather than direct channels. As a result, under price coherence (i.e., PMFC clauses), platforms overinvest in the provision of benefits to buyers, although higher fees are charged to sellers, which eventually engender higher prices and then worsen consumer surplus. Wang and Wright (2016) investigate the effects of free-riding and PMFC clauses on platform investment in the framework of consumer search, which differs from ours. They consider platform investments of three types: (i) platform investment in reducing consumers' search costs via the platform, (ii) platform investment in advertising to attract more consumers to use of the platform, and (iii) platform investment in the per-transaction convenience benefits con-

[6] Actually, Hagiu and Wright (2015) consider choices of some marketing activity that create spillovers across products. Their main concern is investigation of conditions under which the marketplace mode is preferred to the reseller mode. Consequently, they do not examine the effects of PMFC clauses on investment incentives.

sumers obtain from using the platform to complete transactions. Investment in our paper corresponds to the second type of investment in advertising in their model. When compared with the efficient investment level, they demonstrate that the platform underinvests (overinvests) in advertising without (with) a PMFC clause. A PMFC clause consequently lowers consumer surplus. However, the overall welfare effects of a PMFC clause are ambiguous. Furthermore, in their model of advertising investment, they do not consider platform competition. To our knowledge, there is no study of PMFC clauses in a setting where platforms compete on investments for enhancing market demand. We make a significant contribution by explicitly considering the effects of PMFC clauses in a more general setting that includes pricing and investment decisions.

Lastly, we emphasize the difference between our argument and a classic popular argument of retail price maintenance (RPM) agreements by Telser (1960), who states that RPM agreements might be efficiency-enhancing by eliminating free-riding on presale services and by creating incentives for retailers to invest in presale services.[7] One might infer that this discussion is the same as the debate related to PMFC clauses in the present paper. However, they differ in at least three ways. First, the PMFC clause makes a request for relativity of retail pricing, whereas the RPM determines absolute price levels (LEAR, 2012; Edelman and Wright, 2015; Akman and Sokol, 2017). Second, manufacturers (i.e., sellers in this paper) *have PMFC clauses imposed upon them*, whereas manufacturers *impose* RPM agreements. Third, sellers determine prices irrespective of the presence or absence of PMFC clauses, whereas, who decides the prices differs in the case of RPM agreements. Consequently, comparing the results based on the presence or absence of PMFC clauses and comparing the results based on the presence or absence of RPM agreements are fundamentally different.

[7]In the case of only one upstream manufacturer, Mathewson and Winter (1984) formally show that a package of RPM, franchise fees, and a wholesale price below marginal cost might eliminate horizontal externalities and achieve optimal outcomes when there are spillovers between retailers from retail services. When competition exists at both the upstream and downstream levels and when each manufacturer sells through two downstream retailers, Rey and Vergé (2010) show that the RPM raises the equilibrium retail price. Without RPM agreements, the presence of competition at both tiers maintains retail prices below the monopoly level. In contrast, with RPM agreements, an equilibrium always exists in which the retail prices are set at the monopoly level.

Therefore, our results differ from those derived in studies of RPM agreements (e.g., Gabrielsen and Johansen, 2017; Hunold and Muthers, 2017). They show that the introduction of RPM agreements raises equilibrium retail prices when *both* competition between upstream firms and competition between downstream firms are sufficiently intense. This difference suggests that it would be inappropriate to assess the PMFC clause in the same vein as earlier debates related to the RPM agreement.

3 Model

We consider a vertically related market with two downstream platforms ($d = 1, 2$) and two upstream sellers ($u = 1, 2$). Seller u produces good u with a constant marginal cost, which is assumed to be zero, and sells it through both platforms.[8] This paper assumes that agency agreements are signed in the vertical relations, in which the decisions on retail prices are delegated to sellers. Sales revenues on a platform are split between the seller and that platform according to a revenue share, α (the so-called commission rate). Platforms invest in demand-expanding promotions that may involve spillover effects. We use p_d^u and q_d^u, respectively, to denote prices and quantities of good u sold at platform d, and use x_d to represent the investment level chosen by platform d.

We consider a linear demand function first. Section 5.1 presents extension of the model in a manner by which the demand function takes a more general functional form. This paper incorporates investment, in terms of effort to enhance consumers' willingness to pay, into the demand structure used by Rey and Vergé (2010) and by Dobson and Waterson (1996, 2007), which are used widely in this branch of the literature (e.g., Gabrielsen and Johansen, 2015; Foros et al., 2017; Lu, 2017). We consider the following utility function of a representative consumer:

$$U(q_1^1, q_1^2, q_2^1, q_2^2) = \sum_d \left((1 + x_d + \beta x_{-d}) \sum_u q_d^u \right) - \sum_{d,u} \frac{1}{2} (q_d^u)^2$$

[8] We assume the sellers' multi-homing because the main emphasis of this paper is assessment of the effects of PMFC clauses that will work only when the sellers multi-home to multiple platforms.

$$-\delta(q_d^u q_{-d}^u + q_d^{-u} q_{-d}^{-u}) - \mu(q_d^u q_d^{-u} + q_{-d}^u q_{-d}^{-u}) - \delta\mu(q_d^u q_{-d}^{-u} + q_{-d}^u q_d^{-u}), \quad (1)$$

where δ is the substitution between downstream platforms, μ is the substitution between upstream sellers, and β represents the extent of spillover effects of investments. The cost of investment is assumed to be $c(x_d) = kx_d^2/2$. We assume that k is sufficiently large that all equilibrium outcomes are expected to take positive values and assume that the second-order conditions are satisfied in equilibrium.

Utility maximization subject to the budget constraint yields the inverse demand functions: $p_d^u = 1 + x_d + \beta x_{-d} - (q_d^u + \delta q_{-d}^u) - \mu(q_d^{-u} + \delta q_{-d}^{-u})$. Solving for quantities, we can derive the demand function as follows:

$$q_d^u(\mathbf{x}, \mathbf{p}) = \frac{(1-\delta)(1-\mu) + (1-\mu)\{(1-\beta\delta)x_d + (\beta-\delta)x_{-d}\} - p_d^u + \mu p_d^{-u} + \delta(p_{-d}^u - \mu p_{-d}^{-u})}{(1-\delta^2)(1-\mu^2)}, \quad (2)$$

where $\mathbf{x} = (x_1, x_2)$ and $\mathbf{p} = (p_1^1, p_1^2, p_2^1, p_2^2)$. Note that investment terms x_1 and x_2 enter the demand system additively.[9]

The timing of the game is the following. First, platform d chooses its investment level x_d to maximize its profit $\pi_d = \alpha \sum_u p_d^u q_d^u(\mathbf{x}, \mathbf{p}) - c(x_d)$, where α represents a revenue share for platforms.[10] Second, seller u determines prices p_1^u and p_2^u to maximize its profit as $\pi^u = (1-\alpha)\sum_d p_d^u q_d^u(\mathbf{x}, \mathbf{p})$. We analyze this two-stage game under two competitive environments: competition *without* PMFC clauses and competition *with* PMFC clauses. We compare equilibrium outcomes obtained respectively in these two competitive environments. The equilibrium concept we use here is a subgame-perfect Nash equilibrium. We derive the equilibrium outcomes using backward induction.

As a first step, the revenue share is assumed as given exogenously. It is equal across the two platforms. This assumption is made for our purpose of assessing the effects of PMFC clauses on retail pricing and social welfare through changes in platforms' investment incen-

[9] Some earlier studies Wirl (2015, 2018) also use an additive demand form, whereas Hunold and Muthers (2017) assume a multiplicative demand form.

[10] As described herein, revenue sharing is fundamentally equivalent to profit sharing because marginal costs are assumed to be zero. Therefore, no double marginalization problem arises.

tives. The clauses can be expected to have other effects arising from changes in revenue shares, which has been studied in the existing literature. However, mixed results are obtained. On the one hand, Boik and Corts (2016) and Johnson (2017) demonstrate that the PMFC clauses can allow platforms to *heighten* their commissions, which engenders higher retail prices and lower social welfare. On the other hand, Johansen and Vergé (2017) show that, depending on circumstances, the PMFC clauses can *lower* the commission and the resulting retail price. Therefore, we fix the revenue share in order to confine our attentions to the first effect stemming from platform investments.

Aside from the theoretical reason presented above, the following evidence might support our imposition of the assumption. According to an electronic survey conducted by a group of 11 EU Competition Authorities in 2016, 90% of hotels reported no change in the basic commission rate charged to them by OTAs in the periods before and after OTAs stopped imposing wide parity clauses (July 2015 – June 2016).[11]

For the reasons described above, we first consider the exogenously given revenue share. This assumption is later relaxed in Section 5.2.

4 Equilibrium Analysis

The purpose of this section is to derive equilibrium strategies under competition of both types with and without PMFC clauses; then we compare them to answer the question of when PMFC clauses raise investment incentives of competing platforms. Detailed proofs are given in Appendix A.

4.1 Competition without PMFC clauses

In stage two, for a given $\mathbf{x} = (x_1, x_2)$, sellers offer the retail prices which maximize their own profits. The maximization problem of seller u can be written as $\max_{p_1^u, p_2^u} \pi^u = (1 -$

[11]See "Report on the Monitoring Exercise carried out in the Online Hotel Booking Sector by EU Competition Authorities in 2016," available at `http://ec.europa.eu/competition/ecn/hotel_monitoring_report_en.pdf`.

$\alpha)\sum_d p_d^u q_d^u(\mathbf{x},\mathbf{p})$. Solving the first-order conditions yields

$$\begin{cases} \hat{p}_1^u(\mathbf{x}) = \dfrac{1-\mu}{2-\mu}(1+x_1+\beta x_2) \\ \hat{p}_2^u(\mathbf{x}) = \dfrac{1-\mu}{2-\mu}(1+x_2+\beta x_1) \end{cases} \quad \text{for} \quad u = 1,2. \tag{3}$$

Both sellers offer the same price for each platform (i.e., $\hat{p}_d^1 = \hat{p}_d^2$ for $d = 1,2$). The prices depend on the investment levels chosen by the platforms. Investments shift the demand curve upward, which in turn raises not only the price (i.e., $\partial \hat{p}_d^u / \partial x_d > 0$ for $u = 1,2$), but also the prices of goods sold in the rival platform (i.e., $\partial \hat{p}_{-d}^u / \partial x_d > 0$ for $u = 1,2$) as long as there are positive spillover effects. Moreover, the greater the spillover that exists, the higher the prices that both sellers charge.

