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Philippe Bontems, Stephen F. Hamilton and Jason Lepore

Toulouse School of Economics

Sequential Pricing on Multisided Platforms

Philippe Bontems, Stephen F. Hamilton and Jason Lepore *

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Abstract

Multisided platforms have emerged as an increasingly important market structure with the rise of the digital economy. In this paper, we consider sequential price setting behavior by platforms and demonstrate sequential pricing outcomes Pareto dominate simultaneous pricing outcomes in terms of firm and industry profits. We compare policy implications and find prices are more balanced across the platform and average prices are higher under sequential pricing than under simultaneous pricing. We also demonstrate that pricing power can be considered independently on each side of the market under multihoming behavior.

JEL Classification: D43; L13; L40; L86
Keywords: Network Effects; Two-Sided Markets; Platform Competition.

*Hamilton and Lepore are Professors of Economics in the Department of Economics in the Orfalea School of Business at California Polytechnic State University - San Luis Obispo. Bontems is a senior research fellow at Toulouse School of Economics, INRAE, University of Toulouse Capitole, France. Philippe Bontems acknowledges funding from ANR under grant ANR-17-EURE-0010 (Investissements d'Avenir program). Contact Author: Hamilton, Orfalea College of Business, Cal Poly, 1 Grand Ave., San Luis Obispo, CA 93407 805-756-255. Email: shamilto@calpoly.edu.

1 Introduction

Since the pioneering work of Rochet and Tirole (2003) and Armstrong and Wright (2007), considerable research has emerged to examine oligopoly pricing on multisided platforms. Yet, the analysis to date on oligopoly pricing with cross-platform network effects has focused almost exclusively on pricing games in which platforms set prices simultaneously on both sides of the market. [1] In this paper, we examine pricing games with sequential timing on platforms.

Our main findings are as follows. First, we show that platforms that commit to setting prices on one side of the market (e.g., customers) prior to setting prices on the other (e.g., merchants) can use sequential pricing as a tool to soften price competition on the most heavily cross-subsidized side of the market. Second, we demonstrate that the sequential pricing equilibrium in which platforms pre-commit to prices on the side of the market with smaller network externalities Pareto dominates the simultaneous pricing equilibrium in terms of profits. We find this to be true both for singlehoming and multihoming behavior. Third, we demonstrate that sequential timing attenuates the pricing implication of cross-platform network effects in the singlehoming case, and completely eliminates them in the multihoming case.

Our results are consistent with recent findings in the literature on platform competition. Jeitschko and Tremblay (2020) consider a model of simultaneous price competition between homogeneous platforms and show that multihoming makes it possible to escape the Bertrand paradox when competition is weak. In our model, the possibility of multihoming also increases platform profits, but in a context of heterogeneous platforms and sequential pricing.

Belleflamme and Peitz (2019) and Bakos and Halaburda (2020) examine multihoming between platforms with simultaneous pricing on both sides. Bakos and Halaburda (2020) show that when agents can multihome on both sides, then the incentive to subsidize the other side disappears. In our model, we show that setting prices on the multihoming side of the market prior to setting prices on the singlehoming side fully dissipates cross-platform externalities, resulting in monopoly prices on the

[1] An important exception is Hagiu (2006), who considers video game platforms in which content providers have to develop their products prior to the arrival of players.

multihoming side and standard “one-sided” oligopoly prices on the singlehoming side.

2 The Model

Consider two, horizontally differentiated and symmetric platforms that are located at the endpoints of a unit line. On each side of the market, a continuum of sellers (S) and buyers (B) is uniformly distributed on the unit interval with measure one. Following Armstrong and Wright (2007), buyers and sellers incur opportunity cost of visiting a platform that increases linearly over distance at rates t_k, $k = B, S$. Interacting with members of the opposing group generates positive cross-group network externalities, and the platforms facilitate exchange between members by selecting access fees to members of each group, p_k, $k = B, S$. Consumption services in the market are non rival and agents on each side of the market receive the network benefit $b_k n_l$, $k = B, S$, from participating in a market that allows them to interact with n_l, $l \neq k$, agents on the opposite side of the market.

The utility of a consumer belonging to group $k = B, S$, participating in platform $i = 1, 2$ located in x_i (with $x_1 = 0$ and $x_2 = 1$) on the unit line interval $x \in (0, 1)$ is:

$$u_k^i(x) = v_k - p_k^i - t_k |x_i - x| + b_k n_l^i, \tag{1}$$

where n_l^i is the measure of agents participating on side $l = B, S$ of platform i.

Agents on the B side of the market singlehome, while agents on the S side of the market either singlehome or multihome. In the singlehoming case, type-S agents are limited to choosing at most one platform, whereas under multihoming type-S agents can be active on both platforms at once.[2]

In the analysis to follow, we first examine the case of simultaneous price setting behavior, and then turn to the case of sequential pricing by the platforms on each side of the market.

3 Singlehoming

In the singlehoming case, the demand facing platform i from type-S agents, n_S^i, is given by the location of the marginal consumer such that $u_S^1 = u_S^2$ in equation (1). We denote this location by $\widetilde{x}_S^i$, which

[2]Existence conditions for all the equilibria examined in the text are provided in Appendix C.

results in demand facing platform i of

$$n_S^i = \widetilde{x}_S^i = \frac{1}{2} + \frac{p_S^j - p_S^i - b_S(1 - 2n_B^i)}{2t_S}. \quad (2)$$

Proceeding similarly on the B side of the market, consumer demand for platform i in market B is

$$n_B^i = \widetilde{x}_B^i = \frac{1}{2} + \frac{p_B^j - p_B^i - b_B(1 - 2n_S^i)}{2t_B}, \quad (3)$$

Simultaneously solving equations (3) and (2), demand on each side of the platform can be written

$$\begin{aligned} n_B^i(p_S, p_B) &= \frac{1}{2} + \frac{t_S\left(p_B^j - p_B^i\right) + b_B(p_S^j - p_S^i)}{2\Delta}, \\ n_S^i(p_S, p_B) &= \frac{1}{2} + \frac{t_B\left(p_S^j - p_S^i\right) + b_S(p_B^j - p_B^i)}{2\Delta}. \end{aligned}$$

where $p_S = (p_S^1, p_S^2)$ and $p_B = (p_B^1, p_B^2)$ denotes the vector of prices on the S side and B side of the market, respectively, and $\Delta = t_B t_S - b_B b_S > 0$.

