Innovation incentives for competing two-sided platforms

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Abstract

We analyze the incentives for competing two-sided platforms to adopt a cost-reducing innovation. Our first step is to extend Armstrong (2006)'s duopoly model with two-sided singlehoming to incorporate asymmetries across the platforms.Using this extended model, we then show that the presence of cross-group effects challenges the conventional wisdom about incentives to innovate. In particular, the profit incentive can be negative, the positive direct effect being more than compensated by a negative strategic effect. Also, the competitive threat may be smaller than the profit incentive.

PRELIMINARY. NOT TO BE CIRCULATED

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1 Introduction

Multisided platforms intermediate between distinct groups of economic agents that benefit from interacting with one another but fail to organize this interaction by their own forces because of high transaction costs. Such platforms are active in a large variety of settings: *exchanges* help 'buyers' and 'sellers' search for feasible contracts and for the best prices (e.g., eBay, Booking.com, Cambridge Univeristy Press, edX, ...); *hardware & software systems* allow applications developers and end users to interact (e.g., Mac OS, Android, PlayStation, ...); *matchmakers* help members of one group to find the right 'match' within another group (e.g., Alibaba, Monster, Meetic, ...); *peer-to-peer marketplaces* facilitate the exchange of goods and services between 'peers' (e.g., Uber, Airbnb, EatWith, ...); *crowdfunding platforms* allow entrepreneurs to raise funds from a 'crowd' of investors (e.g., Kickstarter, Indiegogo, LendingClub, ...), *transaction systems* provide a method for payment to buyers and sellers that are willing to use it (Visa, Bitcoin, PayPal, ...).

The main function of multisided platforms is to internalize the various external effects that the interaction between the groups generate. They do so by making appropriate decisions about prices, design and governance rules. Of particular interest are the cross-group effects (or indirect network effects) that make the well-being of one group depend (positively or negatively) on the participation of the other group(s). For instance, in the case of hardware & software systems, each group benefiting from a stronger participation of the other group: application developers welcome more users on the platforms as they make their potential demand grow; end users enjoy the presence of more developers as they enjoy a larger number and/or variety of applications. Within-group effects may also play and important role (e.g., as application developers compete for the same demand, a platform may become less attractive for them as their number increases).

Following the seminal contributions of Caillaud and Jullien (2003), Rochet and Tirole (2003 and 2006), and Armstrong (20016), a new strand of literature in industrial organization has developed to analyze mutisided platforms. The focus was initially on pricing strategies in the presence of cross-group effects. A larger set of issues was later studied: singlehoming versus multihoming (e.g., Armstrong and Wright, 2007), ownership structures (e.g., Nocke, Peitz and Stahl, 2007), within-group effects (e.,g., Belleflamme and Toulemonde, 2009), investments by agents on one side of the platform (e.g, Belleflamme and Peitz, 2010), two-part tariffs (Reisinger, 2014), etc (think of others!)

In the vast majority of these papers, platforms are assumed to be symmetric. Even if this assumption does not fit what is observed in reality, it serves as a convenient simplification to deal with the complexities of multisidedness. However, models with symmetric platforms are ill-suited to address strategic choices that may make platforms asymmetric. This is so for investments by platforms aimed at decreasing their costs, fostering the stand-alone benefits of users, modifiying the strength of the cross-group network effects, or adopting different business models (e.g., about which sides to take on board).

Our objective in this paper is to study platforms' incentives to adopt a process innovation, which has the effect of lowering the cost of serving customers on one or the other side of the platform. As platforms become asymmetric as soon as one of them adopts the innovation, we first need to develop a model of price competition between asymmetric platforms. The first contribution of this paper is thus to propose an extension of Armstrong (2006) model of two-sided singlehoming by letting platforms differ in all relevant parameters (costs, stand-alone benefits and cross-group network effects). In spite of the number of parameters, we manage to solve the two-stage game where platforms first choose access fees on both sides and, next, agents on each side decide which platform to join. Moreover, we express the equilibrium prices, number of agents and platforms' profits in a perfectly workable way. That allows us to propose a clear typology of how platforms modify their equilibrium prices when asymmetry increases; we can also show that platforms may have opposite "business models" (i.e., pricing structures) insofar as they may choose different paying sides and subsidy sides.

Equipped with this extended model, we can then perform a number of comparative statics exercises to measure platforms' incentives to adopt a cost-reducing innovation. Following the literature that examines such incentives in one-sided markets (see Belleflamme and Vergari, 2011, for a unifying approach), we consider two alternative measures: the 'profit incentive' and the 'competitive threat'. The two measures compute the variation in profit induced by adoption of the innovation, but differ in terms of counterfactual if the firm under review does not adopt the innovation: the 'profit incentive' approach assumes that the rival firm does not adopt the innovation, while the 'competitive threat' approach assumes that it does.

In a competitive framework, the profit incentive to innovate can be decomposed into a direct and a strategic effect. While the first effect is necessarily positive, the second effect may be positive or negative depending on the nature of competition on the product market (which is affected by the adoption of the innovation). Fudenberg and Tirole (1984) show that the strategic effect is positive if product market decisions are strategic substitutes, or negative if they are strategic complements. In the latter case, the strategic effect does not outweigh the direct effect and the incentive to innovate remains positive.

Our analysis shows that the previous conclusions may no longer hold in two-sided markets. First, the strategic effect may be positive although platforms compete in prices (decisions can thus be seen as strategic complements). Second, and more importantly, when the strategic effect is negative, it may outweigh the direct effect, leading to a disincentive to innovate. In other words, platforms may refrain from investing in a cost-reducing innovation altogether because the increased competition that such investment would trigger would annihilate any direct benefit. Worse, the same result implies that platforms may find it profitable to increase their cost. A direct corollary of the latter result is that a platform may welcome the adoption of an innovation by its rival. As a result, the competitive threat may provide a platform with *lower* incentives to innovate than the profit incentive. This finding reverses again the common wisdom in one-sided markets (where the couterfactual used under the competitive threat is necessarily more detrimental to the innovator). Behind these results is the finding that cross-group effects amplify the strategic effects of cost-reducing investments.