The corresponding quantities are as presented below:

$$\begin{cases} \hat{q}_1^u(\mathbf{x}) = \dfrac{1-\delta+(1-\beta\delta)x_1+(\beta-\delta)x_2}{(1-\delta^2)(2-\mu)(1+\mu)} \\ \hat{q}_2^u(\mathbf{x}) = \dfrac{1-\delta+(1-\beta\delta)x_2+(\beta-\delta)x_1}{(1-\delta^2)(2-\mu)(1+\mu)} \end{cases} \quad \text{for} \quad u = 1,2. \tag{4}$$

In stage one, each platform d chooses the investment level to maximize the following profit.

$$\hat{\pi}_d(\mathbf{x}) = \alpha \sum_u \hat{p}_d^u(\mathbf{x})\hat{q}_d^u(\mathbf{x}) - \frac{k}{2}x_d^2 \tag{5}$$

The best response strategy of platform d is given as

$$\hat{x}_d(x_{-d}) = \frac{\alpha(1-\mu)\{Z^* + 2(2\beta-\delta-\beta^2\delta)\cdot x_{-d}\}}{k(1-\delta^2)(2-\mu)^2(1+\mu) - 4\alpha(1-\mu)(1-\beta\delta)}, \tag{6}$$

where $Z^* = 2(2-\delta-\beta\delta)$. Investment decisions are strategic substitutes (complements) when the spillover effects are weak (strong). Solving the first-order conditions yields

$$x^* = \frac{\alpha(1-\mu)Z^*}{\Phi(Z^*)}, \tag{7}$$

where $\Phi(Z) = k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z$. Further, for ease of exposition, we let $x(Z) \equiv \frac{\alpha(1-\mu)Z}{\Phi(Z)}$, i.e., $x^* = x(Z^*)$.

Table 1: Equilibrium outcome with the linear demand function

Without PMFC clauses	With PMFC clauses
$x^* = x(Z^*) \equiv \frac{\alpha(1-\mu)Z^*}{\Phi(Z^*)}$	$x^{**} = x(Z^{**})$
$p^* = p(Z^*) \equiv \frac{k(1-\delta^2)(2-\mu)(1+\mu)(1-\mu)}{\Phi(Z^*)}$	$p^{**} = p(Z^{**})$
$q^* = q(Z^*) \equiv \frac{k(1-\delta)(2-\mu)}{\Phi(Z^*)}$	$q^{**} = q(Z^{**})$
$\pi_u^* = \pi_u(Z^*) \equiv \frac{(1-\alpha)k^2(1-\delta)^2(1+\delta)(2-\mu)^2(1+\mu)(1-\mu)}{\{\Phi(Z^*)\}^2}$	$\pi_u^{**} = \pi_u(Z^{**})$
$\pi_d^* = \pi_d(Z^*) \equiv \frac{k\alpha(1-\mu)\left\{4k(1-\delta)^2(1+\delta)(2-\mu)^2(1+\mu)-\alpha(1-\mu)(Z^*)^2\right\}}{2\{\Phi(Z^*)\}^2}$	$\pi_d^{**} = \pi_d(Z^{**})$
$CS^* = CS(Z^*) \equiv \frac{2k^2(1-\delta)^2(1+\delta)(2-\mu)^2(1+\mu)}{\{\Phi(Z^*)\}^2}$	$CS^{**} = CS(Z^{**})$
$W^* = W(Z^*) \equiv \frac{k\left\{2k(1-\delta)^2(1+\delta)(2-\mu)^2(3+\mu-2\mu^2)-\alpha^2(1-\mu)^2(Z^*)^2\right\}}{\{\Phi(Z^*)\}^2}$	$W^{**} = W(Z^{**})$

Note: $Z^* = 2(2-\delta-\beta\delta)$, $Z^{**} = 4-(1+\delta)\mu-\beta\{(4-\mu)\delta-\mu\}$, and
$\Phi(Z) = k(1-\delta^2)(2-\mu)^2(1+\mu)-\alpha(1+\beta)(1-\mu)Z$.

Equilibrium investment increases with respect to the revenue share for the platforms (i.e., $\partial x^*/\partial\alpha > 0$). The platforms have a greater incentive to invest in demand-expanding promotions because they can earn greater revenue shares. Using the equilibrium investment level, we can derive the other equilibrium outcomes presented in Table 1.

4.2 Competition with PMFC clauses

With (industry-wide) PMFC clauses, if a seller offers different prices on the two platforms, the higher price would be lowered to be the same as the lower one across both platforms.[12] Eventually, because sellers have no incentive to charge different prices on each platform, the prices set by each seller on both platforms are equal. Consequently, letting $p_1^u = p_2^u = p^u$ for $u = 1, 2$, we consider the game in which seller u chooses only p^u as its strategic variable.[13]

[12] We assume the PMFC clause by which, irrespective of whether it is profitable or not, a high-priced platform must lower its price. Although there might be the case in which such price adjustment is not profitable for the platform, the PMFC clause is a rule to commit to such a price adjustment strategy. Herein, we describe our investigation of the profitability of such commitment.

[13] It would be inappropriate to put $p_1^u = p_2^u$ into the first-order condition derived in the case of competition without PMFC clauses. Without PMFC clauses, we treated p_1^u and p_2^u separately, where changes in p_d^u have

In stage two, given $\mathbf{x} = (x_1, x_2)$, each seller chooses price p^u to maximize its profit. Solving the first-order conditions with respect to p^u yields

$$\tilde{p}^u(\mathbf{x}) = \frac{1-\mu}{2-\mu}\left(1 + \frac{1+\beta}{2}(x_1 + x_2)\right) \quad \text{for} \quad u = 1, 2. \tag{8}$$

All prices are equal; all depend on the aggregate investment level, $x_1 + x_2$.

The corresponding quantities are presented below.

$$\begin{cases} \tilde{q}_1^u(\mathbf{x}) = \dfrac{2(1-\delta) + (3+\delta-\mu-\delta\mu)(x_1+\beta x_2) - (1+3\delta-\mu-\delta\mu)(\beta x_1 + x_2)}{2(1-\delta^2)(2-\mu)(1+\mu)} \\ \tilde{q}_2^u(\mathbf{x}) = \dfrac{2(1-\delta) + (3+\delta-\mu-\delta\mu)(\beta x_1+x_2) - (1+3\delta-\mu-\delta\mu)(x_1 + \beta x_2)}{2(1-\delta^2)(2-\mu)(1+\mu)} \end{cases} \tag{9}$$

In stage one, each platform d chooses the investment level to maximize its profit, which is represented as

$$\tilde{\pi}_d(\mathbf{x}) = \alpha \sum_u \tilde{p}^u(\mathbf{x})\tilde{q}_d^u(\mathbf{x}) - \frac{k}{2}x_d^2 \quad \text{for} \quad d = 1, 2. \tag{10}$$

The best response strategy of platform d is given as

$$\tilde{x}_d(x_{-d}) = \frac{\alpha(1-\mu)\left\{Z^{**} + (1+\beta)^2(1-\delta)\cdot x_{-d}\right\}}{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)\left\{3+\delta-\mu-\delta\mu-\beta(1-\mu-3\delta-\delta\mu)\right\}}, \tag{11}$$

where $Z^{**} = 4 - (1+\delta)\mu - \beta\{(4-\mu)\delta - \mu\}$. Unlike the case of competition without PMFC clauses, investment decisions are strategic complements irrespective of the extent of spillover effects. Solving the first-order conditions yields

$$x^{**} = \frac{\alpha(1-\mu)Z^{**}}{\Phi(Z^{**})} = x(Z^{**}), \tag{12}$$

As in the competition without PMFC clauses, the investment level is increasing in α. The other equilibrium outcomes are presented in Table 1.

4.3 Comparison

Here, we compare the equilibrium outcomes under both cases with and without PMFC clauses. As shown in Table 1, equilibrium outcomes obtained under competition of both

no effect on p_{-d}^u. However, with the PMFC clause, the retail pricing is completely different. Both prices p_d^u and p_{-d}^u would be adjusted automatically to be equal to the lower one if seller u changed p_d^u. Therefore, p_1^u and p_2^u must be treated as a single strategic variable.

types with and without PMFC clauses are similar. The only difference is whether the content of Z is Z^* or Z^{**}.

Before proceeding to a comparison of equilibrium outcomes, we compare equations (3) and (8) to support the following remark.

Remark 1. *Given $x_1 = x_2 = x$, it holds that $\hat{p}_d^u(x,x) = \tilde{p}^u(x,x)$. That is, if both platforms choose the same investment level as common irrespective of PMFC clauses, then the retail prices are unaffected by the presence of the clauses.*

This remark implies that retail pricing is not altered directly by the presence or absence of the PMFC clauses in our model. In this section, we assume the exogenously fixed revenue share in an effort to confine our attention to other important effects of the PMFC clause that stem from the platform investment. In that regard, Remark 1 ensures that, in the following comparison based on the presence or absence of the PMFC clause, the difference in retail price arises completely from the difference in investment incentives for the respective platforms.

At this point, we compare the equilibrium investment levels x^* and x^{**}. As Table 1 shows, the comparison depends on the magnitude relation between Z^* and Z^{**}. Therefore, comparison of Z^* and Z^{**} yields the following proposition.

Proposition 1. *The presence of industry-wide PMFC clauses increases the equilibrium investment level if and only if $\delta > \mu/(2-\mu)$.*

It is noteworthy that condition $\delta > \mu/(2-\mu)$ is independent of β. That is, the extent of spillover effects of platform investments does not affect whether the PMFC clauses increase platform investments, or not. The condition is more likely to be satisfied when substitution between the downstream platforms, δ, is sufficiently larger than the substitution between the upstream sellers, μ.