The profit of platform i is

$$\pi^i(p_S, p_B) = (p_S^i - f_S)n_S^i(p_S, p_B) + (p_B^i - f_B)n_B^i(p_S, p_B). \quad (4)$$

We first consider the simultaneous pricing equilibrium following Armstrong and Wright (2007).[3]

3.1 Simultaneous pricing game

Under simultaneous pricing, a unique price equilibrium exists with the symmetric equilibrium prices, $\hat{p}_S = p_S^1 = p_S^2$ and $\hat{p}_B = p_B^1 = p_B^2$, where $\hat{p}_S = \hat{p}_B = f_S + t_S - b_B$. Profit for each platform in the symmetric market equilibrium is

$$\hat{\pi} = \frac{t_S + t_B - b_S - b_B}{2}.$$

3.2 Sequential pricing game

We specify our sequential pricing game as a two-stage game in which the platforms simultaneously select prices for market S in stage 1, and then simultaneously select prices for market B in stage 2. Given the stage 1 prices, $\overline{p}_S = (\overline{p}_S^1, \overline{p}_S^2)$, the problem for firm i in stage 2 is

$$\max_{p_B^i} \pi^i(\overline{p}_S, p_B) = (\overline{p}_S^i - f_S)n_S^i(\overline{p}_S, p_B) + (p_B^i - f_B)n_B^i(\overline{p}_S, p_B).$$

[3] We confine our analysis to consider the simplest pricing strategy, the so-called "flat pricing", which means that the access price for each side does not depend on the participation rate among agents on the other side of the platform.

The first-order necessary condition for a maximum is

$$\frac{\partial \pi^i(\overline{p}_S, p_B)}{\partial p_B^i} = n_B^i - (p_B^i - f_B)\left(\frac{t_S}{2\Delta}\right) - (\overline{p}_S^i - f_S)\left(\frac{b_S}{2\Delta}\right) = 0. \tag{5}$$

Solving the system of equations (5) for the equilibrium prices $p_B^{i*}(\overline{p}_S)$, we get:

$$p_B^{i*}(\overline{p}_S) = f_B + t_B - \frac{1}{t_S}\left((b_B - f_S)b_S + \frac{\overline{p}_S^i}{3}(2b_S + b_B) - \frac{\overline{p}_S^j}{3}(b_B - b_S)\right). \tag{6}$$

In the case of symmetric pricing on the S side of the market, we have the following result:

Lemma 1. *Suppose there exists a symmetric price equilibrium on the S side of the market, $\overline{p}_S^1 = \overline{p}_S^2 = p_S^*$. Then we have a symmetric price equilibrium on the B side with:*

$$p_B^{1*} = p_B^{2*} = p_B^* = f_B + t_B - \frac{b_S}{t_S}(b_B - f_S + p_S^*)$$

and

$$p_B^* - \hat{p}_B = \frac{b_S}{t_S}(\hat{p}_S - p_S^*)$$

so that $p_B^* > \hat{p}_B \Leftrightarrow p_S^* < \hat{p}_S$.

Proof. With $\overline{p}_S^1 = \overline{p}_S^2 = p_S^*$ we obtain $p_B^{1*} = p_B^{2*} = p_B^* = f_B + t_B - \frac{b_S}{t_S}(b_B - f_S + p_S^*)$. Computing $p_B^* - \hat{p}_B$, we get $p_B^* - \hat{p}_B = \frac{b_S}{t_S}(\hat{p}_S - p_S^*)$. □

This outcome is due to the seesaw principle of two-sided markets (Rochet Tirole 2006), as a higher price on the S side of the market corresponds with a lower price on the B side of the market.

Now consider the choice of p_S in the first stage of the game. Profit for platform 1 is

$$\tilde{\pi}^i(p_S) = \pi^i(p_B^{1*}(p_S), p_B^{2*}(p_S), p_S).$$

The first-order necessary condition for a profit maximum is

$$\frac{\partial \tilde{\pi}^i}{\partial p_S^i} = \underbrace{\frac{\partial \pi^i}{\partial p_B^i}}_{=0}\frac{\partial p_B^{i*}}{\partial p_S^i} + \frac{\partial \pi^i}{\partial p_S^i} + \underbrace{\frac{\partial \pi^i}{\partial p_B^j}\frac{\partial p_B^{j*}}{\partial p_S^i}}_{\text{Strategic term}} = 0. \tag{7}$$

Notice that the essential difference between the simultaneous and sequential pricing conditions is that sequential pricing introduces a strategic effect in equation (7). Evaluating this term, we have

$\frac{\partial \pi^i}{\partial p_B^j} = (p_S^i - f_S)\frac{\partial n_S^i}{\partial p_B^j} + (p_B^i - f_B)\frac{\partial n_B^i}{\partial p_B^j} > 0$ and $\frac{\partial p_B^{j*}}{\partial p_S^i} = \frac{b_B - b_S}{3t_S}$, which implies $\frac{\partial \pi^i}{\partial p_B^j}\frac{\partial p_B^{j*}}{\partial p_S^i} \overset{s}{=} b_B - b_S$, where "$\overset{s}{=}$" denotes "equal in sign". It follows immediately from equation (7) that $\frac{\partial \pi^i}{\partial p_S^i} < 0$ whenever $b_B - b_S > 0$. Thus, we arrive at the following results:

Proposition 1. *If $b_B - b_S > 0$, then the symmetric equilibrium of the sequential pricing game entails $p_S^* > \hat{p}_S$.*

Proof. The FOC for the simultaneous pricing game equilibrium is:

$$\begin{aligned} \left.\frac{\partial \pi^i}{\partial p_S^i}\right|_{p_S^i = \hat{p}_S} &= n_S^i + (\hat{p}_S - f_S)\frac{\partial n_S^i}{\partial p_S^i} + (\hat{p}_B - f_B)\frac{\partial n_B^i}{\partial p_B^i} = 0 \\ &= \frac{1}{2} - (\hat{p}_S - f_S)\frac{t_B}{2\Delta} - (\hat{p}_B - f_B)\frac{b_B}{2\Delta} = 0. \end{aligned} \tag{8}$$