Compared to one-sided (monoproduct) markets, two-sided markets also enlarge the set of potential innovations. In particular, platforms can decide to reduce their cost on either side. To examine this issue, we consider a simple simultaneous game where platforms choose to apply a cost-reducing innovation of a given size either on side a on on side b. Assuming that the platforms are initially identical, we show that the equilibrium depends on whether the cost reduction generated by the innovation is below or above some threshold: below the threshold ('small' innovations), both platforms apply the innovation on the side where users value the interaction the most;

above the threshold ('large' innovations), platforms apply the innovation on different sides. Interestingly, the latter situation dominates the former not only in terms of total profit but also in terms of consumer surplus. Welfare therefore increases if platforms invest on opposite sides, thereby increasing their asymmetry. This suggests in turn that the symmetric equilibrium on which most of the literature has focused so far may be rather unstable.

Related literature (To be written and completed. Very few papers consider asymmetric platforms. Close to us (introduction of vertical differentiation in Armstrong, 2006): Ribeiro et al. 2014a. But different way to make platforms asymmetric (they use the product differentiation model of Gabszewicz and Wauthy, 2012) and to make the model tractable, they impose symmetry on other dimensions (e.g., the two sides see the two platforms as equally horizontally differentiated and they exert the same cross-group effects on each other). Possibly, Ribeiro et al. 2014b (same idea as 2014a but now, vertical and horizontal differentation across platforms is modelled à la Neven and Thisse, 1990; again, to allow some asymmetry between platforms in one dimension, the authors have to impose more symmetry on other dimensions; results are not very instructive and hardly comparable with ours). Other papers with asymmetric two-sided platforms: Viecens (2006), Lin, Li and Whinston (2011), Njoroge et al. (2009, 2010), Ponce (2012), Gabszewicz and Wauthy (2014), Gold (2010), Papers by Yuzuke Zennyo?)

2 The model

We adapt the models of Armstrong (2006) and Armstrong and Wright (2007). Two platforms are located at the extreme points of the unit interval: platform U (for *Uppercase*, identified hereafter by upper-case letters) is located at 0, while platform l (for *lowercase*, identified by lower-case letters) is located at 1. Platforms facilitate the interaction between two groups of agents, noted a and b. Both groups are assumed to be of mass 1 and uniformly distributed on $[0, 1]$. We assume that agents of both sides can join at most one platform (so-called 'two-sided singlehoming'); in the real world, singlehoming environments may result from indivisibilities and limited resources or from contractual restrictions.[1]

[1]For a discussion, see Case 22.4 in Belleflamme and Peitz (2010a, p. 633).

An agent derives a net utility from joining a platform that is defined as the addition of four components: (i) a cross-group external benefit, (ii) a stand-alone benefit, (iii) a 'transportation cost', and (iv) an access fee. The first two components enter the net utility function positively. They correspond to two types of services that a platform offers to its users. Some services facilitate the interaction with the other group; the utility they give is the cross-group external benefit, which is assumed to increase linearly with the number of agents of the other group present on the platform.[2] A platform also offers other services that do not relate to the interaction between the groups; these services give a stand-alone benefit to users. The last two components enter the net utility function negatively. In the usual Hotelling fashion, a user incurs a disutility from not being able to use a platform that corresponds to their ideal definition of a platform; this disutility is assumed to increase linearly with the distance separating the user's and the platform's location on the unit line (at a rate that can be interpreted as a measure of the horizontal differentation between the platforms in the eyes of a particular group of users). Finally, users have to pay a flat fee to access the platform.[3]

The originality of our approach is that we allow all these components to differ not only across sides but also across platforms. We therefore write the net utility functions for an agent of group a and for an agent of group b, respectively located at x and $y \in [0,1]$ as:

$$\begin{aligned} U_a(x) &= E_a N_b + R_a - \tau_a x - P_a && \text{if joining platform } U, \\ u_a(x) &= e_a n_b + r_a - \tau_a (1-x) - p_a && \text{if joining platform } l, \\ U_b(y) &= E_b N_a + R_b - \tau_b y - P_b && \text{if joining platform } U, \\ u_b(y) &= e_b n_a + r_b - \tau_b (1-y) - p_b && \text{if joining platform } l, \end{aligned}$$

where E_j (resp. e_j) measures the strength of the cross-group external effect that users of group k exert on users of group j on platform U (resp. l),[4] N_j (resp. n_j) is the mass of agents of group j that decide to join platform U (resp. l), R_j (resp. r_j) is the valuation of the stand-alone benefit by agents

[2] We focus in this paper on *positive* cross-group external effects; that is, each group positively values the participation of the other group on the platform. (Can we say something with negative effects on one side? Do we want to?)

[3] Mention here that we do not consider usage fees, nor two-part tariffs. See Reisinger (2014) showing that a continuum of equilibria exists with two-part tariffs.

[4] That is, E_j is the valuation by a group j user of the particpation of an extra group k user.

of group j on platform U (resp. l), τ_j is the 'transport cost' parameter for group j, and P_j (resp. p_j) is the access fee that platform U (resp. l) sets for users of group j (with j, $k \in \{a, b\}$ and $j \neq k$).

Let $\hat{x}$ (resp. $\hat{y}$) identify the agent of group a (resp. b) who is indifferent between joining platform U or platform l; that is, $U_a(\hat{x}) = u_a(\hat{x})$ and $U_b(\hat{y}) = u_b(\hat{y})$. Solving these equalities for $\hat{x}$ and $\hat{y}$ respectively, we have

$$\begin{aligned}\hat{x} &= \tfrac{1}{2} + \tfrac{1}{2\tau_a}\left(E_a N_b - e_a(1 - N_b) + R_a - r_a - (P_a - p_a)\right), \\ \hat{y} &= \tfrac{1}{2} + \tfrac{1}{2\tau_b}\left(E_b N_a - e_b(1 - N_a) + R_b - r_b - (P_b - p_b)\right).\end{aligned}$$

In what follows, we assume that stand-alone and cross-group external benefits are sufficiently large to make sure that all agents join one plaform. Both sides are then fully covered, so that $N_j + n_j = 1$ $(j = a, b)$. This entails the following equalities: $\hat{x} = N_a = 1-$ n_a and $\hat{y} = N_b = 1 - n_b$. Using these equalities, we can solve the above systems of equations for N_a and N_b:

$$N_a = \frac{1}{2} + \frac{\tau_b}{2}\frac{\rho_a + \delta_a + p_a - P_a}{\tau_a\tau_b - \sigma_a\sigma_b} + \frac{\sigma_a}{2}\frac{\rho_b + \delta_b + p_b - P_b}{\tau_a\tau_b - \sigma_a\sigma_b}, \tag{1}$$

$$N_b = \frac{1}{2} + \frac{\tau_a}{2}\frac{\rho_b + \delta_b + p_b - P_b}{\tau_a\tau_b - \sigma_a\sigma_b} + \frac{\sigma_b}{2}\frac{\rho_a + \delta_a + p_a - P_a}{\tau_a\tau_b - \sigma_a\sigma_b}, \tag{2}$$

where we have introduced some additional notation (that will prove useful in the rest of the analysis):

- $\sigma_k \equiv \frac{1}{2}(E_k + e_k)$ is the *sum* of the cross-group external benefits on side k of platforms U and L when the agents on the other side split equally;
- $\delta_k \equiv \frac{1}{2}(E_k - e_k)$ is the *difference* of the cross-group external benefits on side k between platforms U and L when the agents on the other side split equally;[5]
- $\rho_k \equiv R_k - r_k$ is the difference in stand-alone benefits on side k between platforms U and L.