The intuition underlying Proposition 1 is the following. The use of PMFC clauses has two effects on platforms' investment incentives. First, presuming that a platform invests more than the rival platform, consumers have a higher willingness to pay for goods sold in the platform with a higher degree of investment. Then, sellers charge higher prices for the platform. However, if PMFC clauses are not imposed, then the sellers need not increase their prices for the rival platform as well. This would engender lower investment incentives for competing platforms. The use of PMFC clauses can resolve this problem of underinvestment by requiring that sellers raise their prices for the rival platform by an equal amount. The fiercer the platform competition becomes, the greater this positive effect becomes also.

Secondly, the existence of PMFC clauses can mitigate inter-seller price competition. A lesser degree of competition shrinks the total quantities demanded in platforms, which in turn discourages the platforms from investing. Therefore, the fiercer the seller competition becomes, the greater this negative effect becomes. In summary, when platform competition is fiercer than seller competition, the former positive effect dominates the latter negative one, implying that the presence of PMFC clauses increases the platforms' investment incentives.

Similarly, related to the equilibrium retail prices, demands, profit of sellers, and consumer surplus, the comparisons depend on the magnitude relation between Z^* and Z^{**}.

Corollary 1. *It follows that* $Sign[x^{**} - x^*] = Sign[p^{**} - p^*] = Sign[q^{**} - q^*] = Sign[\pi_u^{**} - \pi_u^*] = Sign[CS^{**} - CS^*]$.

When the presence of PMFC clauses increases (decreases) the platform investment, it also increases (decreases) the retail price, demand, profit of sellers, and consumer surplus. This result also implies that sellers and consumers share identical preferences for the clauses. The sellers prefer the situation in which higher investments are given by platforms because they can benefit from the platforms' investment in enhancing demand. The same argument holds for consumer surplus.

Regarding the effects of RPM agreement, Hunold and Muthers (2017) show a close but not equal result to ours, such that RPM agreements raise retail prices when both competition between upstream manufacturers and competition between downstream retailers are sufficiently intense. Without RPM agreements, fierce retail competition simply decreases the equilibrium retail price. Moreover, intense competition among manufacturers makes it profitable for each to lower the wholesale price to incentivize retailers to promote its product more than the other rival manufacturers' products, which results in the lower retail price. By contrast, RPM agreements enable manufacturers to fix the retail price at the monopoly level. Overall, in their model, when intense competition prevails in both tiers, RPM agreements raise the equilibrium retail price, which is in sharp contrast to ours.

Next, we compare the equilibrium profit of the platforms.

Proposition 2. *If the substitution between platforms is sufficiently larger than the extent of spillover effects between platforms such that the following condition is satisfied,*

$$\beta < \min\left\{\frac{\delta}{2-\delta}, \frac{(4-\mu)\delta-\mu}{4-\mu-\delta\mu}\right\}, \tag{13}$$

then it holds that $Sign\left[\pi_d^{**}-\pi_d^{*}\right] \neq Sign\left[x^{**}-x^{*}\right]$.

Proposition 2 implies that competing platforms might dislike the intense investment competition. When platform competition is sufficiently fierce and their investments involve weak spillover effects, excessive investments arising from fierce platform competition result in large investment costs, but do not generate sufficiently large spillover effects to compensate for increased investment costs. Therefore, regarding the presence or absence of PMFC clauses, the platforms might prefer the market environment that leads to lower investment levels. Consequently, from Propositions 1 and 2, the platforms' preference for PMFC clauses can conflict with the sellers' and consumers' preferences.

One might consider that the extent of spillover effects is nearly equal to the degree of substitution between platforms (i.e., $\beta \simeq \delta$). For example, investment in advertising that increases demand for some goods in a certain platform will be more prone to cause demand expansion of the same goods in other platforms as the willingness of consumers to substitute among platforms is higher. In such a case, condition (13) is not satisfied. Therefore, we have the following corollary.

Corollary 2. *If* $\beta = \delta$*, then it holds that* $Sign\left[\pi_d^{**}-\pi_d^{*}\right] = Sign\left[x^{**}-x^{*}\right]$.

This corollary implies that the conflict stated in Proposition 2 arises only when the extent of spillover effects is sufficiently small compared to the degree of platform competition.

Finally, we compare social welfare under both competitions with and without PMFC clauses, which is summarized as follows.

Proposition 3. *If α is sufficiently small to satisfy*

$$\alpha(1-\mu)\cdot\max\{Z^*,Z^{**}\}<2(1+\beta)(1-\delta)(3-2\mu), \tag{14}$$

then it follows that $Sign\,[W^{**}-W^*]=Sign\,[x^{**}-x^*]$.

Proposition 3 shows that, if the revenue share for the platforms is not too large, then the welfare effect of PMFC clauses depends on whether they result in greater platform investments. However, as the revenue share becomes higher, the platform profit takes up a larger share of social welfare than the seller profit. Proposition 2 shows that the platforms' preference for PMFC clauses can conflict with the sellers' and consumers' preferences.. Therefore, for large α, the welfare effect of the clauses might be evaluated to a great degree by its effect on the platform profits.

Combining the results of Propositions 1, 2, and 3, we have the following remark:

Remark 2. *Consider that both the extent of spillover effects of platform investments and the revenue share for platforms are sufficiently small to satisfy inequalities* (13) *and* (14)*. Then, $Sign\,[x^{**}-x^*]=Sign\,[W^{**}-W^*]\neq Sign\,[\pi_d^{**}-\pi_d^*]$ holds, implying that the platforms' preference for industry-wide PMFC clauses comes into conflict with social desirability. Specifically, if the extent of the substitution between sellers is sufficiently large to satisfy $\delta<\mu/(2-\mu)$, then the platforms can gain greater profit from industry-wide PMFC clauses. However, this reduces social welfare.*

Remark 2 presents a *sufficient* condition for which competition authorities should be more concerned about industry-wide PMFC clauses. In Section 6, using numerical analysis, we exhibit the parameter ranges which suggest a cautious attitude towards industry-wide PMFC clauses, and make policy discussions.

5 Extensions

In this section, we investigate how alternative market conditions influence the effect of PMFC clauses on investment incentives. We relax the following assumptions of the main analysis: (1) both demand and marginal cost functions take linear forms, and (2) a revenue share is given exogenously.

5.1 General demand and cost functions

We confirm the robustness of the effect of PMFC clauses on investment incentives, which is shown in Proposition 1, under more general demand and cost functions.[14] Detailed proofs are given in Appendix B.

We denote the demand function by $q_d^u(\mathbf{x}, \mathbf{p})$ for $u = 1, 2$ and $d = 1, 2$, where $\mathbf{x} = (x_1, x_2)$ and $\mathbf{p} = (p_1^1, p_1^2, p_2^1, p_2^2)$. We assume that $q_d^u(\mathbf{x}, \mathbf{p})$ is increasing in x_d (positive investment effect), decreasing in p_d^u (negative own-price effect), and increasing in p_d^{-u} and p_{-d}^u (positive cross-price effect).[15] Furthermore, we consider that the investments involve some spillover effects for the rival platform, i.e., $\partial q_{-d}^u(\mathbf{x}, \mathbf{p})/\partial x_d$ takes positive (negative) value when there is positive (negative) spillover.

To maintain alignment with the main analysis, we assume that the demand functions are symmetric and take the additive forms shown below.

Assumption 1.

$$q_d^u(\mathbf{x}, (a, b, c, e)) = q_d^{-u}(\mathbf{x}, (b, a, e, c)) \tag{15}$$

$$q_d^u((\alpha, \beta), (a, b, c, e)) = q_{-d}^u((\beta, \alpha), (c, e, a, b)) \tag{16}$$

[14] Under general demand forms, it is difficult to assess effects on the other equilibrium outcomes such as demand, profit, consumer surplus, and social welfare. Investments affect prices, which change the set of consumers who buy. Those changes in demand depend crucially on specific characteristics of the demand function. In addition, platforms choose their investment levels with a focus on marginal consumers, whereas social welfare depends on the surplus of average consumers. How investments differently affect marginal and average consumers also depends on specific characteristics of the demand function.

[15] As in Foros et al. (2017), we have no preference about the sign of $\partial q_d^u/\partial p_{-d}^{-u}$, which can be positive, negative, or zero. For example, Rey and Vergé (2010) consider a positive sign and Dobson and Waterson (1996, 2007) consider a negative one.

Assumption 2.

$$\frac{\partial^2 q_d^u}{\partial x_d \partial p_{u'}^{d'}} = \frac{\partial^2 q_d^u}{\partial x_{-d} \partial p_{u'}^{d'}} = 0 \quad \text{for all} \quad u, u', d, d' = 1, 2 \tag{17}$$

In addition, we consider a general cost function of platform investments, $c(x_d)$, which is assumed to be an increasing and convex function, i.e., $c'(\cdot) > 0$ and $c''(\cdot) > 0$.

Except for the demand and cost functions, we consider the same structure of the game as that described in Section 3. We solve the game backwards in both cases with and without PMFC clauses. We assume that a unique symmetric equilibrium exists. Details are presented in Appendix B.

Because the purpose of the arguments presented in this section is to answer the question of when PMFC clauses raise investment incentives of competing platforms under the general functional forms, we describe the first-order conditions with respect to the investment level for both competitive environments.

Lemma 1. *Without PMFC clauses, the equilibrium investment level* $\mathbf{x}^* = (x^*, x^*)$ *satisfies*

$$2\alpha \cdot \hat{p}_d(\mathbf{x}^*) \left\{ \frac{\partial q_d^u}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_d^{-u}} - \frac{\partial q_d^u}{\partial p_{-d}^u} \right) \frac{\partial \hat{p}_d(\mathbf{x}^*)}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}} \right) \frac{\partial \hat{p}_{-d}(\mathbf{x}^*)}{\partial x_d} \right\} = c'(x^*), \tag{18}$$

where $\hat{p}_d(\mathbf{x})$ *represents the retail price set by sellers for goods sold on platform* d *in stage two for a given* $\mathbf{x} = (x_1, x_2)$. *Therein, the partial derivatives of the demand function are evaluated at* $(\mathbf{x}^*, \hat{\mathbf{p}}(\mathbf{x}^*))$, *where* $\hat{\mathbf{p}}(\mathbf{x}) = (\hat{p}_1(\mathbf{x}), \hat{p}_1(\mathbf{x}), \hat{p}_2(\mathbf{x}), \hat{p}_2(\mathbf{x}))$.

