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The Stackelberg–Armstrong model

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ABSTRACT

We show that sequential (Stackelberg) competition between two-sided platforms can overturn the price-skewness ranking of the Armstrong (2006) competition benchmark: the side subsidized under simultaneous pricing may become the taxed side under sequential play. The mechanism is that the Stackelberg leader internalizes cross-side feedback through the follower's best response, which introduces both externalities into each side's markup and can reverse which side is subsidized. The equilibrium is unique, admits closed-form solutions under standard interiority/concavity conditions, and is directly comparable to Armstrong's benchmark. Both platforms earn strictly more than under simultaneous play, and we characterize a sharp threshold separating second-mover from first-mover advantage.

1. Introduction

A central insight of the Armstrong (2006) model is that cross-group externalities skew platform prices: the side that generates larger benefits for the other side is subsidized. This price-skewness ranking drives much of the policy intuition derived from the Armstrong–Hotelling benchmark. We show that this ranking can be overturned when platforms compete sequentially rather than simultaneously. In the Stackelberg extension we derive, the leader internalizes the follower's cross-side feedback loop, which amplifies the weight of network effects in each side's markup asymmetrically. As a result, the subsidized side under simultaneous pricing may become the taxed side under sequential play.

The mechanism is distinct from divide-and-conquer strategies that rely on coordination selection (Jullien, 2011; Halaburda and Yehezkel, 2019) and from richer multi-sided settings where sequential pricing interacts with focality or platform heterogeneity (Farhi and Hagiu, 2008; Feng et al., 2020). By working within Armstrong's own Hotelling structure (smooth demand, unique equilibrium under standard interiority/concavity, closed-form solutions) the timing effect is directly comparable to Armstrong (2006) and its extensions (Armstrong and Wright, 2007; Rasch, 2007; Hagiu and Halaburda, 2014).

Our timing structure is *inter-platform*: one platform commits to its full two-sided price vector before the rival responds on both sides. This differs from the *intra-platform* sequencing in Bontems et al. (2025), where both platforms move simultaneously but set prices on one side before the other. The two timing structures answer different economic questions. Intra-platform sequencing speaks to platform design (which side to price first); inter-platform sequencing speaks to market entry timing (who enters first). The comparative statics also differ: intra-platform sequencing attenuates cross-platform network effects (Bontems et al., 2025), whereas inter-platform Stackelberg competition amplifies the role of *both* externalities in each side's pricing, which is what generates the skewness reversal. Beyond the skewness result, we show that both platforms earn strictly more under Stackelberg than under simultaneous play due to higher prices on both sides, and we characterize a sharp threshold separating second-mover from first-mover advantage.

2. The model

We adopt the two-sided market extension of Hotelling (1929) proposed by Armstrong (2006) as the baseline, in which the utility is

$$U_{i,k}(x) = v - p_{i,k} + \alpha_i n_{-i,k} - t_i|x - l_k| \quad (1)$$

where v is a stand-alone value, $p_{i,k}$ is the membership fee that side $i \in \{1,2\}$ on platform $k \in \{A, B\}$ pays for joining, $n_{-i,k}$ represents the number of agents on side $-i$ on platform k and α_i is the marginal benefit for the user of having an additional agent on side $-i$ on platform k, and $t_i|x - l_k|$ is the mismatch cost. We assume prices are set simultaneously across sides within a platform, but sequentially across platforms. Therefore, demands are,

$$n_{i,k} = 1/2 + \frac{t_{-i}(p_{i,-k} - p_{i,k}) + \alpha_i(p_{-i,-k} - p_{-i,k})}{2(t_i t_{-i} - \alpha_i \alpha_{-i})} \quad (2)$$

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And profits under constant marginal costs on each side, f_i are,

$$\Pi_k = \sum_i (p_{i,k} - f_i) n_{i,k} \tag{3}$$

Finally, to keep the model tractable, we make the following assumptions:

- $t_i > 0$
- v is large enough to have the market covered
- $t_1 t_2 - \alpha_1 \alpha_2 > 0$, (interiority)
- $4t_1 t_2 - (\alpha_1 + \alpha_2)^2 > 0$, (concavity)

The last two assumptions ensure that transport costs dominate network effects so that demands are interior (neither platform corners the market); and that the profit functions are concave in own prices, respectively.

