Dynamic Platform Competition: Optimal Pricing and Piggybacking under Network Effects

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joint-work with
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Platform Competition Getting Heated

Piggybacking strategy in platform competition
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Platform Strategies – Non-Pricing Controls: Piggybacking
“Piggybacking Strategy is ... connecting with an existing user base from a different platform and stage the creation of value unit in order to recruit those users to participate.”

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Shared Access

- Embedding in A Bigger Platform
- Strategic Poaching
- Business Model Transformation

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Piggybacking strategy in platform competition
# Piggybacking - Importing Adopters from a Different Platform

| Shared Access | Embedding in A Bigger Platform | Strategic Poaching |

Business Model Transformation

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Piggybacking strategy in platform competition
Our Research Questions

In platform competition with network effects:

- How should platforms adjust **pricing** strategies over time when **piggybacking** is possible (i.e., piggybacking is exogenous)?

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  - Complementary or substitutable between offering lower discount and importing external traffic?
The Logic Flow of the Research

Stage 1: A simple two-sided competition model of symmetric pricing duopoly
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Stage 2: Allow one of the platforms to import a given number of adopters

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Research Question 1
How should platforms adjust pricing strategies when piggybacking is possible?

Research Question 2
What are the optimal piggybacking/Pricing Strategies?
A Brief Literature Review

- Vast literature on two-sided markets and platform competition


Non-pricing controls similar to piggyback strategies

Tipping strategy by building market momentum (Gawer and Cusumano 2008)

Adding initial developers to the software platform (Boudreau 2012)

Attracting early users with single-side functionalities (Hagiu and Eisenmann 2007) or advertising (Tucker and Zhang 2010)

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This paper is the first attempt to explore piggyback strategy analytically under a multi-period and competitive setting
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- $\Pi_k$: platform $k$ ’s two-period overall profit
Stage 1: A Simple Model of Symmetric Duopoly

- In each period $i \in \{1, 2\}$, an identical mass of new consumers enter the market.

$\text{New consumer demand for platform } k \text{ in period } i$, $Q_{c_{k_i}}$: The cumulative consumer demand for platform $k$ in period $i$, i.e., $Q_{c_k}^2 = \delta q_{c_k}^1 + q_{c_k}^2$. 

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Piggybacking strategy in platform competition
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- $q_{ki}^c$: New consumer demand for platform $k$ in period $i$, where $i \in \{1, 2\}$, and $\delta$ is the fraction of consumers who lose interest and leave the platform market after period 1.
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- $q^c_{ki}$: New consumer demand for platform $k$ in period $i$,
- $Q^c_{k1}$: The cumulative consumer demand for platform $k$ in period $i$,
  i.e., $Q^c_{k2} = \delta q^c_{k1} + q^c_{k2}$
Stage 1: A Simple Model of Symmetric Duopoly

The consumer demand function can be written in a classic Hotelling setup with network effects

\[ q_{Ai}^c = \frac{\rho}{2} \left( 1 - \frac{p_{Ai}^c - p_{Bi}^c}{t} \right) \]
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- \( \beta \): the surplus derived by a consumer from the participation of each provider (i.e., consumer-side network effects)
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- \( \rho \): total number of new arrivals in each period
- \( \beta \): the surplus derived by a consumer from the participation of each provider (i.e., consumer-side network effects)
- “Transportation” cost: \( t \)
Stage 1: A Simple Model of Symmetric Duopoly

- Providers believe that both platforms are identical
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- $Q_{ki}^d$: The platform demand on the provider side for platform $k$ in period $i$
Multi-homing Provider: The Competitive Bottleneck
Provider-side demands

Provider demand in period $i \in \{1, 2\}$ for platform $k$ is given by

$$Q_{ki}^d = \alpha Q_{ki}^c - p_{ki}^d$$
Provider demand in period $i \in \{1, 2\}$ for platform $k$ is given by