The left-hand and right-hand sides of equation (18) respectively present the marginal revenue and marginal cost of investment. When PMFC clauses are not imposed, investments by a platform affect not only retail prices for goods sold at the platform but also prices on the rival platform. The Appendix shows that the former effect is positive (i.e., $\frac{\partial \hat{p}_d(\mathbf{x})}{\partial x_d} > 0$). However, as the substitution between platforms becomes larger compared to the substitution between sellers, $\frac{\partial q_d^u}{\partial p_d^{-u}} - \frac{\partial q_d^u}{\partial p_{-d}^u}$ becomes more likely to take a negative value, which dampens the investment incentives of platforms. This discouragement effect is removed by the introduction of PMFC clauses, as demonstrated with the following proposition.

Lemma 2. *With PMFC clauses, the equilibrium investment level* $\mathbf{x}^{**} = (x^{**}, x^{**})$ *satisfies*

$$2\alpha \cdot \tilde{p}(\mathbf{x}^{**}) \left\{ \frac{\partial q_d^u}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_d^{-u}} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}} \right) \frac{\partial \tilde{p}(\mathbf{x}^{**})}{\partial x_d} \right\} = c'(x^{**}), \tag{19}$$

where $\tilde{p}(\mathbf{x})$ *denotes the retail price set by sellers in stage two for a given* $\mathbf{x} = (x_1, x_2)$. *Therein, the partial derivatives of the demand function are evaluated at* $(\mathbf{x}^{**}, \tilde{\mathbf{p}}(\mathbf{x}^{**}))$, *where* $\tilde{\mathbf{p}}(\mathbf{x}) = (\tilde{p}(\mathbf{x}), \tilde{p}(\mathbf{x}), \tilde{p}(\mathbf{x}), \tilde{p}(\mathbf{x}))$.

When PMFC clauses are imposed, sellers are unable to discriminate retail prices across platforms (i.e., $p_1^u = p_2^u = \tilde{p}(\mathbf{x})$). Consequently, the clauses can protect the investment incentives of platforms.

Finally, we derive the following proposition from comparison of the first-order conditions (18) and (19).

Proposition 4. *The presence of industry-wide PMFC clauses increases the equilibrium investment level and retail price if the following condition is satisfied:*

$$\frac{1}{2} \frac{\partial q_d^u(\mathbf{x}^*, \hat{\mathbf{p}}(\mathbf{x}^*))}{\partial p_d^{-u}} < \frac{\partial q_d^u(\mathbf{x}^*, \hat{\mathbf{p}}(\mathbf{x}^*))}{\partial p_{-d}^u} + \frac{1}{2} \frac{\partial q_d^u(\mathbf{x}^*, \hat{\mathbf{p}}(\mathbf{x}^*))}{\partial p_{-d}^{-u}} \tag{20}$$

This proposition shows that the result related to the effect of PMFC clauses on investment incentives, as derived in Proposition 1, remains robust under the general demand and cost functions. That is, condition (20) is more likely to be satisfied when substitution between the downstream platforms (i.e., $\partial q_d^u / \partial p_{-d}^u$) is sufficiently larger than the substitution between the upstream sellers (i.e., $\partial q_d^u / \partial p_d^{-u}$). Under such circumstances, the existence of PMFC clause can engender stronger investment incentives.

Condition (20) further implies that the demand effect of "fourth" product's price (i.e., $\partial q_d^u / \partial p_{-d}^{-u}$) positively or negatively affects the necessary and sufficient condition for which the PMFC promotes the platforms' investment incentive. Inequality (20) is more (less) likely to hold if this "fourth" effect is positive (negative). Our main analysis examined the linear demand function by which the "fourth" effect takes a negative value. In other words, we presented the desirability of PMFC clauses under the demand function which makes it difficult to do so.

It is also worth noting that condition (20) is independent of the extent of spillover effects of platform investments, as stated below Proposition 1.

Corollary 3. *The extent of spillover effects of platform investments does not affect the question of whether the presence of PMFC clauses increases the platforms' investment level.*

5.2 Endogenous decisions related to revenue shares

We demonstrate here that Proposition 1 remains unchanged even if competing platforms determine their revenue shares endogenously. To confirm it, we extend the original model so that in stage one, platform d determines its revenue share, denoted by α_d, in addition to investment level x_d. All proofs are given in Appendix C.

First, the following lemma presents the equilibrium of competition without PMFC clauses.

Lemma 3. *Without PMFC clauses, the equilibrium revenue share and investment level are* $x_1 = x_2 = X^*$ *and* $\alpha_1 = \alpha_2 = \alpha^*$*, respectively, where*

$$(X^*, \alpha^*) = \begin{cases} \left(\frac{(1-\mu)Z^*}{k(2-\mu-\delta\mu)(2+\mu-\mu^2)-(1+\beta)(1-\mu)Z^*} \ , \ \frac{(2-\mu)(1-\delta^2)}{2-\mu-\delta\mu} \right) & \text{if } \delta > \frac{\mu}{2-\mu} \ , \\ \left(x^*|_{\alpha=1} \ , \ 1 \right) & \text{if } \delta \leq \frac{\mu}{2-\mu} \ . \end{cases} \tag{21}$$

This lemma implies that if platform competition is sufficiently mild to satisfy $\delta \leq \frac{\mu}{2-\mu}$, then the equilibrium revenue share is set at the highest level even without PMFC clauses (i.e., $\alpha^* = 1$). It is worth emphasizing that this extremely high revenue share stems from assumptions that sellers multi-home to both platforms and that their outside option is standardized to zero. If sellers have a positive value of outside option (e.g., selling through other channels), then the equilibrium revenue share might be set at the level that makes the sellers' profit equal to the value of their outside option.

By contrast, if platform competition is fierce (i.e., $\delta > \frac{\mu}{2-\mu}$), the platforms charge a revenue share lower than one. When competing platforms are less differentiated, sellers have an incentive to make more sales in the platform that imposes a lower revenue sharing rate, incentivizing the platforms to lower revenue shares. At the same time, however, the resulting low revenue share discourages them from investing.

Next, we turn to the equilibrium of competition with PMFC clauses.

Lemma 4. *With PMFC clauses, the equilibrium revenue share and investment level are* $x_1 = x_2 = X^{**}$ *and* $\alpha_1 = \alpha_2 = \alpha^{**}$*, respectively, where* $(X^{**}, \alpha^{**}) = (x^{**}|_{\alpha=1}, 1)$*.*

The presence of PMFC clauses mitigates platform competition for revenue shares. As a result, competing platforms charge the highest revenue share, irrespective of the extent of platform competition. In terms of investment, mild platform competition incentivizes them to invest more.

Finally, comparing the equilibrium outcomes under competition with and without PMFC clauses, we have the following proposition.

Proposition 5. *When competing platforms choose their revenue shares and investment levels endogenously, the industry-wide adoption of PMFC clauses increases the investment level, retail price, demand, and consumer surplus if and only if* $\delta > \mu/(2-\mu)$*.*

This proposition illustrates the robustness of Proposition 1, which is the purpose of this extended analysis. It is worth emphasizing that the industry-wide PMFC clauses are still consumer-surplus-improving when platform competition is intense compared to seller competition, implying that the positive effect of promoting investments dominates the negative effect of raising retail prices.

6 Policy Discussion: A Numerical Analysis

In Remark 2, given a fixed revenue share, we described the possibility of conflicts between the platforms' profit-maximization and social welfare. Here, we apply a numerical analysis to show the precise parameter range of the condition for which competition authorities should be more concerned about industry-wide PMFC clauses. Let $k = 1$ and $\alpha = 0.3$, where $\alpha = 0.3$ is chosen according to the revenue share that is actually used between Apple and its sellers: the so-called Apple 30-70 rule.

First, we confirm Propositions 1 and 3: the industry-wide adoption of PMFC clauses increases (decreases) the platform investment, seller profit, consumer surplus, and social welfare when platform competition is fierce (mild) compared to seller competition, as verified through the numerical analysis presented in panel (a) of Figure 1.[16] In the light gray area (where platform competition is fierce compared to seller competition), industry-wide PMFC clauses not only increase the platform investment but also increase social welfare. By contrast, in the gray area (where seller competition is fiercer), the clauses engender lower platform investments, which are detrimental to consumers, sellers, and society because the presence of PMFC clauses mitigates the price competition between sellers, which in turn decreases the total quantities demanded and therefore reduces the platforms' investment incentives. It is worth emphasizing that sellers' and consumers' losses are fundamentally attributable to the lower investment.

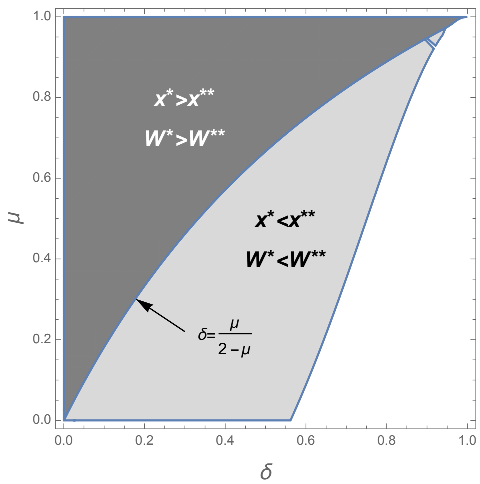
Next, we turn to Proposition 2: we compare the profit of platforms between competition with and without PMFC clauses. The results are shown in panels (b), (c), and (d) of Figure 1, where panel (b) is for $\beta = 0$ (i.e., no spillovers), panel (c) is for $\beta = 0.3$ (i.e., weak spillovers), and panel (d) is for $\beta = 0.6$ (i.e., strong spillovers).[17] In all panels, light gray spaces denote regions in which the platforms benefit from industry-wide PMFC clauses, whereas the gray spaces represent regions where the clauses are detrimental to the platforms.