To ensure that participation on each side is a decreasing function of the access fee on this side, we assume the following:

$$\tau_a\tau_b > \sigma_a\sigma_b. \tag{3}$$

[5]By definition, $E_k = \sigma_k + \delta_k$ and $e_k = \sigma_k - \delta_k$.

This assumption, which is common in the analysis of competition between two-sided platforms, says that the strength of cross-group external effects (measured by $\sigma_a \sigma_b$) is smaller than the strength of horizontal differentiation (measured by $\tau_a \tau_b$).

3 Equilibrium of the pricing game

Platforms simultaneously choose their access prices to maximize their profit, given by $\Pi = (P_a - C_a)\, N_a + (P_b - C_b)\, N_b$ and $\pi = (p_a - c_a)\, n_a + (p_b - c_b)\, n_b$. We assume that they face constant costs per agent, which may also differ across sides and across platforms (C_a and C_b for platform U; c_a and c_b for platform l). For future reference, we define $\gamma_k \equiv C_k - c_k$ as the difference in costs on side k between platforms U and l ($k = a, b$). The first-order conditions require

$$\frac{d\Pi}{dP_a} = \frac{d\Pi}{dP_b} = \frac{d\pi}{dp_a} = \frac{d\pi}{dp_b} = 0,$$

whereas the second-order conditions require

$$\tau_a \tau_b > \sigma_a \sigma_b \text{ and } \tau_a \tau_b > \tfrac{1}{4} (\sigma_a + \sigma_b)^2 .$$

We note that the first condition is equivalent to Assumption (3) and that $\frac{1}{4} (\sigma_a + \sigma_b)^2 - \sigma_a \sigma_b = \frac{1}{4} (\sigma_a - \sigma_b)^2 > 0$, which means that the second condition is more stringent than the first. We thus impose from now on

$$\tau_a \tau_b > \tfrac{1}{4} (\sigma_a + \sigma_b)^2 . \tag{4}$$

We now solve the system of the four first-order conditions. To facilitate the exposition, we define $\Delta_k \equiv \rho_k - \gamma_k$ and $D \equiv 9\tau_a \tau_b - (2\sigma_a + \sigma_b)(\sigma_a + 2\sigma_b)$; Δ_k measures the (dis)advantage that platform U has with respect to platform l on side k; D is positive according to Assumption (4). The equilibrium price of platform U on side a is found as

$$\begin{aligned} P_a^* &= \overbrace{C_a + \tau_a}^{\mathbf{H}} \overbrace{-\sigma_b}^{\mathbf{A}} \overbrace{+\tfrac{1}{3}\Delta_a}^{\mathbf{Vs}} \overbrace{+\tfrac{1}{3}\delta_a}^{\mathbf{Vn}} \\ &\quad + \underbrace{\frac{(\sigma_a - \sigma_b)}{3} \frac{(2\sigma_a + \sigma_b)(\Delta_a + \delta_a) + 3\tau_a (\Delta_b + \delta_b)}{9\tau_a \tau_b - (2\sigma_a + \sigma_b)(\sigma_a + 2\sigma_b)}}_{\mathbf{I}} \end{aligned} \tag{5}$$

We can decompose it as the sum of five components: (i) **H** is the classic *Hotelling* formula (marginal cost + transportation cost); (ii) **A** was identified by *Armstrong* (2006) as the price adjustment due to indirect network effects (the price is decreased by the externality exerted on the other side); (iii) **Vs** is the effect of vertical differentiation in terms of *stand-alone* benefits (or the effect of marginal costs differences);[6] (iv) **Vn** is the effect of vertical differentiation in terms of indirect *network* effects on the side under review; (v) the last term **I** results from the interplay between vertical differentiation and indirect network effects. If platforms are symmetric ($\Delta_k = \delta_k = 0$) only **H** and **A** remain; absent external effects ($\sigma_k = \delta_k = 0$), only **H** an **Vs** remain. In the particular case where indirect externalities are (on average) the same on the two sides ($\sigma_a = \sigma_b$), all terms but the last remain.

The equilibrium price on side b is found by analogy

$$\begin{aligned} P_b^* &= C_b + \tau_b - \sigma_a + \tfrac{1}{3}\Delta_b + \tfrac{1}{3}\delta_b \\ &\quad + \frac{(\sigma_b - \sigma_a)}{3} \frac{(2\sigma_b + \sigma_a)(\Delta_b + \delta_b) + 3\tau_b(\Delta_a + \delta_a)}{9\tau_a\tau_b - (2\sigma_a + \sigma_b)(\sigma_a + 2\sigma_b)} \end{aligned} \tag{6}$$

By analogy, we express the equilibrium prices of platform l as

$$\begin{aligned} p_a^* &= c_a + \tau_a - \sigma_b - \tfrac{1}{3}\Delta_a - \tfrac{1}{3}\delta_a \\ &\quad - \frac{(\sigma_a - \sigma_b)}{3} \frac{(2\sigma_a + \sigma_b)(\Delta_a + \delta_a) + 3\tau_a(\Delta_b + \delta_b)}{9\tau_a\tau_b - (2\sigma_a + \sigma_b)(\sigma_a + 2\sigma_b)} \\ p_b^* &= c_b + \tau_b - \sigma_a - \tfrac{1}{3}\Delta_b - \tfrac{1}{3}\delta_b \\ &\quad - \frac{(\sigma_b - \sigma_a)}{3} \frac{(2\sigma_b + \sigma_a)(\Delta_b + \delta_b) + 3\tau_b(\Delta_a + \delta_a)}{9\tau_a\tau_b - (2\sigma_a + \sigma_b)(\sigma_a + 2\sigma_b)} \end{aligned}$$