In Armstrong (2006), both platforms set prices on both sides simultaneously, and a unique price equilibrium exists with the symmetric equilibrium prices ($p_{i,A} = p_{i,B} = p_i$ where $p_i = f_i + t_i - \alpha_{-i}$) and profits ($\Pi_k = \frac{t_1+t_2-\alpha_1-\alpha_2}{2}$) However, unlike Armstrong (2006), we assume that one platform sets its prices before the competitor à la (Stackelberg, 1934).

2.1. Followers' reaction

Without loss of generality, let us assume platform B is the follower (and platform A is the leader). The follower chooses the pair $(p_{1,B}, p_{2,B})$ that maximizes Eq. (3) given the pair $(p_{1,A}, p_{2,A})$. So, first-order conditions are given by,

$$\begin{aligned} \frac{\partial \Pi_B}{\partial p_{1,B}} &= n_{1,B} + m_{1,B}\frac{\partial n_{1,B}}{\partial p_{1,B}} + m_{2,B}\frac{\partial n_{2,B}}{\partial p_{1,B}} = 0 \\ \frac{\partial \Pi_B}{\partial p_{2,B}} &= n_{2,B} + m_{2,B}\frac{\partial n_{2,B}}{\partial p_{2,B}} + m_{1,B}\frac{\partial n_{1,B}}{\partial p_{2,B}} = 0 \end{aligned} \tag{4}$$

where $m_{i,k} = p_{i,k} - f_i$, $i = 1,2$; $k = A, B$ are the markups. Solving this system, we have the following result:

Lemma 1. *Given the leaders' prices, $(p_{1,A}, p_{2,A})$, the optimal markups of the follower are,*

$$\begin{aligned} m_{1,B} &= \frac{2t_1(D+t_2 m_{1,A}+\alpha_1 m_{2,A})-(\alpha_1+\alpha_2)(D+t_1 m_{2,A}+\alpha_2 m_{1,A})}{4t_1t_2-(\alpha_1+\alpha_2)^2} \\ m_{2,B} &= \frac{2t_2(D+t_1 m_{2,A}+\alpha_2 m_{1,A})-(\alpha_1+\alpha_2)(D+t_2 m_{1,A}+\alpha_1 m_{2,A})}{4t_1t_2-(\alpha_1+\alpha_2)^2} \end{aligned} \tag{5}$$

where $D = t_1 t_2 - \alpha_1 \alpha_2 > 0$

Proof. See Appendix. □

2.2. Leader's reaction

Let us now turn our attention to the leader, who chooses the pair $(p_{1,A}, p_{2,A})$ that maximizes Eq. (3), but taking into account that the follower behaves as Lemma 1 prescribes. In this case, first-order conditions are given by,

$$\begin{aligned} \frac{\partial \Pi_A}{\partial m_{i,A}} &= n_{i,A} + m_{i,A}\left(\frac{\partial n_{i,A}}{\partial m_{i,B}}\frac{\partial m_{i,B}}{\partial m_{i,A}} + \frac{\partial n_{i,A}}{\partial m_{-i,B}}\frac{\partial m_{-i,B}}{\partial m_{i,A}} + \frac{\partial n_{i,A}}{\partial m_{i,A}}\right) + \\ &\quad m_{-i,A}\left(\frac{\partial n_{-i,A}}{\partial m_{i,B}}\frac{\partial m_{i,B}}{\partial m_{i,A}} + \frac{\partial n_{-i,A}}{\partial m_{-i,B}}\frac{\partial m_{-i,B}}{\partial m_{i,A}} + \frac{\partial n_{-i,A}}{\partial m_{i,A}}\right) = 0 \\ \frac{\partial \Pi_A}{\partial m_{i,A}} &= n_{i,A} + m_{i,A}\left(\frac{t_{-i}}{2D}\frac{2t_i t_{-i}-\alpha_{-i}S}{K} + \frac{\alpha_i}{2D}\frac{2t_{-i}\alpha_{-i}-St_{-i}}{K} - \frac{t_{-i}}{2D}\right) + \\ &\quad m_{-i,A}\left(\frac{\alpha_{-i}}{2D}\frac{2t_i t_{-i}-\alpha_{-i}S}{K} + \frac{t_i}{2D}\frac{2t_{-i}\alpha_{-i}-St_{-i}}{K} - \frac{\alpha_{-i}}{2D}\right) = 0 \end{aligned} \tag{6}$$

where $S = \alpha_i + \alpha_{-i}$ and $K = 4t_i t_{-i} - (\alpha_i + \alpha_{-i})^2$, and symmetrically for side $-i$. Solving the system of first-order conditions, we have the following result,