As one might notice, comparison of panels (a) and (b), (c), or (d), the platforms' preference for industry-wide PMFC clauses is aligned with the social desirability when the degree of substitution between platforms, δ, is small (i.e., regions I and II). However, when platform competition is fierce (i.e., regions III and IV), there exists a marked conflict between the platforms and the others over the industry-wide introduction of the clauses. Moreover, as spillover effects (i.e., β) become smaller, conflict becomes more likely to arise.

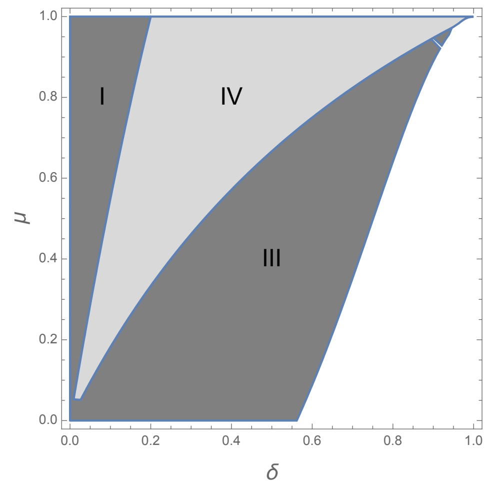
Of particular importance for competition policy is region IV, in which the industry-wide

[16] Although panel (a) of the figure depicts the case of $\beta = 0$, this configuration is unchanged, even for $\beta \in (0, 1)$.

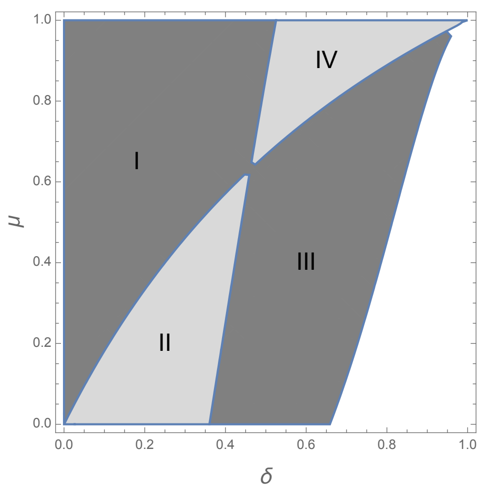
[17] Proposition 2 has only provided the sufficient condition about the magnitude relation, but the numerical analysis in Figure 1 exactly shows the magnitude relation between π_d^* and π_d^{**}.



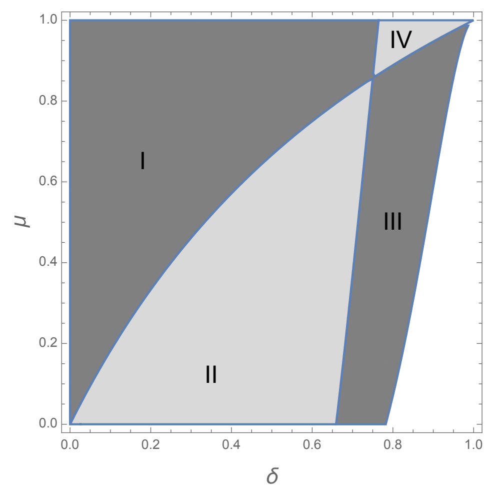
(a) Investment and welfare for $\beta \in [0, 1)$



(b) Platform's profit for $\beta = 0$



(c) Platform's profit for $\beta = 0.3$



(d) Platform's profit for $\beta = 0.6$

Figure 1: Results of numerical analysis $(k = 1, \alpha = 0.3)$.

Note: In panels (b), (c), and (d), the light gray spaces (i.e., regions II and IV) denote the regions where the equilibrium profit of platforms is greater under competition with PMFC clauses (i.e., $\pi_d^* < \pi_d^{**}$) while the gray spaces (i.e., regions I and III) represent the regions where the equilibrium profit is greater under competition without PMFC clauses (i.e., $\pi_d^* > \pi_d^{**}$).

adoption of PMFC clauses is beneficial to the platforms but detrimental to sellers, consumers, and society. The intuitive reason why this conflicting situation arises is the following. First, as explained above, in region IV, where seller competition is intense compared to platform competition, PMFC clauses are socially undesirable because they not only mitigate price competition between sellers but also reduce platform investment. Additionally, in region IV, platform competition is also fierce compared to the extent of the spillover effects of their investments. Intense platform competition in investments increases their investment costs while not creating sufficiently large spillover effects to compensate such costs. Therefore, competing platforms prefer the market environment that results in lower investment levels, which is competition with PMFC clauses. The platforms' preference for industry-wide PMFC clauses comes into conflict with social welfare in region IV.

Finally, we provide a rough indication of whether the industry-wide PMFC clauses should be investigated carefully. Competition authorities should be more concerned about PMFC clauses if all the following three conditions are satisfied: (i) the revenue share for platforms is not too large, (ii) seller competition is intense compared to platform competition, and (iii) the extent of spillover effects of platform investments is small compared to the extent of substitution between platforms.

7 Conclusion

We used a bilateral duopoly model to investigate the relation between the presence of PMFC clauses and platforms' incentives for investments that involve spillover effects. The model shows that the industry-wide adoption of PMFC clauses promotes the platforms' investment incentives when the degree of substitution between platforms is large compared with the degree of substitution between sellers. It is noteworthy that the condition for PMFC clauses leading to greater investments in this paper differs from that for RPM agreements leading the greater investments in Hunold and Muthers (2017), which suggests that it would be inappropriate to assess the PMFC clause in the same way as the debate about the RPM agreement.

We also demonstrate that whenever the industry-wide PMFC clauses increase the platform investment, it engenders higher retail prices and larger quantities demanded. Further, in this case, the PMFC clauses are desirable both for consumers and for sellers. In other words, consumers and sellers share the same view as to whether PMFC clauses are introduced. However, only the platforms might have different incentives for the industry-wide adoption of PMFC clauses: a possible conflict might exist between the platforms' profit-maximization and social welfare.

The result of this paper calls for competition authorities to be more concerned about the implementation of industry-wide PMFC clauses if *all* three of the following conditions are satisfied: (i) the revenue share for platforms is not too large, (ii) seller competition is more intense than platform competition, and (iii) the extent of spillover effects of platform investments is small compared to the extent of substitution between platforms. In such cases, the platforms can gain greater profits from industry-wide PMFC clauses. However, they reduce the sellers' profits, consumer surplus, and social welfare. It should be emphasized that this policy implication relies on our specific model in which neither the choice of PMFC clauses nor the choice of the revenue share is endogenous. The results can be useful in a short-term, where those choices are fixed. However, from a longer-term perspective, their relevance for competition policy might be limited to some degree. In this regard, further research is needed.

We conclude by discussing potential avenues for future research. First, in this paper, we have assumed that sellers multi-home to both platforms and that their outside option is standardized to zero. In practice, however, sellers could stop listing on the platforms and then sell through brick-and-mortar retailers. It would then be important to revisit the welfare effect of PMFC clauses with consideration of such sellers' supply chain management as well as platforms' investment incentives.

Second, we have not examined platforms' endogenous decisions about whether to impose a PMFC clause or not. The central purpose of this paper is assessment of regulations prohibiting PMFC clauses in terms of platform investments. Under regulation, no PMFC clauses are imposed. As a simple comparison, we specifically examine a situation in which all platforms impose clauses. Consideration of asymmetric situations and then endogenization of the decisions on the introduction of PMFC clauses would be valuable, but those steps are beyond the scope of this paper.[18]

Third, throughout this paper, investment terms are assumed to enter the demand function additively. The demand function must be specified to evaluate the welfare effects of PMFC clauses, although the results might depend on the demand specifications. It is important to discuss our results with other various functional specifications (e.g., multiplicative demand form).

Fourth, we have considered competition between two sellers. In fact, numerous sellers might be on a platform. Although we think our qualitative results would not change even when there are more than two sellers, confirmation of that supposition is left as a subject for future work.

Appendix A: Proofs for the analysis with linear demand function

Proof of Proposition 1

Let

$$x(Z) = \frac{\alpha(1-\mu)Z}{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z}, \tag{A.1}$$

$$p(Z) = \frac{k(1-\delta^2)(2-\mu)(1-\mu^2)}{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z}, \tag{A.2}$$

$$q(Z) = \frac{k(1-\delta)(2-\mu)}{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z}. \tag{A.3}$$

$$\pi_u(Z) = \frac{(1-\alpha)k^2(1-\delta)^2(1+\delta)(2-\mu)^2(1-\mu^2)}{\{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z\}^2}, \tag{A.4}$$

[18] In our framework, under asymmetric situations where only one platform imposes a PMFC clause, there exist no pure strategy Nash equilibria in the stage of investment choices. The best response function of either platform is not continuous, and then jumps over the 45-degree line.

$$CS(Z) = \frac{2k^2(1-\delta)^2(1+\delta)(2-\mu)^2(1+\mu)}{\{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z\}^2}. \tag{A.5}$$

It is readily apparent that $x(Z)$, $p(Z)$, $q(Z)$, $\pi_u(Z)$, and $CS(Z)$ are increasing functions with respect to Z. That is,

$$\begin{aligned} & x(Z^*) < x(Z^{**}) \;\&\; p(Z^*) < p(Z^{**}) \;\&\; q(Z^*) < q(Z^{**}) \\ & \&\; \pi_u(Z^*) < \pi_u(Z^{**}) \;\&\; CS(Z^*) < CS(Z^{**}) & \text{(A.6)} \\ & \iff Z^* < Z^{**} & \text{(A.7)} \\ & \iff 2(2-\delta-\beta\delta) < 4-(1+\delta)\mu - \beta\{(4-\mu)\delta - \mu\} & \text{(A.8)} \\ & \iff \delta > \frac{\mu}{2-\mu}. & \text{(A.9)} \end{aligned}$$