Let us evaluate how equilibrium prices change with asymmetry. Without loss of generality, consider an improvement of platform U's position on side a (i.e., an increase in Δ_a) on P_a^* and P_b^*. For given prices, an increase in Δ_a allows platform U to attract more users of group a. In a one-sided market, this advantage allows platform U to charge a higher price at equilibrium: this is the effect that Δ_a has on P_a^* through **Vs**. However, in two-sided markets, an advantage on side a also confers an advantage on side b, meaning that equilibrium prices depend on the strength of the cross-side network effects (effect through **I**). If $\sigma_a > \sigma_b$ (i.e., agents of group a are more willing to interact with agents of group b than the opposite), we see from (5) and (6) that P_a^* increases while P_b^* decreases: platform U amplifies its advantage on side a by increasing participation on side b, which is highly valued by users

[6] In this model R_k and C_k play interchangeable roles. What matters is their difference: $\Delta_k = \rho_k - \gamma_k = (R_k - C_k) - (r_k - c_k)$.

of group a. The opposite prevails if $\sigma_a < \sigma_b$; in that case, P_b^* increases while P_a^* may *decrease* if σ_b is sufficiently large.[7]

The previous conclusions are exactly reversed for platform l. It is indeed readily checked that,

$$\frac{\partial p_a^*}{\partial \Delta_a} = -\frac{\partial P_a^*}{\partial \Delta_a} = -\frac{3\tau_a\tau_b - \sigma_b\left(2\sigma_a + \sigma_b\right)}{D}, \quad \frac{\partial p_b^*}{\partial \Delta_a} = -\frac{\partial P_b^*}{\partial \Delta_a} = \frac{\tau_b\left(\sigma_a - \sigma_b\right)}{D} \tag{7}$$

Any change in asymmetry pushes platforms to vary their prices on a given side in opposite directions by exactly the same amount. Moreover, on each side, the sum of the equilibrium margins of the two platforms is independent of Δ_a and Δ_b:

$$(P_a^* - C_a) + (p_a^* - c_a) = 2\left(\tau_a - \sigma_b\right) \text{ and } (P_b^* - C_b) + (p_b^* - c_b) = 2\left(\tau_b - \sigma_a\right),$$

which generalizes what is observed in a one-sided Hotelling model (with covered market and unit demand).

We can now use the equilibrium prices to compute the equilibrium mass of agents of the two groups on the two platforms:

$$\begin{aligned} N_a^* &= \tfrac{1}{2} + \tfrac{1}{2D}\left(3\tau_b\left(\Delta_a + \delta_a\right) + \left(\sigma_a + 2\sigma_b\right)\left(\Delta_b + \delta_b\right)\right), \; n_a = 1 - N_a^*, \\ N_b^* &= \tfrac{1}{2} + \tfrac{1}{2D}\left(3\tau_a\left(\Delta_b + \delta_b\right) + \left(2\sigma_a + \sigma_b\right)\left(\Delta_a + \delta_a\right)\right), \; n_b = 1 - N_b^*. \end{aligned}$$

To guarantee that the equilibrium mass is strictly positive and lower than unity, we impose the following restrictions on the space of parameters:

$$\begin{gathered} 3\tau_b\left(\Delta_a + \delta_a\right) + \left(\sigma_a + 2\sigma_b\right)\left(\Delta_b + \delta_b\right) \text{ and} \\ 3\tau_a\left(\Delta_b + \delta_b\right) + \left(2\sigma_a + \sigma_b\right)\left(\Delta_a + \delta_a\right) \in (-D, D). \end{gathered} \tag{8}$$

The conditions in (8) are drawn in Figure 1. The locus that satisfies the four conditions is represented by the grey area.[8]

Figure 2 draws the equations $P_a - C_a = 0$, $P_b - C_b = 0$, $p_a - c_a = 0$ and $p_b - c_b = 0$ in the same axes. The sign of those expressions are also

[7] The exact condition is $\sigma_b\left(2\sigma_a + \sigma_b\right) > 3\tau_a\tau_b$, which is compatible with (4). For instance, take $\sigma_a = 0$, and $\sigma_b^2 < 4\tau_a\tau_b$ to satisfy (4). Then for $\sigma_b^2 > 3\tau_a\tau_b$, we have $dP_a^*/d\Delta_a < 0$.

[8] The four conditions have a negative slope in the plane Δ_a, Δ_b. The intercept and the absolute value of the slope of $N_a = 1$ are smaller than the intercept and the absolute value of the slope of $N_b = 1$. The lines $N_a = 1$ and $N_b = 1$ cross at $\Delta_a = 3\tau_a - \sigma_a - 2\sigma_b, \Delta_b = 3\tau_b - \sigma_b - 2\sigma_a$.

represented, under the assumption that $\tau_k > \sigma_l \; \forall k, l \in (a, b)$ so that there is no subsidy in the symmetric case. Without loss of generality, we also assume that $\sigma_a > \sigma_b$. To draw those lines, note that

- $p_a - c_a = 0$ has a positive intercept, which is smaller than the intercept of $N_a = 1$. It passes through the intersection $N_a = 1, N_b = 1$.
- $P_a - C_a$ is a parallel to $p_a - c_a$, passing through the intersection $N_a = 0, N_b = 0$.
- $P_b - C_b = 0$ has an intercept that is larger than the intercept of $N_a = 1$. Its slope is positive. It passes through the intersection $N_a = 0, N_b = 0$.
- $p_b - c_b$ is a parallel to $P_b - C_b$, passing through the intersection $N_a = 0, N_b = 0$.

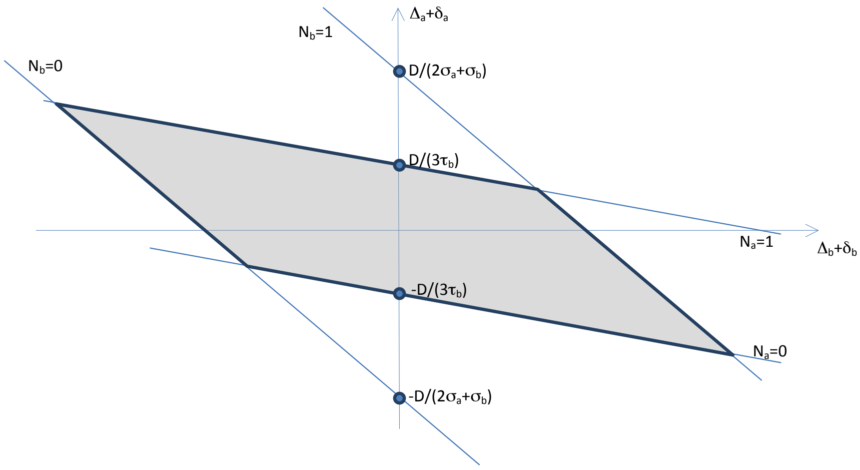

Figure 1: Interior solutions

We note that in the red areas, one platform subsidizes one side and tax the other side whereas the other platform adopts an opposite business model by taxing the first side and subsidizing the second one. In the central diamond, both platforms tax both sides. In yellow, ie the rest of the figure, one platform subsidizes one side and taxes the other side whereas the other