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$\alpha$: the profit made by a provider on every consumer (i.e., provider-side network effects)
Further Assumption

\[(\alpha + \beta)^2 < 4t,\]

which ensures the platform owner’s optimization problem is well-behaved.
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- which ensures the platform owner’s optimization problem is well-behaved
- Standard in literature: e.g., Armstrong (2006) imposes 
  \[(\alpha_1 + \alpha_2)^2 < 4t_1 t_2,\] 
  Hagiu and Halaburda (2014) impose 
  \[\alpha + \beta < 2,\] etc.
Using backward induction, we solve period-2 competition pricing equilibrium first

$$\max_{p_k^c, p_k^d} \pi_{k,2}(p_k^c, p_k^d | Q_{k1}) = p_{k2}^c Q_{k2}^c + p_{k2}^d Q_{k2}^d$$
Using backward induction, we solve period-2 competition pricing equilibrium first

\[
\max_{p_{k2}^c, p_{k2}^d} \pi_{k2}(p_{k2}^c, p_{k2}^d | Q_{k1}^c) = p_{k2}^c Q_{k2}^c + p_{k2}^d Q_{k2}^d
\]

Then solve for the period-1 pricing equilibrium

\[
\max_{p_{k1}^c, p_{k1}^d} \pi_{k1} + \lambda \pi_{k2} = p_{k1}^c Q_{k1}^c + p_{k1}^d Q_{k1}^d + \lambda \pi_{k2}((p_{k2}^c)^*, (p_{k2}^d)^*)
\]
Platform Profit Functions

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\]

- \( \lambda \in [0, 1] \): The discount factor
Stage 1: A Simple Model of Symmetric Duopoly

- Platforms are identical

Proposition 1

Under two-period symmetric duopoly, the optimal pricing strategies of platform $k \in \{A, B\}$ are given by

\[
\left(p_{c1}^k\right)^* = t - \alpha \left(3 \beta + \alpha\right) - \frac{t \delta}{(1 + \delta)(16 - \alpha^2 - 6 \alpha \beta - \beta^2)} \lambda^2,
\]

\[
\left(p_{d1}^k\right)^* = \alpha - \beta, \\
\left(p_{c2}^k\right)^* = (1 + \delta) \left[t - \alpha \left(3 \beta + \alpha\right) - \frac{t \delta}{(1 + \delta)(16 - \alpha^2 - 6 \alpha \beta - \beta^2)} \lambda^2\right],
\]

\[
\left(p_{d2}^k\right)^* = (\alpha - \beta)(1 + \delta)
\]
Stage 1: A Simple Model of Symmetric Duopoly

- Platforms are identical
- $\lambda > 0$ in period-1 profit maximization
Stage 1: A Simple Model of Symmetric Duopoly

- Platforms are identical
- $\lambda > 0$ in period-1 profit maximization

### Proposition 1

Under two-period symmetric duopoly, the optimal pricing strategies of platform $k \in \{A, B\}$ are given by

$$
(p_{k1}^c)^* = t - \frac{\alpha(3\beta + \alpha)}{8} - \frac{t\delta(1 + \delta)(16t - \alpha^2 - 6\alpha\beta - \beta^2)\lambda}{12t - \alpha^2 - 4\alpha\beta - \beta^2},
$$

$$
(p_{k1}^d)^* = \frac{\alpha - \beta}{8};
$$

$$
(p_{k2}^c)^* = (1 + \delta) \left[ t - \frac{\alpha(3\beta + \alpha)}{8} \right], \quad (p_{k2}^d)^* = \frac{(\alpha - \beta)(1 + \delta)}{8}.
$$
Stage 1: A Simple Model of Symmetric Duopoly

Corollary 1

Under symmetric duopoly, the following statements hold true:

1. There exists a threshold $\hat{\lambda}$ such that subsidizing consumers with a negative price becomes optimal when $\lambda > \hat{\lambda}$. The subsidizing strategy is not affected by $\lambda$ in period 2;

2. It is optimal to subsidize providers if and only if $\alpha < \beta$. 

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Piggybacking strategy in platform competition
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Calibrating the Baseline Model with Prior Literature

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Armstrong (2006) the competitive bottleneck
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Hagiu and Halaburda (2014) Considering $\alpha$ and $\beta$ in single-period model

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Calibrating the Baseline Model with Prior Literature

### Consumer (Single-homing) vs. Provider (Multi-homing)

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**Armstrong (2006)**

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**Our two-period model**

- Subsidize early, Charge later on the single-homing side

- $\alpha$, $\beta$, $\lambda$ | $\beta > \alpha$ | $\beta > \alpha$ | $\beta > \alpha$
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Stage 1: A simple two-sided competition model of symmetric pricing duopoly

Stage 2: Allow one of the platforms to import a given number of adopters
Stage 2: Allow One Platform to Import A Given Number of Consumers

Platform A (called *rider*) is endowed with an initial installed base $Q_0$ on consumer side in the beginning of period 1.