Now the FOC for the sequential pricing game equilibrium with $b_B - b_S > 0$ implies that:

$$\begin{aligned} \left.\frac{\partial \pi^i}{\partial p_S^i}\right|_{p_S^i = p_S^*} &= n_S^i + (p_S^* - f_S)\frac{\partial n_S^i}{\partial p_S^i} + (p_B^* - f_B)\frac{\partial n_B^i}{\partial p_B^i} < 0 \\ &= \frac{1}{2} - (p_S^* - f_S)\frac{t_B}{2\Delta} - (p_B^* - f_B)\frac{b_B}{2\Delta} < 0 \end{aligned} \tag{9}$$

Using $p_B^* = \hat{p}_B + \frac{b_S}{t_S}(\hat{p}_S - p_S^*)$ (from Lemma 1) and replacing in (9), we get

$$\left.\frac{\partial \pi^i}{\partial p_S^i}\right|_{p_S^i = p_S^*} = \frac{1}{2} - (p_S^* - f_S)\frac{t_B}{2\Delta} - (\hat{p}_B + \frac{b_S}{t_S}(\hat{p}_S - p_S^*) - f_B)\frac{b_B}{2\Delta} < 0$$

Rearranging and using (8) to replace $\hat{p}_B$, gives $\left.\frac{\partial \pi^i}{\partial p_S^i}\right|_{p_S^i = p_S^*} = \frac{1}{2t_S}(\hat{p}_S - p_S^*) < 0$. □

Proposition 2. *Suppose $b_B > b_S$. A sequential pricing game where platforms set prices on the S side of the market prior to setting prices on the B side of the market yields larger profits in the symmetric equilibrium, compared to the simultaneous pricing equilibrium.*

Proof. Symmetric equilibrium profit under the simultaneous pricing game is $\hat{\pi} = \frac{1}{2}(\hat{p}_S - f_S + \hat{p}_B - f_B)$, whereas under the sequential pricing game it is $\pi^* = \frac{1}{2}(p_S^* - f_S + p_B^* - f_B)$. Then

$$\pi^* - \hat{\pi} = \frac{1}{2}(p_S^* - \hat{p}_S + p_B^* - \hat{p}_B) = (p_S^* - \hat{p}_S)\frac{t_S - b_S}{2t_S}$$

where the latter equality holds by Lemma 1. Because $b_B > b_S$ implies $p_S^* > \hat{p}_S$, it follows from the restriction $t_S - b_S > 0$ that $\pi^* - \hat{\pi} > 0$. □

In the simultaneous pricing game, the cross-subsidy provided to agents in market S for participation on the platform is larger than the subsidy provided to agents in market B when $b_B > b_S$. Under these conditions, setting prices first on the S side of the market prior to setting prices on the B side of the market serves to soften price competition on the S side of the market. This is advantageous when price competition between platforms is relatively more intense on the S side of the market.

Now suppose the firms sequentially set prices first on the B side of the market prior to setting prices on the S side of the market. When $b_B > b_S$, it follows from Proposition 2 that $p_S^* < \hat{p}_S$ and thus $\pi^* - \hat{\pi} < 0$. Hence, there is a clear ranking of profits: Profits are largest when firms set prices sequentially on market Sprior to setting prices on market B when $b_B > b_S$, and smallest when setting prices first on the B side of the market. The opposite is true when $b_S > b_B$.

Solving the system of equations (7) simultaneously for each firm in the stage 1 game, and substituting these results in the stage 2 choices yields the equilibrium prices in the sequential game

$$\begin{aligned} p_S^* &= f_S + t_S - b_B + \frac{b_B - b_S}{3}, \\ p_B^* &= f_B + t_B - b_S\left(1 + \frac{b_B - b_S}{3t_S}\right). \end{aligned}$$

Notice when $b_B = b_S$, the symmetric equilibrium prices in the sequential game reduce to the price level under simultaneous pricing. This outcome illustrates the strategic attenuation effect of setting sequential prices first on the side of the platform where price competition is less intense.

4 Multihoming

In this section, we examine the case in which agents on the S side of the platform have the potential to multihome, while agents on the B side continue to singlehome. Singlehoming on the B side results in demand for platform i of

$$n_B^i = \frac{1}{2} + \frac{p_B^j - p_B^i - b_B(n_S^j - n_S^i)}{2t_B}.$$

Multihoming on the S side results in demand for platform i of

$$n_S^i = \max\left(0, \min\left(\frac{v_S - p_S^i + b_S n_B^i}{t_S}, 1\right)\right).$$

The multihoming case thus encompasses symmetric equilibrium outcomes with zero participation by agents on the S side of the market, full multihoming by all type-S agents, as well as partial multihoming outcomes in which a subset of agents singlehome and the remaining agents multihome. We consider each case, in turn.

4.1 Zero participation on the S side

Consider, first, the symmetric equilibrium in which prices on S side of the market are large enough such that $n_S^i = 0$. In this case, agents are only active on one side of the market, and it follows that the platforms play a standard Hotelling game on the B side. This results in the equilibrium prices, $p_B = f_B + t_B$, and equilibrium profits $\Pi = \frac{t_B}{2}$. For such an outcome to be an equilibrium, the symmetric equilibrium price p_S must be larger than $v_S + b_S/2$. The timing of prices on each side of the market (simultaneous or sequential) has no impact on the equilibrium in this case.