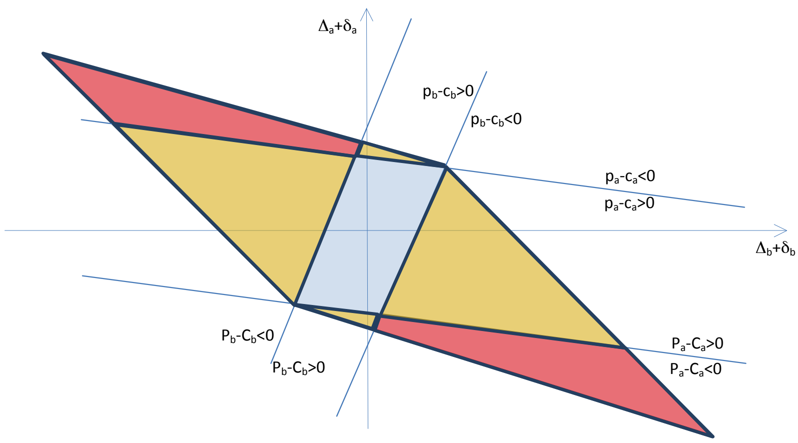

Figure 2: Sign of the mark-ups

platform taxes both sides. There is no equilibrium in which both platforms subsidize the same side; this is caused by our assumption that $\tau_k > \sigma_l$ $\forall k, l \in (a, b)$ so that there is no subsidy in the symmetric case. Of course none of the platform can profitably subsidize both sides.

More generally, Figure 3 represents two lines: one in which $P_a - C_a = p_a - c_a$ and the other with $P_b - C_b = p_b - c_b$. Those lines are parallel resp. to $P_a - C_a = 0$ and $P_b - C_b = 0$ and pass through the origin. In the green areas (North and South), one platform sets a higher markup on one side than the other platform, whereas the other platform does the opposite on the other side. They thus have different business models. In the two remaining areas, one platform benefits from an advantage on both sides (e.g. $\Delta_a + \delta_a > 0$ and $\Delta_b + \delta_a > 0$ so that Capital has an advantage on both sides), which allows her to benefit from higher markups on both sides. Note that here again, the figure is drawn under the assumption that $\tau_k > \sigma_l$ $\forall k, l \in (a, b)$.

3.1 Equilibrium profits

The profits of platforms U and l are, respectively:

$$\begin{aligned}
\Pi &= (P_a - C_a) N_a + (P_b - C_b) N_b, \\
\pi &= (p_a - c_a)(1 - N_a) + (p_b - c_b)(1 - N_b).
\end{aligned}$$

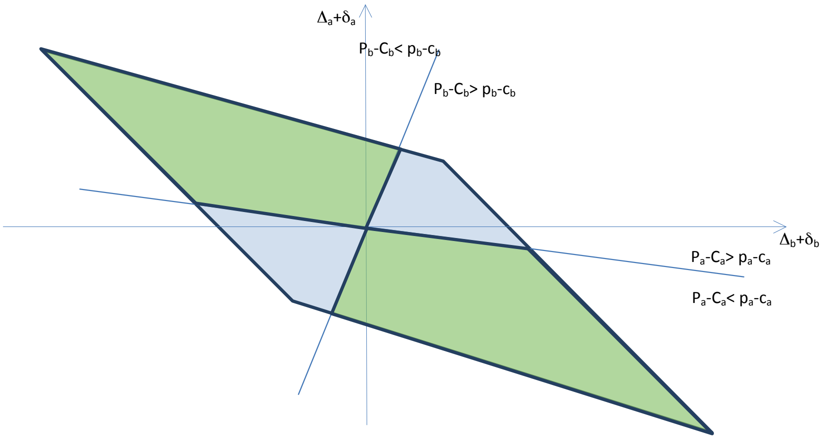

Figure 3: Sign of the mark-ups

Using the equilibrium values of prices and number of agents, we find

$$\begin{aligned}
\Pi &= \frac{1}{2}\left(\tau_a+\tau_b-\sigma_a-\sigma_b\right) \\
&\quad +\frac{1}{2D}\Big(\tau_b\left(\Delta_a+\delta_a\right)^2+\tau_a\left(\Delta_b+\delta_b\right)^2+\left(\sigma_a+\sigma_b\right)\left(\Delta_a+\delta_a\right)\left(\Delta_b+\delta_b\right)\Big) \\
&\quad +\frac{1}{2D}\left(6\tau_a\tau_b+\tau_b\left(\sigma_a-\sigma_b\right)-\left(\sigma_a+\sigma_b\right)\left(2\sigma_a+\sigma_b\right)\right)\left(\Delta_a+\delta_a\right) \qquad (9) \\
&\quad +\frac{1}{2D}\left(6\tau_a\tau_b-\tau_a\left(\sigma_a-\sigma_b\right)-\left(\sigma_a+\sigma_b\right)\left(\sigma_a+2\sigma_b\right)\right)\left(\Delta_b+\delta_b\right)
\end{aligned}$$

$$\begin{aligned}
\pi &= \frac{1}{2}\left(\tau_a+\tau_b-\sigma_a-\sigma_b\right) \\
&\quad +\frac{1}{2D}\Big(\tau_b\left(\Delta_a+\delta_a\right)^2+\tau_a\left(\Delta_b+\delta_b\right)^2+\left(\sigma_a+\sigma_b\right)\left(\Delta_a+\delta_a\right)\left(\Delta_b+\delta_b\right)\Big) \\
&\quad -\frac{1}{2D}\left(6\tau_a\tau_b+\tau_b\left(\sigma_a-\sigma_b\right)-\left(\sigma_a+\sigma_b\right)\left(2\sigma_a+\sigma_b\right)\right)\left(\Delta_a+\delta_a\right) \qquad (10) \\
&\quad -\frac{1}{2D}\left(6\tau_a\tau_b-\tau_a\left(\sigma_a-\sigma_b\right)-\left(\sigma_a+\sigma_b\right)\left(\sigma_a+2\sigma_b\right)\right)\left(\Delta_b+\delta_b\right)
\end{aligned}$$