\[
\begin{align*}
Q_{A1}^c &= Q_0 + q_{A1}^c = Q_0 + \rho \left[ \frac{1}{2} + \frac{\beta (Q_{A1}^d - Q_{B1}^d) - \tilde{p}_{A1}^c + \tilde{p}_{B1}^c}{2t} \right] \\
Q_{B1}^c &= \rho - q_{A1}^c.
\end{align*}
\]
Stage 2: Allow One Platform to Import A Given Number of Consumers

- Platform A (called *rider*) is endowed with an initial installed base $Q_0$ on consumer side in the beginning of period 1.
- Platform B (called *dummy*) competes with an initial disadvantage on consumer side.

$$
Q^c_{A1} = Q_0 + q^c_{A1} = Q_0 + \rho \left[ \frac{1}{2} + \beta \left( Q^d_{A1} - Q^d_{B1} \right) - \tilde{p}^c_{A1} + \tilde{p}^c_{B1} \right] \\
Q^c_{B1} = \rho - q^c_{A1}.
$$

We are interested in the partial derivatives $\Delta_{ci} = \frac{\partial (\tilde{p}_{ci})}{\partial Q_0}$ and $\Delta_{di} = \frac{\partial (\tilde{p}_{di})}{\partial Q_0}$ which reflect the impacts of piggybacking on pricing strategies.
Stage 2: Allow One Platform to Import A Given Number of Consumers

- Platform A (called \textit{rider}) is endowed with an initial installed base $Q_0$ on consumer side in the beginning of period 1.
- Platform B (called \textit{dummy}) competes with an initial disadvantage on consumer side.

\[ Q^c_{A1} = Q_0 + q^c_{A1} = Q_0 + \rho \left[ \frac{1}{2} + \frac{\beta (Q^d_{A1} - Q^d_{B1}) - \tilde{p}^c_{A1} + \tilde{p}^c_{B1}}{2t} \right] \]

\[ Q^c_{B1} = \rho - q^c_{A1}. \]

- We are interested in the partial derivatives $\Delta^c_{ki} = \frac{\partial (\tilde{p}^c_{ki})^*}{\partial Q_0}$ and $\Delta^d_{ki} = \frac{\partial (\tilde{p}^d_{ki})^*}{\partial Q_0}$ which reflect the impacts of piggybacking on pricing strategies.
Pricing Impacts of Piggyback on Rider’s Strategy in Period 1

(a). Consumer-side Price Change

\[ \Delta^c_{A1} > 0: \text{Rider raises the price} \]

\[ \Delta^c_{A1} < 0: \text{Rider reduces the price} \]

\[ (\alpha + \beta)^2 = 4t \]

(b). Provider-side Price Change

\[ \Delta^d_{A1} > 0: \text{Rider raises the price} \]

\[ \Delta^d_{A1} < 0: \text{Rider reduces the price} \]

\[ (\alpha + \beta)^2 = 4t \]
Pricing Impacts of Piggyback on Dummy’s Strategy in Period 1

(a). Consumer-side Price Change

\[ \Delta c_{B1} > 0: \] Dummy raises the price
\[ \Delta c_{B1} < 0: \] Dummy reduces the price

\[ \Delta c_{B1} = (\alpha + \beta)^2 = 4t \]

(b). Provider-side Price Change

\[ \Delta d_{B1} > 0 \]
Dummy raises the price

\[ \Delta d_{B1} < 0 \]
Dummy reduces the price

\[ \Delta d_{B1} = (\alpha + \beta)^2 = 4t \]
Pricing Impacts of Piggybacking - Both Platforms Lower Prices

(a) Consumer-side Equilibrium Prices Change

\[ \Delta c_A < 0, \Delta c_B < 0: \]

Both platforms reduce prices

\[ (\alpha + \beta)^2 = 4t \]

(b) Provider-side Equilibrium Prices Change

\[ \Delta d_A < 0, \Delta d_B < 0 \]

Both platforms reduce prices
Pricing Impacts of Piggybacking - Both Platforms Raise Prices

(a) Consumer-side Equilibrium Prices Change

\[ \Delta c^A_1 > 0, \Delta c^B_1 > 0 \]
Both platforms raise prices

\[ (\alpha + \beta)^2 = 4t \]