Lemma 2. *Leader's markups in the Stackelberg–Armstrong game are,*

$$\begin{aligned} m_{1,A} &= \frac{3}{2}t_1 - \frac{\alpha_1}{2} - \alpha_2 \\ m_{2,A} &= \frac{3}{2}t_2 - \frac{\alpha_2}{2} - \alpha_1 \end{aligned} \tag{7}$$

Proof. See Appendix. □

It is straightforward that the leader always sets higher prices than in the Armstrong model in the interior equilibrium, but more relevant is the fact that the timing imposed by Stackelberg competition can reverse which side faces higher prices. In the original (Armstrong, 2006) model, side 1 has lower markups if $m_1 < m_2$, which happens when $t_1 - t_2 < \alpha_2 - \alpha_1$. In the Stackelberg–Armstrong framework, side 1 has lower markups (skewness condition) when $t_1 - t_2 < \frac{\alpha_2 - \alpha_1}{3}$. Therefore, there is a region where $\frac{\alpha_2-\alpha_1}{3} < t_1 - t_2 < \alpha_2 - \alpha_1$ in which side 1 has lower markups in the Armstrong model and higher markups in the Stackelberg–Armstrong model with respect to side 2.

Proposition 1. *Sequential platform competition can invert the logic of the relative price skewness between sides when $\frac{\alpha_2-\alpha_1}{3} < t_1 - t_2 < \alpha_2 - \alpha_1$.*

The mechanism behind this reversal is as follows. In Armstrong's simultaneous game, each externality enters only the *opposite* side's price. Under Stackelberg, two things change. First, the leader raises the weight on its own transportation cost from 1 to $\frac{3}{2}$, reflecting the softened competition that commitment provides. Second, each side's markup now depends on *its own* externality α_i as well, because the leader anticipates how the follower's best response transmits a price cut on side i into demand gains on side $-i$. This additional channel compresses the gap between the two sides' markups: the skewness condition tightens from $t_1 - t_2 < \alpha_2 - \alpha_1$ to $t_1 - t_2 < \frac{\alpha_2-\alpha_1}{3}$. The factor $\frac{1}{3}$ arises because the leader's feedback internalization triples the effective weight of each externality difference in the relative-markup comparison.

This result has a practical implication for platform regulation. A regulator assessing which side is "subsidized" – a determination relevant to predatory pricing investigations or price-parity mandates – would reach opposite conclusions depending on whether it assumes simultaneous or sequential competitive conduct. Consider $t_1 = 1.3, t_2 = 1, \alpha_1 = 0.2, \alpha_2 = 0.8$: Armstrong's markups are $m_{Arm,1} = 0.5$ and $m_{Arm,2} = 0.8$ (side 1 is more subsidized), whereas the Stackelberg leader's markups are $m_{SA,1} = 1.05$ and $m_{SA,2} = 0.9$ (side 2 is more subsidized).

Combining Lemmas 1 and 2, we can derive the optimal follower's markups. For illustrative purposes, we assume both sides are symmetric, but the intuitions hold for the general asymmetric case (which is in the Appendix). Assuming $t_1 = t_2 = t$, $\alpha_1 = \alpha_2 = \alpha$, and $f_1 = f_2 = f$, we have the following corollary,

Corollary 1. *If both sides are symmetric, the Armstrong–Stackelberg equilibrium is given by,*

$$m_B = \frac{5}{4}(t - \alpha) \qquad m_A = \frac{3}{2}(t - \alpha) \tag{8}$$

The impact is not limited to prices alone, as the repercussions of Stackelberg timing are also reflected in profits. Combining Lemmas 1 and 2, we have that,

$$\Pi_S^L - \Pi_A = \frac{D(t_1 + t_2 - (\alpha_1 + \alpha_2))}{4K} \tag{9}$$

where Π_S^L denotes the profits of the Stackelberg leader and Π_A the profits of a platform in the Armstrong model; and $D \equiv t_1 t_2 - \alpha_1 \alpha_2$, $K = 4t_1 t_2 - (\alpha_1 + \alpha_2)^2 > 0$. Note that since $K > 0$ and $D > 0$, we have $\alpha_1 + \alpha_2 < 2\sqrt{t_1 t_2} \leq t_1 + t_2$, so the numerator is strictly positive. Stackelberg softens competition enough to make the leader prefer this timing to the simultaneous-move profit everywhere in the interior market-sharing region.

