

Selling Synergies

Thomas Jungbauer

Cornell University

SEA–NOEG Joint Conference

@ Central European University

September 11–12, 2026

COMPLEMENTARITY CREATES VALUE

- ▶ Complementary products often have **standalone value**, but become more valuable when used together because they exhibit **synergies**.

COMPLEMENTARITY CREATES VALUE

- ▶ Complementary products often have **standalone value**, but become more valuable when used together because they exhibit **synergies**.
- ▶ Canonical intuition: **complementarities**
 - ▶ should **increase** total **value**, and
 - ▶ **increase** incentives to **invest** and **innovate**.

COMPLEMENTARITY CREATES VALUE

- ▶ Complementary products often have **standalone value**, but become more valuable when used together because they exhibit **synergies**.
- ▶ Canonical intuition: **complementarities**
 - ▶ should **increase** total **value**, and
 - ▶ **increase** incentives to **invest** and **innovate**.
- ▶ Firms prefer **more compatible** products (Matutes and Regibeau, 1988), and may even choose **lower prices** to stimulate demand of complementary products (Katz and Shapiro, 1986; Economides and Salop, 1992).

COMPLEMENTARITY CREATES VALUE

- ▶ Complementary products often have **standalone value**, but become more valuable when used together because they exhibit **synergies**.
- ▶ Canonical intuition: **complementarities**
 - ▶ should **increase** total **value**, and
 - ▶ **increase** incentives to **invest** and **innovate**.
- ▶ Firms prefer **more compatible** products (Matutes and Regibeau, 1988), and may even choose **lower prices** to stimulate demand of complementary products (Katz and Shapiro, 1986; Economides and Salop, 1992).
- ▶ Many discussions revolving around ‘**Big Tech**’ and their **ecosystems** focus on products by one firm.

COMPLEMENTARITY CREATES VALUE

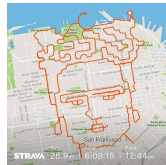
- ▶ Complementary products often have **standalone value**, but become more valuable when used together because they exhibit **synergies**.
- ▶ Canonical intuition: **complementarities**
 - ▶ should **increase** total **value**, and
 - ▶ **increase** incentives to **invest** and **innovate**.
- ▶ Firms prefer **more compatible** products (Matutes and Regibeau, 1988), and may even choose **lower prices** to stimulate demand of complementary products (Katz and Shapiro, 1986; Economides and Salop, 1992).
- ▶ Many discussions revolving around ‘**Big Tech**’ and their **ecosystems** focus on products by one firm.
- ▶ What if **complements** are developed by **distinct firms**?

COMPLEMENTARITY CREATES VALUE: EXAMPLES

Shopify + Klaviyo



Garmin + Strava



Salesforce + DocuSign



Amazon Echo + Philips Hue



THIS PAPER

Research question:

When **complementary products** are developed by **independent** firms, how do **synergies** affect market outcomes?

THIS PAPER

Research question:

When **complementary products** are developed by **independent** firms, how do **synergies** affect market outcomes?

In particular:

- ▶ How much do firms **invest** in product **quality**?
- ▶ **When** do firms want to **enter** the market?
- ▶ What **prices** do sellers choose?
- ▶ What are the consequences for **welfare** and its **distribution**?

MODEL AND MECHANISM

The model:

- ▶ Two symmetric **sellers independently develop** products starting at $t = 0$.
- ▶ Development is **costly** and **increases** product **quality**.

MODEL AND MECHANISM

The model:

- ▶ Two symmetric **sellers independently develop** products starting at $t = 0$.
- ▶ Development is **costly** and **increases** product **quality**.
- ▶ A mass of **heterogeneous buyers** is interested in buying **both products** that provide **standalone** value but are **more valuable together**.

MODEL AND MECHANISM

The model:

- ▶ Two symmetric **sellers independently develop** products starting at $t = 0$.
- ▶ Development is **costly** and **increases** product **quality**.
- ▶ A mass of **heterogeneous buyers** is interested in buying **both products** that provide **standalone** value but are **more valuable together**.
- ▶ Sellers decide when to stop development and sell their product at which price.

MODEL AND MECHANISM

The model:

- ▶ Two symmetric **sellers independently develop** products starting at $t = 0$.
- ▶ Development is **costly** and **increases** product **quality**.
- ▶ A mass of **heterogeneous buyers** is interested in buying **both products** that provide **standalone** value but are **more valuable together**.
- ▶ Sellers decide when to stop development and sell their product at which price.