4.2 Full Multihoming

Next, consider the case of full multihoming, in which all agents on side S of the market multihome, $n_s^i = 1$.[4] This outcome results in demand on the B side of platform i given by

$$n_B^i(p_B) = \frac{1}{2} + \frac{p_B^j - p_B^i}{2t_B}$$

For full multihoming to hold, it must be the case that the price on side S of the market is not too large in the sense that

$$p_S^i \leq v_S - t_S + n_B^i b_S \text{ for } i = 1, 2. \tag{10}$$

The problem facing platform i is to select p_S^i and p_B^i to maximize

$$\pi_i(p_S^i, p_B^i) = (p_B^i - f_B)n_B^i(p_B) + p_S^i - f_S. \tag{11}$$

4.2.1 Simultaneous pricing game

Under simultaneous pricing, a unique price equilibrium exists with the symmetric equilibrium prices (Armstrong and Wright, 2007), $\widehat{p}_B^m = f_B + t_B - b_S$. Notice that the platform price on the B side

[4] We confine attention to cases where the full multihoming equilibrium exists. Details on the primitives needed for existence of such an equilibrium are provided in Belleflamme and Peitz (2019).

of the market does not depend on whether agents on the S side of the market are singlehoming or multihoming; that is, $\widehat{p}_B^m = \widehat{p}_B$. Substitution into the constraint (10) yields $\widehat{p}_S^m = v_S - t_S + \frac{b_S}{2}$. Equilibrium profits for each platform are $\widehat{\pi}^m = v_S + t_B/2 - t_S - f_S$.

4.2.2 Sequential pricing game

In stage 2 of the sequential pricing game, platform i sets prices on the B side of the market given the prices previously determined in the stage 1 pricing game, $\overline{p}_S^i$. The problem facing platform i is to select p_B^i to maximize

$$\pi^i(\overline{p}_S^i, p_B^i) = (p_B^i - f_B)\left(\frac{1}{2} + \frac{p_B^j - p_B^i}{2t_B}\right) + \overline{p}_S^i - f_S. \tag{12}$$

The problem reduces to a standard one-sided Hotelling pricing game. Solving for prices in the symmetric market equilibrium gives $p_B^* = f_B + t_B > \widehat{p}_B^m$.

Now consider the choice of p_S in the first stage of the game given equilibrium pricing in the stage 2 subgame. In stage 1, each platform anticipates the pricing equilibrium, p_B^*, in the continuation game. Accordingly, the problem facing platform i is to select p_S^i to maximize $\pi^i(p_S^i, p_B^i) = t_B/2 + p_S^i - f_S$ subject to the constraint (10). Because the platforms anticipate symmetric market shares of consumers on side B of the platform, $n_B^i = \frac{1}{2}$, the pricing constraint reduces to

$$p_S^i \leq v_S - t_S + \frac{b_S}{2} \text{for } i = 1, 2. \tag{13}$$

As before, it follows immediately from inspection of the objective function that the constraint always binds. Therefore, the equilibrium price in the Sside game is $p_S^* = v_S - t_S + \frac{b_S}{2}$.

Notice that the equilibrium price to type-S agents is the same in both cases, $p_S^* = \widehat{p}_S = v_S - t_S + \frac{b_S}{2}$, while the equilibrium price to type-B agents is strictly higher in the sequential pricing equilibrium $p_B^* = f_B + t_B > f_B + t_B - b_S = \widehat{p}_B$. Thus, we arrive at:

Proposition 3. *In a sequential pricing game where platforms set prices on the multihoming side of the market prior to setting prices on the singlehoming side, cross-platform externalities are fully dissipated in the sense that the platforms set monopoly prices on the multihoming side and standard "one-sided" Hotelling prices on the singlehoming side.*

4.3 Partial multihoming

Suppose a portion of type-S agents multihome, while the remaining type-S agents singlehome. This outcome under partial multihoming is characterized by $0 < n_S^i < 1$, where the "reach" of each platform is less than the full extent of the line on the multihoming side of the market. That is, multihoming agents arise in the middle of the line segment on side S of the market under circumstances where $\frac{1}{2} < n_S^i$. Solving the resulting system of equations yields the following demands:

$$n_B^i = \frac{1}{2} + \frac{t_S\left(p_B^j - p_B^i\right) + b_B(p_S^j - p_S^i)}{2\Delta}, \tag{14}$$

as above, while the demand facing platform i on the S side of the market is

$$n_S^i = \frac{2v_S + b_S}{2t_S} + \frac{b_S}{2\Delta}\left(p_B^j - p_B^i\right) + \frac{1}{2t_S\Delta}(b_B b_S p_S^j - (\Delta + t_S t_B)p_S^i). \tag{15}$$

Partial multihoming arises in the symmetric market equilibrium when $v_S - t_S + b_S/2 < p_S < v_S + b_S/2$.

Profit for platform i is

$$\pi^i = (p_S^i - f_S)n_S^i + (p_B^i - f_B)n_B^i. \tag{16}$$

where both n_S^i and n_B^i are given by (15) and (14) respectively.

4.3.1 Simultaneous pricing game

The symmetric price equilibrium (Belleflamme and Peitz 2019) is given by

$$\widehat{p}_S^p = \frac{f_S + v_S}{2} - \frac{b_B - b_S}{4} \tag{17}$$

$$\widehat{p}_B^p = f_B + t_B - \frac{b_S}{4t_S}(2v_S + b_S + 3b_B - 2f_S). \tag{18}$$

On the S side of the market, the price $\widehat{p}_S^p$ is the monopoly price, while on the B side of the market, the price $\widehat{p}_B^p$ is the Hotelling price that depends on externality terms and side S market characteristics.

Profits in the symmetric equilibrium are

$$\Pi = \frac{1}{16t_S}\left(8t_S t_B - (b_B + b_S)^2 - 4b_B b_S + 4(v_S - f_S)^2\right).$$

4.3.2 Sequential pricing game

Now consider the case in which platforms commit to pricing on the S side of the market before engaging price competition on the B side. For given prices selected by the platforms on the S side of the market, platform i chooses the price on side B of the market such that

$$\frac{\partial \pi^i}{\partial p_B^i} = (p_S^i - f_S)\frac{\partial n_S^i}{\partial p_B^i} + n_B^i + (p_B^i - f_B)\frac{\partial n_B^i}{\partial p_B^i} = 0. \tag{19}$$

In the first stage of the game, the platforms choose prices on the S side of the market according to

$$\frac{\partial \pi^i}{\partial p_S^i} = (p_S^i - f_S)\frac{\partial n_S^i}{\partial p_S^i} + n_S^i + (p_B^i - f_B)\frac{\partial n_B^i}{\partial p_S^i} + \underbrace{\frac{\partial \pi^i}{\partial p_B^j}\frac{\partial p_B^j}{\partial p_S^i}}_{\text{Strategic effect}} = 0, \tag{20}$$

where $\frac{\partial \pi^i}{\partial p_B^j} = (p_S^i - f_S)\frac{\partial n_S^i}{\partial p_B^j} + (p_B^i - f_B)\frac{\partial n_B^i}{\partial p_B^j} > 0$. Notice that the sign of the strategic effect depends on the sign the rival's reaction function, $\frac{\partial p_B^j}{\partial p_S^i}$, which in turn depends on the sign of the term, $b_B - b_S$. This implies that sequential equilibrium prices are higher than in the simultaneous price equilibrium whenever $b_B > b_S$.