Lemma 3. *Profits are always larger for the leader platform under Stackelberg competition than in the Armstrong (2006) model.*

However, although profits are higher and Stackelberg competition in the Hotelling framework suggests an advantage for the follower Fleckinger and Lafay (2010), this cannot be taken for granted, as there is a threshold separating the first- and second-mover advantages.

$$\Pi_S^F - \Pi_S^L = \frac{(t_1 + t_2 - (\alpha_1 + \alpha_2))(7t_1t_2 - (2\alpha_1^2 + 3\alpha_1\alpha_2 + 2\alpha_2^2))}{8K} \tag{10}$$

where Π_S^F are the profits of the Stackelberg follower. In the interior region, the first factor is always positive, as previously noted, and the denominator is positive by definition. Therefore, the sign is governed entirely by the second bracket, which is positive when $7t_1t_2 > (2\alpha_1^2 + 3\alpha_1\alpha_2 + 2\alpha_2^2)$. In the symmetric case ($t_1 = t_2 = t; \alpha_1 = \alpha_2 = \alpha$), this condition is automatically satisfied. There are extreme cases in which this sign can flip, for instance, when $t_1 = t_2 = 4$, $\alpha_1 = 0$, and $\alpha_2 = 7.9$; in this case, $K > 0$, but the sign flips.

Proposition 2. *In the Stackelberg–Armstrong model:*

- *Under the model Assumptions, both platforms earn more than in Armstrong (simultaneous play)*
- *If $7t_1t_2 > (2\alpha_1^2 + 3\alpha_1\alpha_2 + 2\alpha_2^2)$, the follower earns more than the leader (second-mover advantage); otherwise, the leader earns more (first-mover advantage).*

These results indicate that platforms may prefer not to enter the market simultaneously, and that staggered entry may be beneficial for both platforms. Moreover, since each platform serves half the market in the symmetric equilibrium and prices are higher on both sides, consumer surplus on each side falls mechanically compared to Armstrong (2006).

3. Conclusions

The main takeaway from this note is that the timing of platform competition is not neutral for the structure of two-sided prices. When one platform commits before its rival, the leader internalizes cross-side feedback loops that are absent under simultaneous play. This changes not just the *level* of markups but their *relative* structure across sides, potentially reversing which side is subsidized, a conclusion that matters for regulatory assessments of platform pricing conduct. The higher profits for both platforms and the possibility of second-mover advantage further suggest that staggered market entry, as observed in the early phases of console generations or streaming markets, where singlehoming is most prevalent before multihoming develops as installed bases mature, may reflect equilibrium incentives rather than mere happenstance. Endogenizing the timing choice is a natural extension (Hamilton and Slutsky, 1990), as is exploring whether the skewness reversal survives under multihoming or asymmetric platform differentiation.

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Appendix

Let $m_{ik} \equiv p_{ik} - f_k$, $S \equiv \alpha_1 + \alpha_2$, $D \equiv t_1t_2 - \alpha_1\alpha_2$, $K = 4t_1t_2 - S^2 > 0$. From Armstrong (2006), we have that demands are given by Eq. (2) and profits Eq. (3).

Considering that platform B is the follower, its optimal decision is given by Eq. (4), where $\frac{\partial n_{1,B}}{\partial m_{1,B}} = -t_2/2D$, $\frac{\partial n_{1,B}}{\partial m_{2,B}} = -\alpha_1/2D$, $\frac{\partial n_{2,B}}{\partial m_{1,B}} = -\alpha_2/2D$, and $\frac{\partial n_{2,B}}{\partial m_{2,B}} = -t_1/2D$. Therefore, the system can be written as,

$$2Dn_{1,B} - t_2m_{1,B} - \alpha_2m_{2,B} = 0$$
$$2Dn_{2,B} - t_1m_{2,B} - \alpha_1m_{1,B} = 0$$