Total profit at equilibrium is computed as

$$\begin{aligned}
\Pi+\pi &= \left(\tau_a+\tau_b-\sigma_a-\sigma_b\right) \\
&\quad +\frac{1}{D}\Big(\tau_b\left(\Delta_a+\delta_a\right)^2+\tau_a\left(\Delta_b+\delta_b\right)^2+\left(\sigma_a+\sigma_b\right)\left(\Delta_a+\delta_a\right)\left(\Delta_b+\delta_b\right)\Big).
\end{aligned}$$

4 Incentives to innovate

We consider the adoption of a process innovation that reduces a platform's marginal cost to serve one of the two groups of customers by some positive amount x. Recalling that we defined $\Delta_k = \rho_k - \gamma_k$ with $\rho_k \equiv R_k - r_k$ and $\gamma_k \equiv C_k - c_k$ $(k = a, b)$, we see that if platform U (resp. l) adopts the innovation, we have $\Delta'_k = \Delta_k + x$ (resp. $\Delta'_k = \Delta_k - x$).[9] As explained in the introduction, we examine two alternative measures of the incentives to innovate: the profit incentive and the competitive threat. To define them formally, consider (without loss of generality) platform U and an innovation that is applied to side a. If platform U does not adopt the innovation, the profit incentive approach poses that platform l does not either, while the competitive threat approach poses that it does. In both approaches, the incentive is computed as the profit difference with and without the innovation. We therefore define

$$\begin{aligned} PI_a(x) &= \Pi(C_a - x, C_b; c_a, c_b) - \Pi(C_a, C_b; c_a, c_b), \\ CT_a(x) &= \Pi(C_a - x, C_b; c_a, c_b) - \Pi(C_a, C_b; c_a - x, c_b). \end{aligned} \tag{11}$$

We can define accordingly $PI_b(x)$ and $CT_b(x)$ for platform U, as well as $pi_k(x)$ and $ct_k(x)$ for platform l. Note that in the competitive threat approach, we could have used as couterfactual the application of the innovation by platform l on side b rather than on side a. As we will show below, this distinction is not necessary for the point that we want to make.

4.1 Profit incentive

We focus here on the decomposition of the profit incentive into a direct and a strategic effect. To facilitate the exposition, we consider an infinitesimal descrease in cost (i.e., we let x tend to zero); all our results can be shown to hold for positive values of x. (to be formally shown)

The total effect of a change in Δ_a (i.e., the profit incentive) can be decomposed as follows:

$$\frac{d\Pi}{d\Delta_a} = \underbrace{\frac{\partial \Pi}{\partial \Delta_a}}_{\text{DE}} + \underbrace{\frac{\partial \Pi}{\partial P_a}}_{=0} \frac{\partial P_a^*}{\partial \Delta_a} + \underbrace{\frac{\partial \Pi}{\partial P_b}}_{=0} \frac{\partial P_b^*}{\partial \Delta_a} + \underbrace{\frac{\partial \Pi}{\partial p_a} \frac{\partial p_a^*}{\partial \Delta_a} + \frac{\partial \Pi}{\partial p_b} \frac{\partial p_b^*}{\partial \Delta_a}}_{\text{SE}}$$

The first term is the direct effect; the second and third terms are nil by the envelope theorem; the fourth term is the strategic effect. The next lemma derives the value of the first and fourth term.

Lemma 1 $[DE] = N_a^*$ *and* $[SE] = -\frac{3\tau_a\tau_b - \sigma_b(2\sigma_a + \sigma_b)}{D} N_a^* + \frac{\tau_b(\sigma_a - \sigma_b)}{D} N_b^*$.

[9] We also note that in this model, an innovation that increases the stand-alone benefit by x on side k would have exactly the same effect on a platform's profit.

Proof. The direct effect is defined as

$$[DE] = \frac{\partial \Pi}{\partial \Delta_a} = N_a^* \frac{\partial (P_a - C_a)}{\partial \Delta_a} + N_b^* \frac{\partial (P_b - C_b)}{\partial \Delta_a}.$$

Solving (1) and (2) for P_a and P_b, we can express the inverse demand functions as

$$\begin{aligned} P_a - C_a &= \Delta_a + \tau_a - \sigma_a + \delta_a + p_a - c_a + 2\sigma_a N_b - 2\tau_a N_a, \\ P_b - C_b &= \Delta_b + \tau_b - \sigma_b + \delta_b + p_b - c_b + 2\sigma_b N_a - 2\tau_b N_b. \end{aligned}$$

Hence,

$$\frac{\partial (P_a - C_a)}{\partial \Delta_a} = 1, \ \frac{\partial (P_b - C_b)}{\partial \Delta_a} = 0,$$

and, $[DE] = N_a^*$.

The strategic effect is defined as

$$[SE] = \frac{\partial \Pi}{\partial p_a} \frac{\partial p_a^*}{\partial \Delta_a} + \frac{\partial \Pi}{\partial p_b} \frac{\partial p_b^*}{\partial \Delta_a}$$

We know that

$$\begin{aligned} \frac{\partial \Pi}{\partial p_a} &= (P_a - C_a) \frac{\partial N_a}{\partial p_a} + (P_b - C_b) \frac{\partial N_b}{\partial p_a} \\ &= -\left[(P_a - C_a) \frac{\partial N_a}{\partial P_a} + (P_b - C_b) \frac{\partial N_b}{\partial P_a} \right] \\ &= N_a^* \end{aligned}$$

where the second line uses the fact that $\partial N_a / \partial P_a = -\partial N_a / \partial p_a$, $\partial N_b / \partial P_b = -\partial N_b / \partial p_b$ by (1) and (2), and where the third line uses platform U's first-order condition for profit maximization on side a ($\partial \Pi / \partial P_a = 0$). By analogy, $\partial \Pi / \partial p_b = N_b^*$. Using (7), we know

$$\frac{\partial p_a^*}{\partial \Delta_a} = -\frac{\partial P_a^*}{\partial \Delta_a} = -\frac{3\tau_a \tau_b - \sigma_b (2\sigma_a + \sigma_b)}{D}, \qquad \frac{\partial p_b^*}{\partial \Delta_a} = -\frac{\partial P_b^*}{\partial \Delta_a} = \frac{\tau_b (\sigma_a - \sigma_b)}{D}$$

Hence

$$\begin{aligned} [SE] &= \frac{\partial p_a^*}{\partial \Delta_a} N_a^* + \frac{\partial p_b^*}{\partial \Delta_a} N_b^* \\ &= -\frac{3\tau_a \tau_b - \sigma_b (2\sigma_a + \sigma_b)}{D} N_a^* + \frac{\tau_b (\sigma_a - \sigma_b)}{D} N_b^* \end{aligned}$$

■

Before deriving the total effect, we first examine the strategic effect.