In Appendix B, we show that the symmetric price equilibrium that solves (19)-(20) is

$$p_S^* = \frac{f_S + v_S}{2} - \frac{b_B - b_S}{6}, \tag{21}$$

and

$$p_B^* = f_B + t_B - \frac{b_S}{6t_S}(3v_S + b_S + 5b_B - 3f_S). \tag{22}$$

Compared with the simultaneous pricing equilibrium in (17) and (18), the sequential pricing equilibrium under partial multihoming entails a reduced subsidy on the S side and an increased subsidy on the B side given that $b_B - b_S > 0$. This is the same change brought by the sequential timing as under singlehoming. Profits are

$$\Pi = \frac{1}{36t_S}\left(18t_St_B - (b_B + b_S)^2 - 14b_Bb_S + 9(v_S - f_S)^2\right).$$

By inspection, the sequential pricing equilibrium yields higher profits than the simultaneous pricing equilibrium.

5 Conclusion

In this paper, we have demonstrated that sequential pricing outcomes Pareto dominate simultaneous pricing outcomes in terms of firm and industry profits under both singlehoming and multihoming behavior. Platforms can can employ a sequential pricing strategy to relax price competition on the most heavily cross-subsidized side of the platform by setting prices first on the side of the market with smaller network externalities.

Appendix

A Partial Multihoming: simultaneous pricing equilibrium

The linearity and symmetry of demands implies that the following property must hold for $k = B, S$ and $l \neq k$.

Property 1:

$$
\begin{aligned}
\frac{\partial n_k^i}{\partial p_k^i} &= \frac{\partial n_k^j}{\partial p_k^j} = \text{constant} = \frac{\partial n_k}{\partial p_k} < 0 \\
\frac{\partial n_k^i}{\partial p_l^i} &= \frac{\partial n_k^j}{\partial p_l^j} = \text{constant} = \frac{\partial n_k}{\partial p_l} < 0 \\
\frac{\partial n_k^i}{\partial p_k^j} &= \frac{\partial n_k^j}{\partial p_k^i} = \text{constant} = \left(\frac{\partial n_k}{\partial p_k}\right)^c > 0 \\
\frac{\partial n_k^i}{\partial p_l^j} &= \frac{\partial n_k^j}{\partial p_l^i} = \text{constant} = \left(\frac{\partial n_k}{\partial p_l}\right)^c > 0,
\end{aligned}
$$

where the superscript c indicates "cross-market" derivatives of demands w.r.t. prices.

Using Property 1, the first-order necessary conditions for profit in expression (16) reduce to

$$
\begin{aligned}
(p_S^i - f_S)\frac{\partial n_S}{\partial p_S} + n_S^i + (p_B^i - f_B)\frac{\partial n_B}{\partial p_S} &= 0 \\
(p_S^i - f_S)\frac{\partial n_S}{\partial p_B} + n_B^i + (p_B^i - f_B)\frac{\partial n_B}{\partial p_B} &= 0
\end{aligned}
$$

for $i = 1, 2$.

In the symmetric equilibrium, $p_S^i = p_S^j = p_S$ and $p_B^i = p_B^j = p_B$ it follows that $n_S^i = n_S^j = n_S$ and $n_B^i = n_B^j = n_B$. The system of equations becomes

$$
\begin{aligned}
(p_S - f_S)\frac{\partial n_S}{\partial p_S} + n_S + (p_B - f_B)\frac{\partial n_B}{\partial p_S} &= 0 \\
(p_S - f_S)\frac{\partial n_S}{\partial p_B} + n_B + (p_B - f_B)\frac{\partial n_B}{\partial p_B} &= 0,
\end{aligned} \tag{23}
$$

where

$$
\begin{aligned}
\frac{\partial n_B}{\partial p_B} &= -\frac{t_S}{2\Delta} \\
\frac{\partial n_B}{\partial p_S} &= -\frac{b_B}{2\Delta}
\end{aligned}
$$

$$\frac{\partial n_S}{\partial p_S} = -\frac{\Delta + t_S t_B}{2t_S\Delta}$$
$$\frac{\partial n_S}{\partial p_B} = -\frac{b_S}{2\Delta}$$

The simultaneous price equilibrium in the symmetric case solves the system of equations (23) with $n_B = 1/2$ and $n_S = \frac{2v_S+b_S-2p_S}{2t_S}$, which yields, on substitution,

$$-(p_S - f_S)\frac{\Delta + t_S t_B}{2t_S\Delta} + \frac{2v_S + b_S - 2p_S}{2t_S} - (p_B - f_B)\frac{b_B}{2\Delta} = 0$$
$$-(p_S - f_S)\frac{b_S}{2\Delta} + \frac{1}{2} - (p_B - f_B)\frac{t_S}{2\Delta} = 0.$$

Solving this system leads to the expressions (17) and (18).