Substituting $n_{1,B}$ and $n_{2,B}$ in this expression,

$$D - (t_2(m_{1,B} - m_{1,A}) + \alpha_1(m_{2,B} - m_{2,A})) = t_2m_{1,B} + \alpha_2m_{2,B}$$
$$D - (t_1(m_{2,B} - m_{2,A}) + \alpha_2(m_{1,B} - m_{1,A})) = t_1m_{2,B} + \alpha_1m_{1,B}$$

Simplifying and expressing it in matrix notation,

$$\begin{pmatrix} D + t_2m_{1,A} + \alpha_1m_{2,A} \\ D + t_1m_{2,A} + \alpha_2m_{1,A} \end{pmatrix} = \underbrace{\begin{pmatrix} 2t_2 & S \\ S & 2t_1 \end{pmatrix}}_{B} \begin{pmatrix} m_{1,B} \\ m_{2,B} \end{pmatrix}$$

Note that $\det B > 0$ if $K > 0$. If so, we can invert B, and solving the following expression leads to Lemma 1,

$$\begin{pmatrix} m_{1,B} \\ m_{2,B} \end{pmatrix} = B^{-1} \begin{pmatrix} D + t_2m_{1,A} + \alpha_1m_{2,A} \\ D + t_1m_{2,A} + \alpha_2m_{1,A} \end{pmatrix}$$

For the leader's reaction function, it is useful to denote some derivatives first: $\frac{\partial m_{1,B}}{\partial m_{1,A}} = \frac{2t_1t_2 - S\alpha_2}{K}$, $\frac{\partial m_{1,B}}{\partial m_{2,A}} = \frac{2t_1\alpha_1 - St_1}{K}$, $\frac{\partial m_{2,B}}{\partial m_{1,A}} = \frac{2t_2\alpha_2 - St_2}{K}$, $\frac{\partial m_{2,B}}{\partial m_{2,A}} = \frac{2t_1t_2 - S\alpha_1}{K}$. Substituting these expressions into Eq. (6) and using matrix notation, demands are thus given by

$$n_A = \begin{pmatrix} n_{1,A} \\ n_{2,A} \end{pmatrix} = 1/2 \begin{pmatrix} 1 \\ 1 \end{pmatrix} + \frac{1}{2D} \underbrace{\begin{pmatrix} t_2 & \alpha_1 \\ \alpha_2 & t_1 \end{pmatrix}}_{G} \delta$$

where $\delta \equiv (\delta_1, \delta_2)^T$, $\delta_1 \equiv m_{1,B} - m_{1,A}$, and $\delta_2 \equiv m_{2,B} - m_{2,A}$. From the follower's reaction function, we have $m_B = B^{-1}(D\mathbf{1} + Gm_A)$. Compute $\delta = m_B - m_A = B^{-1}(D\mathbf{1} + Gm_A) - m_A$, which simplifies to $\delta(m_A) = B^{-1}(D\mathbf{1} + Gm_A - Bm_A) = B^{-1}(D\mathbf{1} + (G - B)m_A) = B^{-1}(D\mathbf{1} - G^Tm_A)$

And rewrite the profit function as,

$$\Pi^A = n_{1,A}m_{1,A} + n_{2,A}m_{2,A} = m_A^Tn_A = \frac{1}{2}1^Tn_A + \frac{1}{2D}m_A^TG\delta(m_A)$$

by substituting $\delta(m_A)$ and denoting $R \equiv GB^{-1}$,

$$\Pi^A = \frac{1}{2}1^Tn_A + \frac{1}{2D}\left(Dm_A^TR\mathbf{1} - m_A^TRG^Tm_A\right)$$

Denoting by $\nabla_{\Pi^A}(m_A) = 0$ the leader's first-order conditions in matrix notation,

$$\nabla_{\Pi^A}(m_A) = \frac{1}{2}\mathbf{1} + \frac{1}{2D}\left(DR\mathbf{1} - (RG^T + (RG^T)^T)m_A\right) = 0$$