□

Proof of Proposition 2

Let

$$\pi_d(Z) = \frac{k\alpha(1-\mu)\{4k(1-\delta)^2(1+\delta)(2-\mu)^2(1+\mu) - \alpha(1-\mu)Z^2\}}{2\{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z\}^2}. \tag{A.10}$$

The magnitude relation of π_d^* and π_d^{**} becomes opposite to that of Z^* and Z^{**} if a function $\pi_d(Z)$ is decreasing in Z between Z^* and Z^{**}.

$$\begin{aligned} & \pi_d'(Z^*) < 0 \quad \& \quad \pi_d'(Z^{**}) < 0 & \text{(A.11)} \\ & \iff 2\{\beta(2-\delta) - \delta\} < 0 \quad \& \quad \beta(4-\mu-\delta\mu) + \mu - \delta(4-\mu) < 0 & \text{(A.12)} \\ & \iff \beta < \min\left\{\frac{\delta}{2-\delta}, \frac{(4-\mu)\delta-\mu}{4-\mu-\delta\mu}\right\} & \text{(A.13)} \end{aligned}$$

□

Proof of Proposition 3

Let

$$W(Z) = \frac{k\{2k(1-\delta)^2(1+\delta)(2-\mu)^2(3+\mu-2\mu^2) - \alpha^2(1-\mu)^2Z^2\}}{\{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z\}^2}. \tag{A.14}$$

The derivative of $W(Z)$ with respect to Z is computed as shown below.

$$W'(Z) = \frac{2k^2\alpha(1-\delta^2)(2-\mu)^2(1-\mu^2)}{\{k(1-\delta^2)(2-\mu)^2(1+\mu) - \alpha(1+\beta)(1-\mu)Z\}^3} \times \{2(1+\beta)(1-\delta)(3-2\mu) - \alpha(1-\mu)Z\} \tag{A.15}$$

We find that $W'(Z)$ is positive between Z^* and Z^{**} if an inequality $\alpha(1-\mu)\cdot\max\{Z^*, Z^{**}\} < 2(1+\beta)(1-\delta)(3-2\mu)$ holds. In this case, the magnitude relation between $W(Z^*)$ and $W(Z^{**})$ matches that of Z^* and Z^{**}. □

Proof of Corollary 2

When $\beta = \delta$ holds, then the derivatives of $\pi_d(Z)$ and $W(Z)$ with respect to Z can be rewritten as follows.

$$\pi'_d(Z) = \frac{k^2\alpha^2(1-\delta^2)(2-\mu)^2(1-\mu)^2(1+\mu)}{\{k(1-\delta^2)(2-\mu)^2(1+\mu)-\alpha(1+\delta)(1-\mu)Z\}^3} \times \{4(1-\delta^2)-Z\} \tag{A.16}$$

$$W'(Z) = \frac{2k^2\alpha(1-\delta^2)(2-\mu)^2(1-\mu^2)}{\{k(1-\delta^2)(2-\mu)^2(1+\mu)-\alpha(1+\delta)(1-\mu)Z\}^3} \times \{2(1-\delta^2)(3-2\mu)-\alpha(1-\mu)Z\} \tag{A.17}$$

The signs of $\pi'_d(Z)$ and $W'(Z)$ depend on the sign of $4(1-\delta^2)-Z$ and $2(1-\delta^2)(3-2\mu)-\alpha(1-\mu)Z$, respectively. We can confirm that both $\pi_d(Z)$ and $W(Z)$ are increasing in the interval between Z^* and Z^{**}. Therefore, the magnitude relations match that of Z^* and Z^{**}. □

Appendix B: Proofs for the analysis with general demand function

Proof of Lemma 1

We solve the game of competition without PMFC clauses using backward induction.

In stage two, given $\mathbf{x} = (x_1, x_2)$, sellers offer the retail prices which maximize their own profits. The maximization problem of seller u can be written as $\max_{p_1^u, p_2^u} \pi^u = (1-\alpha)\sum_d p_d^u q_d^u(\mathbf{x}, \mathbf{p})$. The first-order condition is given as

$$\frac{\partial \pi^u}{\partial p_d^u} = (1-\alpha)\left(q_d^u(\mathbf{x},\mathbf{p}) + p_d^u \frac{\partial q_d^u(\mathbf{x},\mathbf{p})}{\partial p_d^u} + p_{-d}^u \frac{\partial q_{-d}^u(\mathbf{x},\mathbf{p})}{\partial p_d^u}\right) = 0 \quad \text{for} \;\; u = 1,2,\; d = 1,2. \tag{B.1}$$

One must make additional assumptions related to the cross derivatives of the profit functions to ensure that the system of the above four first-order conditions has a unique solution. As in Foros et al. (2017), a sufficient condition for the uniqueness can be derived as $\frac{\partial^2 \pi^u}{(\partial p_d^u)^2} +$

$\left|\frac{\partial^2 \pi^u}{\partial p_d^u \partial p_{-d}^u}\right| + \left|\frac{\partial^2 \pi^u}{\partial p_d^u \partial p_d^{-u}}\right| + \left|\frac{\partial^2 \pi^u}{\partial p_d^u \partial p_{-d}^{-u}}\right| < 0$ for all $\mathbf{x}$ and $\mathbf{p}$. More details are provided in Vives (1999).

From Assumption 1, if $x_1 = x_2$, all prices will be the same (i.e., $p_1^1 = p_1^2 = p_2^1 = p_2^2$). Otherwise, if $x_1 \neq x_2$, two sellers set the same price for their goods sold at the same platform, i.e., $p_d^u = p_d^{-u} \equiv \hat{p}_d(\mathbf{x})$ for $d = 1, 2$. Let $\hat{\mathbf{p}}(\mathbf{x}) = (\hat{p}_1(\mathbf{x}), \hat{p}_1(\mathbf{x}), \hat{p}_2(\mathbf{x}), \hat{p}_2(\mathbf{x}))$. We denote the corresponding demand as $q_d^u(\mathbf{x}, \hat{\mathbf{p}}(\mathbf{x})) \equiv \hat{q}_d^u(\mathbf{x})$. Again, from Assumption 1, it holds that $\hat{q}_d^u(\mathbf{x}) = \hat{q}_d^{-u}(\mathbf{x}) \equiv \hat{q}_d(\mathbf{x})$.

Therefore, $\hat{p}_1(\mathbf{x})$ and $\hat{p}_2(\mathbf{x})$ satisfy the following system:

$$\hat{q}_d(\mathbf{x}) + \hat{p}_d(\mathbf{x})\frac{\partial q_d^u(\mathbf{x}, \hat{\mathbf{p}}(\mathbf{x}))}{\partial p_d^u} + \hat{p}_{-d}(\mathbf{x})\frac{\partial q_{-d}^u(\mathbf{x}, \hat{\mathbf{p}}(\mathbf{x}))}{\partial p_d^u} = 0 \quad \text{for } \ d = 1, 2. \tag{B.2}$$

By applying the implicit function theorem to system (B.2), we derive two equations including $\partial \hat{p}_d(\mathbf{x})/\partial x_d$ and $\partial \hat{p}_d(\mathbf{x})/\partial x_{-d}$. Solving those equations yields

$$\frac{\partial \hat{p}_d(\mathbf{x})}{\partial x_d} = \frac{-\left(2\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_d^{-u}}\right)\frac{\partial q_d^u}{\partial x_d} + \left(2\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)\frac{\partial q_d^u}{\partial x_{-d}}}{\left(2\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_d^{-u}}\right)^2 - \left(2\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)^2} > 0, \tag{B.3}$$

$$\frac{\partial \hat{p}_d(\mathbf{x})}{\partial x_{-d}} = \frac{\left(2\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)\frac{\partial q_d^u}{\partial x_d} - \left(2\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_d^{-u}}\right)\frac{\partial q_d^u}{\partial x_{-d}}}{\left(2\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_d^{-u}}\right)^2 - \left(2\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)^2} > 0, \tag{B.4}$$

where the partial derivatives of the demand function are evaluated at $(\mathbf{x}, \hat{\mathbf{p}}(\mathbf{x}))$. These will appear in the first-order conditions with respect to investment levels.

In stage one, each platform chooses its investment level. The maximization problem of platform d is written as $\max_{x_d} \hat{\pi}_d(\mathbf{x}) \equiv 2\alpha \cdot \hat{p}_d(\mathbf{x})\hat{q}_d(\mathbf{x}) - c(x_d)$. The first-order condition is given as

$$\frac{\partial \hat{\pi}_d(\mathbf{x})}{\partial x_d} = 2\alpha\left(\frac{\partial \hat{p}_d(\mathbf{x})}{\partial x_d}\hat{q}_d(\mathbf{x}) + \hat{p}_d(\mathbf{x})\frac{\partial \hat{q}_d(\mathbf{x})}{\partial x_d}\right) - c'(x_d) = 0, \tag{B.5}$$

where

$$\frac{\partial \hat{q}_d(\mathbf{x})}{\partial x_d} = \frac{\partial q_d^u}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_d^{-u}}\right)\frac{\partial \hat{p}_d}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)\frac{\partial \hat{p}_{-d}}{\partial x_d}. \tag{B.6}$$

After simplification, we rewrite the first-order condition as follows.

$$\hat{p}_d(\mathbf{x})\frac{\partial q_d^u}{\partial x_d} + \left(\begin{array}{c} \left\{ \hat{q}_d(\mathbf{x}) + \hat{p}_d(\mathbf{x}) \left(\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_d^{-u}} \right) \right\} \frac{\partial \hat{p}_d(\mathbf{x})}{\partial x_d} \\ + \hat{p}_d(\mathbf{x}) \left(\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}} \right) \frac{\partial \hat{p}_{-d}(\mathbf{x})}{\partial x_d} \end{array} \right) = \frac{c'(x_d)}{2\alpha} \quad \text{(B.7)}$$

Because of Assumption 1, we obtain the symmetric equilibrium $x_1 = x_2 = x^*$. Let $\mathbf{x}^* = (x^*, x^*)$. After simplifying the above first-order condition with equation (B.2), we can derive the following condition that the equilibrium investment level should satisfy:

$$2\alpha \cdot \hat{p}_d(\mathbf{x}^*) \left\{ \frac{\partial q_d^u}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_d^{-u}} - \frac{\partial q_d^u}{\partial p_{-d}^u} \right) \frac{\partial \hat{p}_d(\mathbf{x}^*)}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}} \right) \frac{\partial \hat{p}_{-d}(\mathbf{x}^*)}{\partial x_d} \right\} = c'(x^*), \quad \text{(B.8)}$$

where the partial derivatives of the demand function are evaluated at $(\mathbf{x}^*, \hat{\mathbf{p}}(\mathbf{x}^*))$. □

Proof of Lemma 2

We solve the game of competition with PMFC clauses using backward induction.