4.1.1 Sign of the strategic effect

In one-sided markets, the strategic effect is negative when firms' strategies are complements. We can mimic one-sided markets in this model by setting $\sigma_a = \sigma_b = 0$. In that case we check that $[SE]$ is indeed negative. However, in a two-sided market, platforms choose two prices and it is not clear how to define strategic complementarity or substitutability. In the present case, it turns out that the *strategic effect can be positive*, implying that an investment that makes platform U though is met by a favourable response from platform l. First note that the strategic effect from an investment on side a is more likely to be positive if $\sigma_a > \sigma_b$. Next, supposing $\sigma_a > \sigma_b$, we know from our analysis of equilibrium prices, that platform l reacts by decreasing its price on side a and increasing its price on side b. Other things being equal, platform U welcomes such reaction as $\sigma_a > \sigma_b$ implies that it is more profitable to attract additional users on side b than on side a. Yet, things are not equal: the price variations are not equal and apply to different quantities. Obviously, $[SE]$ is even more likely to be positive if N_a^* is close to zero and/or N_b^* close to one. But the strategic effect can be positive even if we start from a symmetric situation ($N_a^* = N_b^* = 1/2$). For instance, set $\sigma_a = 2$, $\sigma_b = 1$, $\tau_a = 0.8$ and $\tau_b = 3$ (which satisfy the second-order condition) and compute $[SE] = 0.4/D > 0$. This example demonstrates that the positivity of the strategic effect is not a pathological phenomenon.

4.1.2 Sign of the total effect

Combining the above results, we can now express the total effect as the sum of the direct and strategic effects:

$$\begin{aligned}[TE] &= N_a^* - \frac{3\tau_a\tau_b - \sigma_b(2\sigma_a + \sigma_b)}{D} N_a^* + \frac{\tau_b(\sigma_a - \sigma_b)}{D} N_b^* \\ &= \frac{6\tau_a\tau_b - (2\sigma_a + \sigma_b)(\sigma_a + \sigma_b)}{D} N_a^* + \frac{\tau_b(\sigma_a - \sigma_b)}{D} N_b^*\end{aligned}$$

In one-sided markets ($\sigma_a = \sigma_b = 0$), the total effect is clearly positive: even if a negative strategic effect may lead the firm to underinvest, the direct effect is large enough to make the investment profitable. In contrast, in two-sided markets, the presence of cross-group effects may challenge this result as stated in the next proposition.

Proposition 1 *Consider two platforms competing in prices and let one of* *them have access to a cost-reducing innovation. This platform may not adopt this innovation as it would reduce its profit.*

For instance, start from a symmetric situation ($N_a^* = N_b^* = 1/2$) and set $\sigma_a = 1$, $\sigma_b = 2$, $\tau_a = 1.15$ and $\tau_b = 2$ (which satisfy the second-order condition). We can then compute $[TE] = -0.1/D < 0$.

To understand this result, note first that $[TE]$ is a negative function of σ_b. Hence, an investment on side a becomes less profitable the more users on side b value interactions. This is because the strategic effect becomes more negative (see the discussion above for the opposite case when $\sigma_a > \sigma_b$). The strategic effect might become larger than the direct effect as the value of σ_b continues to grow.

It would be wrong to think that if a platform has no incentive to invest on one side, it would necessarily have an incentive to invest on the other side. It is indeed possible to show that both $d\Pi/d\Delta_a$ and $d\Pi/d\Delta_b$ can be negative for the same configuration of parameters. Keeping for instance the same values of the parameters that yielded a negative total effect of an investment on side a ($\sigma_a = 1$, $\sigma_b = 2$, $\tau_a = 1.15$ and $\tau_b = 2$), we also find a negative total effect of an investment on side b.[10]

4.2 Competitive threat

Our objective in this section is not to redo the previous analysis for this alternative measure of the incentive to innovate. We just want to compare the two measures and show that, contrary to the conventional wisdom in one-sided markets, taking the competitive threat into account may *decrease* a platform's incentive to innovate. We also want to push the analysis a bit further by analyzing a simple game of innovation adoption.

4.2.1 When the competitive threat becomes an opportunity

Using the definitions (11), we see that the competitive threat is smaller than the profit incentive if (focusing again, without loss of generality, on platform l and side a)

$$CT_a(x) < PI_a(x) \Leftrightarrow \Pi(C_a, C_b; c_a - x, c_b) > \Pi(C_a, C_b; c_a, c_b);$$

[10] It suffices to switch the indices a and b in the expression of $[TE]$; doing so, we find $[TE] = -0.025/D$.

that is, if platform l's profit increases when the rival platform reduces its marginal cost. We have already demonstrated above that this possibility exists. Indeed, the adoption of the innovation by platform l reduces Δ_a by x (as platform l's marginal cost is reduced from c_a to $c_a - x$) and we know that $d\Pi/d\Delta_a$ can be negative when the strategic effect is sufficiently negative. In this model with covered markets on both sides, it is the relative efficiency of the two platforms that matters. Hence, a platform is affected in the same way if it decreases its cost by some amount or if the rival platform increases its by the same amount.

This apparently counter-intuitive result can be explained as above. Cross-group externalities may amplify the strategic effects of a cost-reducing investment to such an extent that a investment meant to make a platform tough (cost reduction) makes her eventually soft as it raises the profit of the other platform.

4.2.2 On which side to innovate?

The competitive threat (based on the idea that if a firm does not adopt the innovation, the other firm will do) naturally leads to the analysis of situations where both firms simultaneously contemplate the possibility of adopting the innovation. In the present context, platforms face a larger strategy set than in traditional markets: if they decide to adopt the innovation, they still have to decide on which side they will apply it. (Give here an example of a multipurpose technology that can decrease the platform's cost on either side of the market.)

For simplicity, we focus on this second issue (assuming, for instance, that the technology is very inexpensive). We also assume that platforms are identical when the game starts; that is, we set Δ_k and δ_k equal to zero (on each side, platforms have the same marginal cost and offer the same stand-alone benefits and marginal external effects). The innovation allows platform to reduce marginal cost by x on the side of their choice. Each platform decides thus whether to apply the innovation on side a or on side b.[11] We note by $\{A, B\}$ and $\{a, b\}$ the choices of, respectively, platform U and platform l.