Solving $\nabla_{\Pi^A}(m_A) = 0$, we have $Bm_A = \frac{K}{2}(1 + R\mathbf{1})$. After some algebraic manipulation,

$$m_{1,A} = \frac{2t_1h_1 - Sh_2/2}{K}, \quad m_{2,A} = \frac{2t_2h_2 - Sh_1/2}{K}, \text{ where } \begin{aligned} h_1 &= 6t_1t_2 - 2\alpha_1^2 - 3\alpha_1\alpha_2 - \alpha_2^2 + t_2(\alpha_1 - \alpha_2) \\ h_2 &= 6t_1t_2 - \alpha_1^2 - 3\alpha_1\alpha_2 - 2\alpha_2^2 + t_1(\alpha_2 - \alpha_1) \end{aligned}$$

Solving the system of prices,

$$m_{1,A} = \frac{3}{2}t_1 - \frac{\alpha_1}{2} - \alpha_2$$
$$m_{2,A} = \frac{3}{2}t_2 - \frac{\alpha_2}{2} - \alpha_1$$

In the Stackelberg–Armstrong game, the follower's SOC is the same condition as in the Armstrong (2006) model, and the leader's reduced-form objective (after substituting the follower's best response) remains concave under the same inequality. So, by the assumption $K > 0$, this equilibrium is unique and interior. To obtain the results of Eqs. (9) and (10), let us proceed with the follower, which is a bit more involved. The case for the leader follows a similar logic. Using Eq. (4), we can denote demands as,

$$n_{1,B} = \frac{t_2m_{1,B} + \alpha_2m_{2,B}}{2D}$$
$$n_{2,B} = \frac{\alpha_1m_{1,B} + t_1m_{2,B}}{2D}$$

so follower's profits are given by $\Pi^B = \Pi_S^F = \frac{t_2m_{1,B}^2 + Sm_{1,B}m_{2,B} + t_1m_{2,B}^2}{2D}$. To avoid the messy substitution that implies using $m_{i,B}$, consider the matrix form $Bm_B = D\mathbf{1} + Gm_A$, using Eq. (7), we have,

$$u \equiv D\mathbf{1} + Gm_A^* = \begin{matrix} -\alpha_1^2 - \frac{3}{2}\alpha_1\alpha_2 + (\alpha_1 - \alpha_2)t_2 + \frac{5}{2}t_1t_2 \\ -\alpha_2^2 - \frac{3}{2}\alpha_1\alpha_2 + (\alpha_2 - \alpha_1)t_1 + \frac{5}{2}t_1t_2 \end{matrix}$$

Then, the follower equilibrium markups are $m_B^* = \frac{1}{K}adj(B)u$, and profits are $\Pi^B = m_B^Tn_B$. We can rewrite n_B using the FOC as $n_{1,B} = (t_2m_{1,B} + \alpha_2m_{2,B})/(2D)$, and similar for $n_{2,B}$, so that profits become $\Pi^B = \frac{1}{2D}m_B^THm_B$, where $H \equiv \begin{pmatrix} t_2 & S/2 \\ S/2 & t_1 \end{pmatrix}$. By substitution, $\Pi^B =$

$\frac{1}{2DK^2} u^T adj(B)^T H\ adj(B)\ u$. Since $adj(B)^T = adj(B)$, we have $adj(B)\ H\ adj(B) = K \begin{pmatrix} t_1 & -S/2 \\ -S/2 & t_2 \end{pmatrix} = KJ$ and we can simplify the profit function to $\Pi^B = \frac{1}{2DK} u^T J u$, where $u^T J u = t_1 u_1^2 - S u_1 u_2 + t_2 u_2^2$, plugging into Π^B, we have

$$\Pi^B = \frac{(t_1 + t_2 - S)(25t_1 t_2 - (6\alpha_1^2 + 13\alpha_1\alpha_2 + 6\alpha_2^2))}{8(4t_1 t_2 - S^2)}$$

In the case of the leaders, we can also compute $n^A(m^A)$, and substitute into $\Pi^A = n^A m_A$, which leads to

$$\Pi^A = \frac{(t_1 + t_2 - S)(9t_1 t_2 - (2\alpha_1^2 + 5\alpha_1\alpha_2 + 2\alpha_2^2))}{4(4t_1 t_2 - S^2)}$$

Finally, note that profits in Armstrong (2006) are given by $\Pi_A = \frac{t_1 + t_2 - \alpha_1 - \alpha_2}{2}$, and thus the comparisons are direct.

Data availability

No data was used for the research described in the article.

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