B Partial Multihoming: sequential pricing equilibrium

Evaluating the conditions (19) and (20) at a symmetric price equilibrium, $p_S^i = p_S^j = p_S$ and $p_B^i = p_B^j = p_B$ (and thus $n_S^i = n_S^j = n_S$ and $n_B^i = n_B^j = n_B$), the system of equations can be written

$$(p_S - f_S)\frac{\partial n_S}{\partial p_B} + n_B + (p_B - f_B)\frac{\partial n_B}{\partial p_B} = 0$$
$$(p_S - f_S)\frac{\partial n_S}{\partial p_S} + n_S + (p_B - f_B)\frac{\partial n_B}{\partial p_S}$$
$$+\underbrace{\left((p_S - f_S)\left(\frac{\partial n_S}{\partial p_B}\right)^c + (p_B - f_B)\left(\frac{\partial n_B}{\partial p_B}\right)^c\right)\left(\frac{\partial p_B}{\partial p_S}\right)^c}_{\text{Strategic effect}} = 0.$$

Next, note from Property 1 that

$$\frac{\partial p_k^j}{\partial p_l^i} = \frac{\partial p_k^i}{\partial p_l^j} = \left(\frac{\partial p_k}{\partial p_l}\right)^c$$

holds due to symmetry of demand and profit functions. Making use of this result, we rearrange the system to get

$$(p_S - f_S)\frac{\partial n_S}{\partial p_B} + n_B + (p_B - f_B)\frac{\partial n_B}{\partial p_B} = 0 \tag{24}$$
$$(p_S - f_S)\left(\frac{\partial n_S}{\partial p_S} + \left(\frac{\partial n_S}{\partial p_B}\right)^c\left(\frac{\partial p_B}{\partial p_S}\right)^c\right) + n_S$$
$$+(p_B - f_B)\left(\frac{\partial n_B}{\partial p_S} + \left(\frac{\partial n_B}{\partial p_B}\right)^c\left(\frac{\partial p_B}{\partial p_S}\right)^c\right) = 0$$

The sequential pricing equilibrium can be found by solving the system (24) with $n_B = 1/2$ and

$n_S = \frac{2v_S + b_S - 2p_S}{2t_S}$, which yields

$$
\begin{aligned}
-(p_S - f_S)\frac{b_S}{2\Delta} + \frac{1}{2} - (p_B - f_B)\frac{t_S}{2\Delta} &= 0 \\
(p_S - f_S)\left(-\frac{\Delta + t_S t_B}{2t_S\Delta} + \frac{b_S}{2\Delta}\left(\frac{\partial p_B}{\partial p_S}\right)^c\right) + \frac{2v_S + b_S - 2p_S}{2t_S} & \\
+(p_B - f_B)\left(-\frac{b_B}{2\Delta} + \frac{t_S}{2\Delta}\left(\frac{\partial p_B}{\partial p_S}\right)^c\right) &= 0
\end{aligned}
$$

Notice that the strategic effect term has the same expression as in the case of singlehoming

$$\left(\frac{\partial p_B}{\partial p_S}\right)^c = \frac{b_B - b_S}{3t_S}.$$

The reason is that n_B^i takes the same value as in the singlehoming case, while n_S^i depends on p_B^i and p_B^j in the same manner as under singlehoming behavior by type-S agents. Hence, given prices on the S side of the market, solving for the equilibrium prices on the B side of the market results in identical expressions as under singlehoming.

On substitution of terms, the system of equations reduces to

$$
\begin{aligned}
-(p_S - f_S)\frac{b_S}{2\Delta} + \frac{1}{2} - (p_B - f_B)\frac{t_S}{2\Delta} &= 0 \\
(p_S - f_S)\left(-\frac{\Delta + t_S t_B}{2t_S\Delta} + \frac{b_S}{2\Delta}\frac{b_B - b_S}{3t_S}\right) + \frac{2v_S + b_S - 2p_S}{2t_S} & \\
+(p_B - f_B)\left(-\frac{b_B}{2\Delta} + \frac{t_S}{2\Delta}\frac{b_B - b_S}{3t_S}\right) &= 0
\end{aligned}
$$

Solving this system leads to the expressions contained in (21) and (22).

C Existence of Equilibrium

In each subsection we verify that the assumptions are sufficient to guarantee existence of the type of equilibrium described in the main text. The following steps are taken in each case to verify the strategies are equilibrium of the simultaneous and sequential games: (A) verify each platform makes a nonnegative profit, (B) verify each platform i has no beneficial defection, (C) verify no buyer has a beneficial defection, and (D) verify no seller has a beneficial defection. In all games buyers are only permitted to single home, so checking (C) only requires that each buyer recieves more than zero utility buying from a platform.

C.1 Single Homing

Assumption 1 (Single Homing)**.** *In the single homing case, parameters satisfy*

$$\Delta > 0 \tag{25}$$

$$t_S + t_B \geq b_S + b_B + \max\left\{0, \frac{b_B - b_S}{3}\left(\frac{b_S}{t_S} - 1\right)\right\} \tag{26}$$

$$b_S \geq b_B \text{ or } t_S \geq b_B \tag{27}$$

$$2(v_B - f_B) \geq 3t_B - b_B - 2b_S - \min\{0, b_S(b_B - b_S)/3t_S\} \tag{28}$$

$$2(v_S - f_S) \geq 3t_S - b_S - 2b_S + \max\{0, (b_B - b_S)/3\} \tag{29}$$

(A) Simultaneous Game:

$$\widehat{\pi} = (\hat{p}_S - f_S)/2 + (\hat{p}_B - f_B)/2 = (t_S - b_B)/2 + (t_B - b_S)/2$$

This profit is nonnegative if and only if $t_S + t_B \geq b_S + b_B$, which holds based on condition (26).

Sequential Game:

$$\begin{aligned} \pi^* &= (p_S^* - f_S)/2 + (p_B^* - f_B)/2 \\ &= (t_S - b_B + \frac{b_B - b_S}{3})/2 + (t_B - b_S\left(1 + \frac{b_B - b_S}{3t_S}\right))/2 \end{aligned}$$

This profit is nonnegative if and only if $t_S + t_B \geq b_S + b_B + \frac{b_B - b_S}{3}\left(\frac{b_S}{t_S} - 1\right)$, which holds based on condition (26).