[11]Naturally, we assume here that both platforms have positive incentives to innovate: $d\Pi/d\Delta_k > 0$ and $d\pi/d\Delta_k > 0$ ($k = a, b$). We could, more generally, allow platforms to allocate the cost reduction x in any possible way between the two sides. We show in the appendix that platforms would nevertheless find it optimal to concentrate the full

Suppose first that both platforms decide to invest on the same side. That is, C_k becomes $C_k - x$ and c_k becomes $c_k - x$. This leaves γ_k unchanged: $\gamma_k = C_k - c_k = (C_k - x) - (c_k - x)$. As a result, Δ_k remains equal to zero. Using expressions (9) and (10), we have thus

$$\Pi(A,a) = \pi(A,a) = \Pi(B,b) = \pi(B,b) = \tfrac{1}{2}(\tau_a + \tau_b - \sigma_a - \sigma_b).$$

Suppose now that platform U invests on side a and platform l on side b. It follows that $\Delta_a = x$ and $\Delta_b = -x$. Plugging these values in expressions (9) and (10), we find

$$\begin{aligned}
\Pi(A,b) &= \tfrac{1}{2}(\tau_a + \tau_b - \sigma_a - \sigma_b) + \tfrac{1}{2D}(\tau_a + \tau_b - \sigma_a - \sigma_b)\, x\,(x + (\sigma_a - \sigma_b)), \\
\pi(A,b) &= \tfrac{1}{2}(\tau_a + \tau_b - \sigma_a - \sigma_b) + \tfrac{1}{2D}(\tau_a + \tau_b - \sigma_a - \sigma_b)\, x\,(x - (\sigma_a - \sigma_b)).
\end{aligned}$$

In the reverse situation, we easily find by symmetry that $\Pi(B,a) = \pi(A,b)$ and $\pi(B,a) = \Pi(A,b)$.

We can now characterize the Nash equilibrium of the game. For both platforms to apply the innovation on side a, we need $\Pi(A,a) \geq \Pi(B,a)$ and $\pi(A,a) \geq \pi(A,b)$. As $\Pi(A,a) = \pi(A,a)$ and $\Pi(B,a) = \pi(A,b)$, the two conditions are equivalent; given that $x > 0$ and $\tau_a + \tau_b > \sigma_a - \sigma_b$, they boil down to $x \leq \sigma_a - \sigma_b$. By analogy, both firms choose side b at equilibrium if $x \leq -(\sigma_a - \sigma_b)$. It is then clear that the equilibrium involves the two platforms choosing different sides if $x \geq |\sigma_a - \sigma_b|$. We have therefore proven the following proposition.

Proposition 2 *Suppose that the platforms can freely adopt an innovation that reduces their marginal cost on one side by x and that they have to choose on which side they apply this innovation. Suppose, without loss of generality, that $\sigma_a > \sigma_b$ (users on side a value more the intraction with the other group than users on side b). At the Nash equilibrium, both platforms apply the innovation on side a if $x \leq \sigma_a - \sigma_b$; otherwise, they apply the innovation on different sides.*

Hence, if the innovation is sufficiently important, the platforms will 'specialize' by investing on different sides, which will break the initial symmetry. It is important to note that such specialization increases total profits. Setting $\delta_a = \delta_b = 0$, we have that total profits are equal to

$$\Pi + \pi = (\tau_a + \tau_b - \sigma_a - \sigma_b) + \frac{1}{D}\left(\tau_b \Delta_a^2 + \tau_a \Delta_b^2 + (\sigma_a + \sigma_b)\Delta_a \Delta_b\right).$$

reduction on one side or on the other.

Starting from the symmetric situation, $\Delta_a = \Delta_b = 0$ when both platforms invest on the same side, or $\Delta_a = x$ and $\Delta_b = -x$ (or $\Delta_a = -x$ and $\Delta_b = x$) when they specialize. Substituting in the previous expression, we find

$$\Pi + \pi|_{\text{Specialization}} - \Pi + \pi|_{\text{Same side}} = \frac{1}{D}\left(\tau_b + \tau_a + (\sigma_a + \sigma_b)\right) x^2 > 0.$$

We can also show (to be formally done) that the consumer surplus is also larger under specialization.

(Comment on unstability of symmetric situation)

5 Discussion and concluding remarks

TBW

6 Appendix

(to be cleaned)

Start from symmetric situation: $\Delta_a = \delta_a = \Delta_b = \delta_b = 0$, implying that $N_a^* = n_a^* = N_b^* = n_b^* = 1/2$. Suppose that the total effect is positive for both platforms on both sides; that is,

$$\begin{aligned}
[TE]_a \text{ and } [te]_a &> 0 \iff 6\tau_a\tau_b + (\sigma_a - \sigma_b)\tau_b - (\sigma_a + \sigma_b)(2\sigma_a + \sigma_b) > 0, \\
[TE]_b \text{ and } [te]_b &> 0 \iff 6\tau_a\tau_b + (\sigma_b - \sigma_a)\tau_a - (\sigma_a + \sigma_b)(\sigma_a + 2\sigma_b) > 0.
\end{aligned}$$

Platforms can reduce cost by x. This x has to be split among the two sides. Platform U (resp. l) chooses $0 \leq A \leq 1$ (resp. $0 \leq a \leq 1$) as the fraction of the cost reduction that goes to side a; the remaining fraction goest to side b. As a result, $\Delta_a = (A - a)x$ and $\Delta_b = (1 - A - (1 - a))x = -(A - a)x$. Hence, for a given pair (A, a), platform U's equilibrium profit at the price game is given by

$$\Pi(A, a) = \frac{1}{2D}(\tau_a + \tau_b - \sigma_a - \sigma_b)\left(D + (A - a)^2 x^2 + (\sigma_a - \sigma_b)(A - a)x\right)$$

Platform U chooses $A \in (0, 1)$ to maximize $\Pi(A, a)$. We have

$$\begin{aligned}
\frac{d\Pi}{dA} &= \frac{1}{2D}(\tau_a + \tau_b - \sigma_a - \sigma_b)\left(2(A - a)x^2 + (\sigma_a - \sigma_b)x\right) \\
\frac{d^2\Pi}{dA^2} &= \frac{1}{D}(\tau_a + \tau_b - \sigma_a - \sigma_b)x^2 > 0.
\end{aligned}$$

From the SOC, we see that the platform will choose either $A = 0$ or $A = 1$.

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