The mechanism:

1. The first firm to launch (the **leader**) creates an **installed base**. The leader **prices restrictively high** to push the follower toward the broader mass market.

MODEL AND MECHANISM

The model:

- ▶ Two symmetric **sellers independently develop** products starting at $t = 0$.
- ▶ Development is **costly** and **increases** product **quality**.
- ▶ A mass of **heterogeneous buyers** is interested in buying **both products** that provide **standalone** value but are **more valuable together**.
- ▶ Sellers decide when to stop development and sell their product at which price.

The mechanism:

1. The first firm to launch (the **leader**) creates an **installed base**. The leader **prices restrictively high** to push the follower toward the broader mass market.
2. The **follower** develops until the **optimal standalone time** and chooses the monopoly price (regardless of the leader's stopping time).

MODEL AND MECHANISM

The model:

- ▶ Two symmetric **sellers independently develop** products starting at $t = 0$.
- ▶ Development is **costly** and **increases** product **quality**.
- ▶ A mass of **heterogeneous buyers** is interested in buying **both products** that provide **standalone** value but are **more valuable together**.
- ▶ Sellers decide when to stop development and sell their product at which price.

The mechanism:

1. The first firm to launch (the **leader**) creates an **installed base**. The leader **prices restrictively high** to push the follower toward the broader mass market.
2. The **follower** develops until the **optimal standalone time** and chooses the monopoly price (regardless of the leader's stopping time).
3. The leader benefits from **launching early** and **free-riding** on the follower's quality.

MODEL AND MECHANISM

The model:

- ▶ Two symmetric **sellers independently develop** products starting at $t = 0$.
- ▶ Development is **costly** and **increases** product **quality**.
- ▶ A mass of **heterogeneous buyers** is interested in buying **both products** that provide **standalone** value but are **more valuable together**.
- ▶ Sellers decide when to stop development and sell their product at which price.

The mechanism:

1. The first firm to launch (the **leader**) creates an **installed base**. The leader **prices restrictively high** to push the follower toward the broader mass market.
2. The **follower** develops until the **optimal standalone time** and chooses the monopoly price (regardless of the leader's stopping time).
3. The leader benefits from **launching early** and **free-riding** on the follower's quality.
4. When either firm can become the leader, a **preemption race** ensues.

RESULTS PREVIEW

- ▶ **Strategic underinvestment.** The leader launches early and earns a premium by appropriating part of the follower's product quality.

RESULTS PREVIEW

- ▶ **Strategic underinvestment.** The leader launches early and earns a premium by appropriating part of the follower's product quality.
- ▶ **Preemption and rent dissipation.** When leadership is endogenous, both firms race to the first date at which leading is as valuable as following; the premium determines timing but is dissipated in expected payoffs.

RESULTS PREVIEW

- ▶ **Strategic underinvestment.** The leader launches early and earns a premium by appropriating part of the follower's product quality.
- ▶ **Preemption and rent dissipation.** When leadership is endogenous, both firms race to the first date at which leading is as valuable as following; the premium determines timing but is dissipated in expected payoffs.
- ▶ **Two welfare failures.** Decentralized development combines premature launch with strategic exclusion. Integrated development raises producer surplus, consumer surplus, and total welfare.

RESULTS PREVIEW

- ▶ **Strategic underinvestment.** The leader launches early and earns a premium by appropriating part of the follower's product quality.
- ▶ **Preemption and rent dissipation.** When leadership is endogenous, both firms race to the first date at which leading is as valuable as following; the premium determines timing but is dissipated in expected payoffs.
- ▶ **Two welfare failures.** Decentralized development combines premature launch with strategic exclusion. Integrated development raises producer surplus, consumer surplus, and total welfare.
- ▶ **A welfare reversal.** Stronger complementarity raises coordinated welfare but can lower decentralized welfare by accelerating preemption and expanding exclusion.