In stage two, as in the linear demand case, letting $p_1^u = p_2^u = p^u$ for $u = 1, 2$, we consider the game in which seller u chooses only p^u as its strategic variable. Given $\mathbf{x} = (x_1, x_2)$, each seller faces the maximization problem, $\max_{p^u} \pi^u = (1-\alpha)\sum_d p^u q_d^u(\mathbf{x}, \mathbf{p}) = (1-\alpha)p^u(q_1^u(\mathbf{x}, \mathbf{p}) + q_2^u(\mathbf{x}, \mathbf{p}))$. The first-order condition is given as shown below.

$$\begin{aligned} \frac{\partial \pi^u}{\partial p^u} &= (1-\alpha)\left\{ q_d^u(\mathbf{x}, \mathbf{p}) + q_{-d}^u(\mathbf{x}, \mathbf{p}) + p^u \left(\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_{-d}^u}{\partial p_d^u} + \frac{\partial q_{-d}^u}{\partial p_{-d}^u} \right) \right\} \\ &= (1-\alpha)\left\{ q_d^u(\mathbf{x}, \mathbf{p}) + q_{-d}^u(\mathbf{x}, \mathbf{p}) + 2p^u \left(\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_{-d}^u} \right) \right\} = 0 \end{aligned} \quad \text{(B.9)}$$

Additional assumptions are necessary for the cross derivatives of the profit functions to ensure that the pricing subgame has a unique interior equilibrium. As explained above, a sufficient condition for the uniqueness can be derived as shown below: $\frac{\partial^2 \pi^u}{(\partial p^u)^2} + \left| \frac{\partial^2 \pi^u}{\partial p^u \partial p^{-u}} \right| < 0$ for all $\mathbf{x}$ and $\mathbf{p}$.

From Assumption 1, two first-order conditions are symmetric, which means that the sellers set the same retail price for all goods, i.e., $p_1^1 = p_1^2 = p_2^1 = p_2^2 \equiv \tilde{p}(\mathbf{x})$. Let $\tilde{\mathbf{p}}(\mathbf{x}) = (\tilde{p}(\mathbf{x}), \tilde{p}(\mathbf{x}), \tilde{p}(\mathbf{x}), \tilde{p}(\mathbf{x}))$. The corresponding demand is given as $q_d^u(\mathbf{x}, \tilde{\mathbf{p}}(\mathbf{x}))$. Again, from Assumption 1, it holds that $q_d^u(\mathbf{x}, \tilde{\mathbf{p}}(\mathbf{x})) = q_d^{-u}(\mathbf{x}, \tilde{\mathbf{p}}(\mathbf{x})) \equiv \tilde{q}_d(\mathbf{x})$.

Therefore, $\tilde{p}(\mathbf{x})$ satisfies the following equation:

$$\tilde{q}_d(\mathbf{x}) + \tilde{q}_{-d}(\mathbf{x}) + 2\tilde{p}(\mathbf{x}) \left(\frac{\partial q_d^u(\mathbf{x}, \tilde{\mathbf{p}}(\mathbf{x}))}{\partial p_d^u} + \frac{\partial q_d^u(\mathbf{x}, \tilde{\mathbf{p}}(\mathbf{x}))}{\partial p_{-d}^u} \right) = 0 \tag{B.10}$$

By applying the implicit function theorem to equation (B.10), we obtain

$$\frac{\partial \tilde{p}(\mathbf{x})}{\partial x_d} = -\frac{\frac{\partial q_d^u}{\partial x_d} + \frac{\partial q_{-d}^u}{\partial x_d}}{2\left(2\frac{\partial q_d^u}{\partial p_d^u} + \frac{\partial q_d^u}{\partial p_d^{-u}} + 2\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)} > 0, \tag{B.11}$$

where the partial derivatives of the demand function are evaluated at $(\mathbf{x}, \tilde{\mathbf{p}}(\mathbf{x}))$. This result will appear in the first-order conditions with respect to investment levels.

In stage one, each platform chooses its investment level. The maximization problem of platform d is written as $\max_{x_d} \tilde{\pi}_d(\mathbf{x}) \equiv 2\alpha \cdot \tilde{p}(\mathbf{x})\tilde{q}_d(\mathbf{x}) - c(x_d)$. The first-order condition is given as

$$\frac{\partial \tilde{\pi}_d(\mathbf{x})}{\partial x_d} = 2\alpha \left(\frac{\partial \tilde{p}_d(\mathbf{x})}{\partial x_d}\tilde{q}_d(\mathbf{x}) + \tilde{p}_d(\mathbf{x})\frac{\partial \tilde{q}_d(\mathbf{x})}{\partial x_d} \right) - c'(x_d) = 0, \tag{B.12}$$

where

$$\frac{\partial \tilde{q}_d(\mathbf{x})}{\partial x_d} = \frac{\partial q_d^u}{\partial x_d} + \frac{\partial q_d^u}{\partial p_d^u}\frac{\partial p_d^u}{\partial x_d} + \frac{\partial q_d^u}{\partial p_d^{-u}}\frac{\partial p_d^{-u}}{\partial x_d} + \frac{\partial q_d^u}{\partial p_{-d}^u}\frac{\partial p_{-d}^u}{\partial x_d} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\frac{\partial p_{-d}^{-u}}{\partial x_d}. \tag{B.13}$$

After simplification, we can rewrite the first-order condition as follows.

$$\tilde{p}(\mathbf{x})\frac{\partial q_d^u}{\partial x_d} + \left\{ \tilde{q}_d(\mathbf{x}) + \tilde{p}(\mathbf{x}) \left(\frac{\partial q_d^u}{p_d^u} + \frac{\partial q_d^u}{p_d^{-u}} + \frac{\partial q_d^u}{p_{-d}^u} + \frac{\partial q_d^u}{p_{-d}^{-u}} \right) \right\} \frac{\partial \tilde{p}(\mathbf{x})}{x_d} = \frac{c'(x_d)}{2\alpha} \tag{B.14}$$

Because of Assumption 1, we obtain the symmetric equilibrium $x_1 = x_2 = x^{**}$. Let $\mathbf{x}^{**} = (x^{**}, x^{**})$. After simplifying the above first-order condition with equation (B.10), we can derive the following condition that the equilibrium investment level should satisfy:

$$2\alpha \cdot \tilde{p}(\mathbf{x}^{**}) \left\{ \frac{\partial q_d^u}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_d^{-u}} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}} \right) \frac{\partial \tilde{p}(\mathbf{x}^{**})}{\partial x_d} \right\} = c'(x^{**}), \tag{B.15}$$

where the partial derivatives of the demand function are evaluated at $(\mathbf{x}^{**}, \tilde{\mathbf{p}}(\mathbf{x}^{**}))$. □

Proof of Proposition 4

First, we compare the first-order conditions with respect to retail pricing in stage two, as derived in equations (B.2) and (B.10).

Lemma 5. *Given a symmetric investment* $\mathbf{x} = (x, x)$*, it holds that* $\hat{p}_d(\mathbf{x}) = \tilde{p}(\mathbf{x})$*.*

This lemma corresponds to Remark 1, which implies that, if both platforms choose the same investment level which is common irrespective of PMFC clauses, then the retail prices are unaffected by the presence of these clauses.

Then, we compare the first-order conditions with respect to investments under both competition with and without PMFC clauses as presented below:

$$\hat{p}_d(\mathbf{x})\left\{\frac{\partial q_d^u}{\partial x_d} + \underbrace{\left(\frac{\partial q_d^u}{\partial p_d^{-u}} - \frac{\partial q_d^u}{\partial p_{-d}^u}\right)\frac{\partial \hat{p}_d(\mathbf{x})}{\partial x_d} + \left(\frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)\frac{\partial \hat{p}_{-d}(\mathbf{x})}{\partial x_d}}_{\substack{\text{indirect effects of investment on demands} \\ \text{under competition } without \text{ PMFC clause}} \equiv \hat{\zeta}(\mathbf{x})}\right\} = \frac{c'(x)}{2\alpha} \tag{B.16}$$

$$\tilde{p}(\mathbf{x})\left\{\frac{\partial q_d^u}{\partial x_d} + \underbrace{\left(\frac{\partial q_d^u}{\partial p_d^{-u}} + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right)\frac{\partial \tilde{p}(\mathbf{x})}{\partial x_d}}_{\substack{\text{indirect effects of investment on demands} \\ \text{under competition } with \text{ PMFC clause}} \equiv \tilde{\zeta}(\mathbf{x})}\right\} = \frac{c'(x)}{2\alpha} \tag{B.17}$$

On one hand, by definition, equation (B.16) holds at $\mathbf{x} = \mathbf{x}^*$ (i.e., $x_1 = x_2 = x^*$). On the other hand, evaluating the difference between left-hand and right-hand sides of equation (B.17) at $\mathbf{x} = \mathbf{x}^*$ yields $\tilde{\zeta}(\mathbf{x}^*) - \hat{\zeta}(\mathbf{x}^*)$, which can be either positive, negative, or zero. When it takes a positive (negative) value, x^* is less (greater) than x^{**}. We have the following.