(B) Simultaneous Game: The second order conditions are for $k \in \{B, S\}$, $l \neq k$,

$$\frac{\partial^2 \pi^i}{\partial \left(p_k^i\right)^2} = -\frac{t_l}{2\Delta} < 0.$$

Sequential Game: The second order condition for S (B is the same as in the simultaneous game):

$$\begin{aligned} \frac{\partial^2 \widetilde{\pi}_S^i}{\partial \left(p_S^i\right)^2} &= 2\left(\frac{\partial n_S^i}{\partial p_S^i} + \frac{\partial n_S^i}{\partial p_B^j}\frac{\partial p_B^{j*}}{\partial p_S^i}\right) + \frac{\partial p_B^{i*}}{\partial p_S^i}\left(\frac{\partial n_B^i}{\partial p_S^i} + \frac{\partial n_B^i}{\partial p_B^j}\frac{\partial p_B^{j*}}{\partial p_S^i}\right) \\ &= \frac{1}{\Delta}\left(\underbrace{-t_B + \frac{b_S(b_B - b_S)}{t_S}}_{(a)}\right) - \frac{2b_S + b_B}{6\Delta t_S}\left(\underbrace{t_S - \frac{b_B(b_B - b_S)}{t_S}}_{(b)}\right). \end{aligned}$$

It is easy to verify that $(a) < -b_S/t_S$. Next notice that if $b_S \geq b_B$, then the second order condition is negative. On the other hand, if $t_S \geq b_B$, and $(b) > t_S - b_B + b_S > 0$, then the second derivative is negative.

(C) The marginal buyer $x = 1/2$ gets at least as much utility from buying as not buying based on condition (28).

(D) In this game, sellers are only permitted to single home, so checking (D) only requires that each seller gets more than zero utility selling to a platform. The marginal seller $x = 1/2$ gets at least as much utility from selling as not selling based on condition (29).

C.2 Full Multihoming

Assumption 2 (Full Multihoming)**.** *In the full multihoming case, parameters satisfy*

$$\begin{aligned} v_S - f_S &\geq t_S - t_B && (30)\\ 2(v_B - f_B) &\geq 3t_B - 2b_B && (31)\\ 2(v_S - f_S) &\geq 4t_S - b_S && (32) \end{aligned}$$

(A) Simultaneous Game:

$$\begin{aligned} \widehat{\pi}^m &= (\widehat{p}_B^m - f_B)/2 + (\widehat{p}_S^m - f_S) \\ &= (t_B - b_S)/2 + v_S - t_S + b_S/2 - f_S \\ &= v_S + t_B - t_S - f_S \end{aligned}$$

Note, this must be nonnegative from condition (30).

Sequential Game: We have already established that in the text that $\pi^* \geq \widehat{\pi}^m$.

(B) Simultaneous Game: The second order conditions for the simultaneous game are:

$$\begin{aligned} \frac{\partial^2 \pi_B^i}{\partial \left(p_B^i\right)^2} &= -\frac{1}{t_B} < 0, \\ \frac{\partial^2 \pi_S^i}{\partial \left(p_S^i\right)^2} &= 0. \end{aligned}$$

The two conditions for the sequential game are also:

$$\begin{aligned}\frac{\partial^2 \pi_B^i}{\partial \left(p_B^i\right)^2} &= -\frac{1}{t_B} < 0,\\ \frac{\partial^2 \widetilde{\pi}_S^i}{\partial \left(p_S^i\right)^2} &= 0.\end{aligned}$$

(C) Recall that buyers are only allowed to single home in these games. Simultaneous Game: The utility of the marginal buyer $x = 1/2$ is $\widehat{u}_B^m(1/2) = v_B - 3t_B/2 + b_B - f_B + b_S$, which can be rewritten $2(v_B - f_B) \geq 3t_B - 2b_B - 2b_S$, a condition that is implied by (31).

Sequential Game: The utility of the marginal buyer $x = 1/2$ is $\widehat{u}$ $x = 1/2$, $u_B^*(1/2) = v_B - 3t_B/2 + b_B - f_B \backslash \geq 0$, which can be rewritten as exactly condition (31).

(D) Note that buyers are only allowed to single home in this game. In both games, the equilibrium price for sellers is that same: $\widehat{p}_S^m = p_S^* = v_S - t_S + \frac{b_S}{2}$.

The utility of the seller with least preference for platform i is $v_S - t_S + b_S/2 - \widehat{p}_S^m = 0$. Thus, at these prices all sellers multihoming is an equilibrium.

C.3 Partial Multihoming

Assumption 3 (Partial Multihoming)**.** *In the partial multihoming case, parameters satisfy*

$$\Delta > 0 \tag{33}$$

$$4(v_S - f_S)^2 \geq b_B^2 + b_S^2 - \frac{5}{9}t_B t_S - \frac{31}{9}\Delta \tag{34}$$

$$9b_B \geq b_S \tag{35}$$

$$v_B - f_B \geq 3t_B t_s - \min\left\{\frac{b_S^2 + b_B^2 + 4b_S b_B}{2(t_S + b_S + b_B)}, \frac{b_S^2 + b_B^2 + 7b_S b_B}{3(t_S + b_S + b_B)}\right\} \tag{36}$$

$$v_S - f_S \geq \max\left\{\frac{1}{2}b_B + \frac{1}{2}b_S, \frac{1}{3}b_B + \frac{2}{3}b_S\right\} \tag{37}$$

$$v_S - f_S < 2t_S - \max\left\{\frac{1}{2}b_B + \frac{1}{2}b_S, \frac{1}{3}b_B + \frac{2}{3}b_S\right\} \tag{38}$$

(A) Simultaneous Game:

$$\begin{aligned}\pi &= (p_B - f_B)\frac{1}{2} + (p_S - f_S)\left(\frac{2(v_S - f_S) + b_B + b_S}{4t_S}\right)\\ &= \left(t_B - b_S\left(\frac{2(v_S - f_S) + b_S + 3b_B}{4t_S}\right)\right)\frac{1}{2} + \left(\frac{v_S - f_S}{2} - \frac{b_B - b_S}{4}\right)\left(\frac{2(v_S - f_S) + b_B + b_S}{4t_S}\right)\\ &= \frac{t_B}{2} + \frac{(v_S - f_S)^2}{4t_S} - \frac{b_B^2 + 6b_B b_S + b_S^2}{16t_s}.\end{aligned}$$

This expression is nonnegative if $4(v_S - f_S)^2 \geq b_B^2 + b_S^2 - 2t_B t_S - 6\Delta$, which holds based on condition (34).