(b) Provider-side Equilibrium Prices Change

\[ \Delta d^A_1 > 0, \Delta d^B_1 > 0 \]
Both platforms raise prices

\[ (\alpha + \beta)^2 = 4t \]
## Summary - Exogenous Piggybacking

<table>
<thead>
<tr>
<th>Period 1</th>
<th>Consumer Side</th>
<th>Provider Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both raise prices</td>
<td>$\alpha \gg \beta$</td>
<td>$\alpha &lt; \beta$</td>
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<td>Both reduce prices</td>
<td>$\alpha \ll t, \beta \ll t$</td>
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Yifan Dou, D. J. Wu

Piggybacking strategy in platform competition
## Summary - Exogenous Piggybacking

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<td><strong>Never</strong></td>
<td>$\alpha &lt; \beta$</td>
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The Logic Flow of The Research

Stage 1: A simple two-sided competition model of symmetric pricing duopoly

Stage 2: Allow one of the platforms to import a given number of adopters

Research Question 1
How should platforms adjust pricing strategies when piggybacking is possible?
Piggybacking in competition might either intensify or alleviate the pricing competition between platforms, depending on the strength of cross-side network effects.
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In the long run (2nd period), the pricing competition becomes more intensified on the single-homing side.
Stage 1: A simple two-sided competition model of symmetric pricing duopoly

Stage 2: Allow one of the platforms to import a given number of adopters

Stage 3: Allow one of the platforms to choose the number of imported adopters at a cost

Research Question 1
How should platforms adjust pricing strategies when piggybacking is possible?
Stage 3: Endogenous Piggybacking

- When acquiring $Q_0$ is costly, we modify Rider’s period 1 objective function

$$\max_{p_{A1}^c, p_{A1}^d, Q_0} \Pi_{A1} = p_{A1}^c Q_{A1}^c + p_{A1}^d Q_{A1}^d - bQ_0^2 + \lambda \Pi^*_{A2},$$
Stage 3: Endogenous Piggybacking

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$$
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$$

- $bQ_0^2$: the total investment for the acquisition of $Q_0$

- We are interested in the partial derivatives $\Delta_{ki}^c = \frac{\partial (\tilde{p}_{ki})^*}{\partial b}$ and $\Delta_{ki}^d = \frac{\partial (\tilde{p}_{ki})^*}{\partial b}$ which reflect the complementarity or substitutability between piggybacking and pricing strategies
Proposition 2

When rider incurs a piggybacking cost of $bQ_0^2$, at equilibrium, the following holds when $b$ increases.
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1. Rider’s $Q_0^*$ decreases (i.e., $\frac{Q_0^*}{\partial b} < 0$);
Stage 3: Endogenous Piggybacking

Proposition 2

When rider incurs a piggybacking cost of $bQ_0^2$, at equilibrium, the following holds when $b$ increases:

1. Rider’s $Q_0^*$ decreases (i.e., $\frac{Q_0^*}{\partial b} < 0$);
2. On the consumer side, pricing discount and piggybacking is complementary (i.e., $\frac{(\tilde{p}_{c_{A1}}^*)}{\partial b} > 0$) only when $t < \hat{t}$ and $\frac{\beta}{\alpha} < \hat{u}$, otherwise they are substitutable;
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3. On the provider side, they are always substitutable (i.e., $\frac{\partial (\tilde{p}_d^{A_i})^*}{\partial b} < 0$) if and only if $\alpha > \beta$. 
Consumer-side strategy (single-homing): Platforms should import either more or fewer consumers in together with a greater price discount, depending on the degree of horizontal differentiation and cross-side network effects.
Summary - Endogenous Piggybacking

- Consumer-side strategy (single-homing): Platforms should import either more or fewer consumers in together with a greater price discount, depending on the degree of horizontal differentiation and cross-side network effects.

- Provider-side strategy (multi-homing): Platform should always offer a smaller discount to providers when more consumers are imported.
The Logic Flow of The Research

Stage 1: A simple two-sided competition model of symmetric pricing duopoly

Stage 2: Allow one of the platforms to import a given number of adopters

Stage 3: Allow one of the platforms to choose the number of imported adopters at a cost

Research Question 1
How should platforms adjust pricing strategies when piggybacking is possible?

Research Question 2
What are the optimal piggybacking/Pricing Strategies?
We develop a formal model that intends to capture the novel piggybacking strategies arise from the sharing economy.
Summary

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- How piggybacking affects the dynamic pricing competition between platforms?
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  - How to optimize pricing and piggybacking strategy in tandem
    - Import more, subsidize more
Thank You!

Q & A