$$\begin{aligned}
&\tilde{\zeta}(\mathbf{x}^*) - \hat{\zeta}(\mathbf{x}^*) \\
=&\frac{\partial q_d^u}{\partial p_d^{-u}}\underbrace{\left(\frac{\partial \tilde{p}(\mathbf{x}^*)}{\partial x_d} - \frac{\partial \hat{p}_d(\mathbf{x}^*)}{\partial x_d}\right)}_{=-\frac{1}{2}\left(\frac{\partial \hat{p}_d(\mathbf{x}^*)}{\partial x_d} - \frac{\partial \hat{p}_{-d}(\mathbf{x}^*)}{\partial x_d}\right)} + \frac{\partial q_d^u}{\partial p_{-d}^u}\left(\frac{\partial \hat{p}_d(\mathbf{x}^*)}{\partial x_d} - \frac{\partial \hat{p}_{-d}(\mathbf{x}^*)}{\partial x_d}\right) + \frac{\partial q_d^u}{\partial p_{-d}^{-u}}\underbrace{\left(\frac{\partial \tilde{p}(\mathbf{x}^*)}{\partial x_d} - \frac{\partial \hat{p}_{-d}(\mathbf{x}^*)}{\partial x_d}\right)}_{=\frac{1}{2}\left(\frac{\partial \hat{p}_d(\mathbf{x})}{\partial x_d} - \frac{\partial \hat{p}_{-d}(\mathbf{x})}{\partial x_d}\right)} && \text{(B.18)} \\
=&\left(\frac{\partial \hat{p}_d(\mathbf{x}^*)}{\partial x_d} - \frac{\partial \hat{p}_{-d}(\mathbf{x}^*)}{\partial x_d}\right)\left(-\frac{1}{2}\frac{\partial q_d^u}{\partial p_d^{-u}} + \frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{1}{2}\frac{\partial q_d^u}{\partial p_{-d}^{-u}}\right) && \text{(B.19)} \\
>&0 \iff \frac{1}{2}\frac{\partial q_d^u}{\partial p_d^{-u}} < \frac{\partial q_d^u}{\partial p_{-d}^u} + \frac{1}{2}\frac{\partial q_d^u}{\partial p_{-d}^{-u}}\ , && \text{(B.20)}
\end{aligned}$$

In those equations, the partial derivatives of the demand function are evaluated at $(\mathbf{x}^*, \hat{\mathbf{p}}(\mathbf{x}^*))$. Therefore, if inequality (B.20) holds, then the PMFC clauses promote the platforms' investment incentives (i.e., $x^* < x^{**}$). It is noteworthy that, with linear demand system (2), condition (B.20) is rewritten as $\frac{1}{2}\mu < \delta - \frac{1}{2}\delta\mu$, which is equivalent to the condition shown in Proposition 1 (i.e., $\delta > \frac{\mu}{2-\mu}$).

Furthermore, as shown in equations (B.3) and (B.11), the retail prices set in stage two are increasing in the investment levels chosen in stage one. In addition, as in Lemma 5, given the same investment level, the sellers set the retail price at the same level, irrespective of whether PMFC clauses are imposed, or not. Overall, the presence of PMFC clause raises the equilibrium retail price, as well as the investment level, if inequality (B.20) is satisfied. □

Appendix C: Proofs for endogenous decisions on revenue shares

Proof of Lemma 3

We examine the case of competition *without* PMFC clauses. In stage two, seller u chooses p_1^u and p_2^u to maximize $\pi^u = \sum_{d=1,2}(1-\alpha_d)p_d^u q_d^u$. If $\alpha_1 = \alpha_2 = 1$, then the profit becomes equal to zero. For ease of exposition, we presume that when $\alpha_1 = \alpha_2 = 1$, seller u maximizes its total revenue, $\sum_{d=1,2} p_d^u q_d^u$, as in the case of $\alpha_1 = \alpha_2$. Solving these maximization problems, we derive $p_d^1 = p_d^2 = \hat{p}_d$, where $\hat{p}_d$ is characterized as the following.

$$\hat{p}_d \equiv \begin{cases} \frac{1-\mu}{2-\mu}(1 + x_d + \beta x_{-d}) & \text{if } \alpha_1 = \alpha_2 = 1 \\ \frac{(1-\alpha_{-d})(1-\mu)}{(2-\mu)^2\{(1-\delta^2)(1-\alpha_1-\alpha_2)+\alpha_1\alpha_2\}-\delta^2\{(1-\mu)\alpha_1+\alpha_2\}\{\alpha_1+(1-\mu)\alpha_2\}} & \\ \times \begin{pmatrix} (1-\delta)\left\{(2+\delta-\mu-\delta\mu)(1-\alpha_d)+\delta(1-\alpha_{-d})\right\} \\ +\left\{(1-\delta^2)(2-\mu)-(2-\beta\delta-\delta^2-\mu+\delta^2\mu)\alpha_d-\delta(\beta-\delta)\alpha_{-d}\right\}x_d \\ +\left\{\beta(1-\delta^2)(2-\mu)+(\delta-2\beta+\beta\mu+\beta\delta^2(1-\mu))\alpha_d-\delta(1-\beta\delta)\alpha_{-d}\right\}x_{-d} \end{pmatrix} & \text{otherwise} \end{cases} \tag{C.1}$$

Here, when $\alpha_1 = \alpha_2$, the second line of equation (C.1) is equal to the first line, which is the same as that shown in equation (3). We denote the corresponding demand by $\hat{q}_d$.

In stage one, platform d chooses x_d and α_d to maximize $\hat{\pi}_d = 2\alpha_d\ \hat{p}_d\ \hat{q}_d - \frac{k}{2}x_d^2$. Solving the platforms' profit-maximizations yields the symmetric equilibrium, $x_1 = x_2 = X^*$ and $\alpha_1 = \alpha_2 = \alpha^*$, where X^* and α^* are characterized as shown below.

$$(X^*, \alpha^*) = \begin{cases} \left(\frac{(1-\mu)Z^*}{k(2-\mu-\delta\mu)(2+\mu-\mu^2)-(1+\beta)(1-\mu)Z^*}\ ,\ \frac{(2-\mu)(1-\delta^2)}{2-\mu-\delta\mu}\right) & \text{if } \delta > \frac{\mu}{2-\mu} \\ \left(x^*|_{\alpha=1}\ ,\ 1\right) & \text{otherwise} \end{cases} \tag{C.2}$$

Note that α^* is less than 1 if $\delta > \mu/(2-\mu)$ and is equal to 1 if $\delta \leq \mu/(2-\mu)$. By virtue of these results, one can derive the other equilibrium outcomes, denoted by P^* and Q^*. □

Proof of Lemma 4

We investigate the case of competition *with* PMFC clauses. As in the main analysis, with PMFC clauses, each seller chooses only one retail price, p^u, in stage two. Seller u chooses p^u to maximize its profit, $\pi^u = \sum_{d=1,2}(1-\alpha_d)p^u q_d^u$. As explained above, we presume that when $\alpha_1 = \alpha_2 = 1$, seller u maximizes its total revenue, $\sum_{d=1,2} p_d^u q_d^u$. Solving these problems yields the following pricing.

$$p^1 = p^2 = \tilde{p} \equiv \begin{cases} \frac{1-\mu}{2-\mu}\left(1 + \frac{1+\beta}{2}(x_1 + x_2)\right) & \text{if } \alpha_1 = \alpha_2 = 1 \\ \frac{1-\mu}{2-\mu}\left(1 + \frac{\sum_{d=1,2} x_d\{(1+\beta)(1-\delta)-(1-\beta\delta)\alpha_d-(\beta-\delta)\alpha_{-d}\}}{(1-\delta)(2-\alpha_1-\alpha 2)}\right) & \text{otherwise} \end{cases} \tag{C.3}$$

When $\alpha_1 = \alpha_2$, the second line of equation (C.3) is equal to the first line, which is the same as that shown in equation (8). Moreover, when $x_1 = x_2 = x$, $\tilde{p} = \frac{1-\mu}{2-\mu}(1 + x + \beta x) > 0$. We denote the corresponding demand by $\tilde{q}_d$.

In stage one, platform d chooses x_d and α_d to maximize its profit, $\tilde{\pi}_d = 2\alpha_d\, \tilde{p}\, \tilde{q}_d - \frac{k}{2}x_d^2$. Here, fixing $x_1 = x_2 = x$, then $\frac{\partial \tilde{\pi}_d}{\partial \alpha_d} = \frac{2(1-\mu)(1+x+\beta x)^2}{(1+\delta)(1+\mu)(2-\mu)^2} > 0$ holds for $(\alpha_1, \alpha_2) \in [0,1]^2$. This outcome implies that each platform sets the highest revenue share as $\alpha^{**} = 1$.

Given $\alpha_1 = \alpha_2 = 1$, then solving the first-order condition for platforms' profit-maximization with respect to investment level x_d yields $x_1 = x_2 = X^{**}$, which is equal to $x^{**}|_{\alpha=1}$. Based on these results, one can derive the other equilibrium outcomes as $P^{**} = p^{**}|_{\alpha=1}$ and $Q^{**} = q^{**}|_{\alpha=1}$. □

Proof of Proposition 5

First, we examine the case of $\delta \leq \frac{\mu}{2-\mu}$, in which $X^* = x^*|_{\alpha=1}$ and $X^{**} = x^{**}|_{\alpha=1}$. Consequently, $P^* = p^*|_{\alpha=1}$, $P^{**} = p^{**}|_{\alpha=1}$, $Q^* = q^*|_{\alpha=1}$, and $Q^{**} = q^{**}|_{\alpha=1}$. Actually, Proposition 1 and Corollary 1 are obtained for all $\alpha \in [0,1]$. It follows that $X^* > X^{**}$, $P^* > P^{**}$, $Q^* > Q^{**}$, and $CS^* > CS^{**}$ when $\delta \leq \frac{\mu}{2-\mu}$.

Next, we turn to the case of $\delta > \frac{\mu}{2-\mu}$. In this parameter range, it turns out that $X^* < x^*|_{\alpha=1} < x^{**}|_{\alpha=1} = X^{**}$. In the same vein, we can show that $P^* < P^{**}$, $Q^* < Q^{**}$, and $CS^* < CS^{**}$ hold. □

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