Sequential Game:

$$
\begin{aligned}
\pi &= (p_B - f_B)\frac{1}{2} + (p_S - f_S)\left(\frac{2v_S + b_S - 2p_S}{2t_S}\right) \\
&= \left(t_B - b_S\left(\frac{3(v_S - f_S) + b_S + 5b_B}{6t_S}\right)\right)\frac{1}{2} + \left(\frac{v_S - f_S}{2} - \frac{b_B - b_S}{6}\right)\left(\frac{2v_S + b_S}{2t_S} - \frac{1}{t_S}\left(\frac{f_S + v_S}{2} - \frac{b_B - b_S}{6}\right)\right. \\
&= \left(\frac{t_S t_B + 5\Delta}{6t_S}\right)\frac{1}{2} + \frac{(v_S - f_S)^2}{4t_S} + \frac{b_B(v_S - f_S)}{6t_S} - \frac{b_B^2 + b_B b_S + b_S^2}{36t_s}.
\end{aligned}
$$

Then we have

$$
4(v_S - f_S)^2 + \frac{2b_B}{3}(v_S - f_S) \geq \frac{1}{9}\left(b_B^2 + b_S^2\right) - \frac{31}{9}\Delta - \frac{5}{9}t_S t_B,
$$

which holds based on condition (34).

(B) Simultaneous Game: The second order conditions are:

$$
\begin{aligned}
\frac{\partial^2 \pi^i}{\partial\left(p_B^i\right)^2} &= 2\frac{\partial n_B^i}{\partial p_B^i} = -\frac{t_S}{\Delta} < 0 \\
\frac{\partial^2 \pi^i}{\partial\left(p_S^i\right)^2} &= 2\frac{\partial n_S^i}{\partial p_S^i} = -\frac{\Delta + t_S t_B}{t_S \Delta} < 0
\end{aligned}
$$

Sequential Game: The second order conditions are:

$$
\frac{\partial^2 \pi_B^i}{\partial\left(p_B^i\right)^2} = -2\frac{\partial n_B^i}{\partial p_B^i} = -\frac{t_S}{\Delta}
$$

$$
\begin{aligned}
\frac{\partial^2 \widetilde{\pi}_S^i}{\partial\left(p_S^i\right)^2} &= -2\left(\frac{\Delta + t_S t_B}{2t_S \Delta} + \frac{b_S^2}{6t_S \Delta}\right) + \frac{2b_S}{3t_S}\left(\frac{b_S}{2\Delta} + \frac{b_S}{6\Delta}\right) \\
&= -\frac{1}{t_S} - \frac{t_B}{\Delta} + \frac{b_S^2}{9t_S \Delta}
\end{aligned}
$$

Then we can multiply the entire expression by $9t_S\Delta$ while imposing required inequality

$$
\begin{aligned}
-9\Delta - 9t_S t_B + b_S^2 &\leq 0 \\
9(\Delta + t_S t_B) &\geq b_S^2.
\end{aligned}
$$

Since $\Delta = t_S t_B - b_S b_B > 0$ by (33), the above inequality holds if

$$
\begin{aligned}
9b_S b_B &\geq b_S^2 \\
9b_B &\geq b_S,
\end{aligned}
$$

which is condition (35).

(C) Simultaneous Game: The utility of the marginal buyer $x = 1/2$ is

$$\begin{aligned} u_B(1/2) &= v_B - t_B/2 + b_B\left(\frac{2(v_S - f_S) + b_B + b_S}{4t_S}\right) - p_B \\ &= v_B - f_B - 3t_B/2 + \frac{b_S + b_B}{2t_s}(v_S - f_S) + \frac{b_S^2 + b_B^2 + 4b_S b_B}{4t_S}. \end{aligned}$$

This utility is nonnegative if

$$v_B - f_B + \frac{b_S + b_B}{2t_s}(v_S - f_S) \geq \frac{3t_B}{2} - \frac{b_S^2 + b_B^2 + 4b_S b_B}{4t_S},$$

which holds based on condition (36).

Sequential Game: The utility of the marginal buyer $x = 1/2$ is

$$\begin{aligned} u_B(1/2) &= v_B - t_B/2 + b_B\left(\frac{v_S - f_S + b_S}{2t_S} + \frac{b_B - b_S}{6t_S}\right) - p_B \\ &= v_B - f_B - 3t_B/2 + \frac{(b_B + b_S)(v_S - f_S)}{2t_s} + \frac{b_S^2 + b_B^2 + 7b_S b_B}{6t_S} \end{aligned}$$

This utility is nonnegative if

$$v_B - f_B + \frac{b_B + b_S}{2t_s}(v_S - f_S) \geq \frac{3t_B}{2} - \frac{b_S^2 + b_B^2 + 7b_S b_B}{6t_S},$$

which holds based on condition (36).

(D) Simultaneous Game: First we verify that the marginal seller $x = n_S$ sells to the farther platform. That is,

$$\begin{aligned} u_S(n_S) &= v_s - t_S(n_S) + b_S/2 - p_s \\ &= v_s - t_S\left(\frac{2(v_S - f_S) + b_B + b_S}{4t_S}\right) + b_S/2 - \frac{f_S + v_S}{2} + \frac{b_B - b_S}{4} \\ &= v_S - f_S + \frac{b_B + b_S}{2}, \end{aligned}$$

which is nonnegative based on (37).

Second, we verify that $n_S < 1$. This is true if

$$\begin{aligned} 2(v_S - f_S) &< 4t_S - b_B - b_S \\ v_S - f_S &< 2t_S - \frac{1}{2}b_B - \frac{1}{2}b_S, \end{aligned}$$

which hold based on condition (38).

Sequential Game: First, we verify that the marginal seller $x = n_S$ sells to the farther platform. That is,

$$
\begin{aligned}
u_S(n_S) &= v_s - t_S\,(n_S) + b_S/2 - p_s \\
&= v_s - t_S\left(\frac{3\,(v_S - f_S) + 2b_S + b_B}{6t_S}\right) + \frac{b_S}{2} - \frac{f_S + v_S}{2} + \frac{b_B - b_S}{6} \\
&= v_S - f_S + \frac{b_B + 2b_S}{3},
\end{aligned}
$$

which is nonnegative based on (37).

Second, we verify that $n_S < 1$. This true if

$$
\begin{aligned}
3(v_S - f_S) &< 6t_S - b_B - 2b_S \\
v_S - f_S &< 2t_S - \frac{1}{3}b_B - \frac{2}{3}b_S,
\end{aligned}
$$

which hold based on condition (38).

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