RESULTS PREVIEW

- ▶ **Strategic underinvestment.** The leader launches early and earns a premium by appropriating part of the follower's product quality.
- ▶ **Preemption and rent dissipation.** When leadership is endogenous, both firms race to the first date at which leading is as valuable as following; the premium determines timing but is dissipated in expected payoffs.
- ▶ **Two welfare failures.** Decentralized development combines premature launch with strategic exclusion. Integrated development raises producer surplus, consumer surplus, and total welfare.
- ▶ **A welfare reversal.** Stronger complementarity raises coordinated welfare but can lower decentralized welfare by accelerating preemption and expanding exclusion.
- ▶ **Extensions.** The mechanism disciplines private investment into complementarity and the main findings are robust to buyer delay, alternative timing strategies, general buyer value distributions and production functions.

RELATED LITERATURE

- ▶ **Timing and preemption games:** equilibrium timing from leader and follower payoff curves (Reinganum, 1981; Fudenberg and Tirole, 1985; Dutta and Rustichini, 1993; Hoppe and Lehmann-Grube, 2005).
 - ▶ **Here:** the payoff geometry is generated endogenously by a complementary-product pricing subgame.

RELATED LITERATURE

- ▶ **Timing and preemption games:** equilibrium timing from leader and follower payoff curves (Reinganum, 1981; Fudenberg and Tirole, 1985; Dutta and Rustichini, 1993; Hoppe and Lehmann-Grube, 2005).
 - ▶ **Here:** the payoff geometry is generated endogenously by a complementary-product pricing subgame.
- ▶ **Complementary products and ecosystems:** static pricing, bundling, access, and platform competition (Matutes and Regibeau, 1988; Economides and Salop, 1992; Nalebuff, 2004; Chen and Rey, 2019; Carrillo and Tan, 2021).
 - ▶ **Here:** customer segmentation feeds back into product quality and launch timing.

RELATED LITERATURE

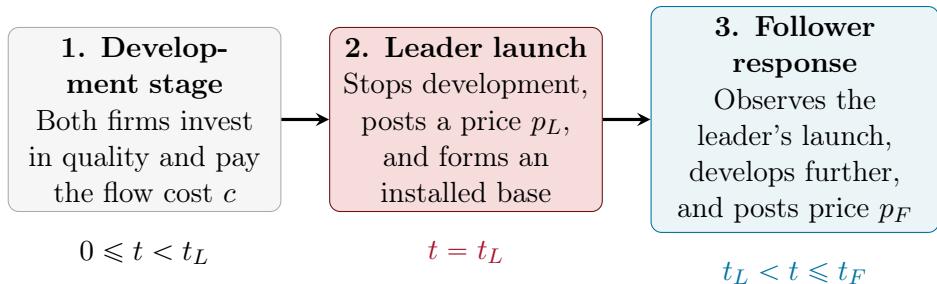
- ▶ **Timing and preemption games:** equilibrium timing from leader and follower payoff curves (Reinganum, 1981; Fudenberg and Tirole, 1985; Dutta and Rustichini, 1993; Hoppe and Lehmann-Grube, 2005).
 - ▶ **Here:** the payoff geometry is generated endogenously by a complementary-product pricing subgame.
- ▶ **Complementary products and ecosystems:** static pricing, bundling, access, and platform competition (Matutes and Regibeau, 1988; Economides and Salop, 1992; Nalebuff, 2004; Chen and Rey, 2019; Carrillo and Tan, 2021).
 - ▶ **Here:** customer segmentation feeds back into product quality and launch timing.
- ▶ **Sequential innovation:** inability to appropriate follow-on value can cause underinvestment (Scotchmer, 1991; Green and Scotchmer, 1995; Bobtcheff et al., 2017).
 - ▶ **Here:** partial appropriation of the follower's future quality induces premature launch.

ROADMAP

1. **The Model**
2. **Equilibrium Analysis**
3. **Welfare**
4. **Extensions**
5. **Discussion**

THE MODEL

TIMING AND INFORMATION



- ▶ First to launch determines the **leader** and **follower** roles.
- ▶ Posted prices (and aggregate sales) are public.
- ▶ The follower infers the leader's owner cutoff (installed base).
- ▶ All continuation payoffs are discounted at rate $\beta > 0$.

THE SETUP

Sellers

- ▶ Two initially identical firms S_1, S_2 .
- ▶ Product quality:

$$q_j(t) = \sqrt{t}.$$

- ▶ Development flow cost c until irreversible stopping.
- ▶ Zero marginal production cost.
- ▶ First seller to launch is leader; second is follower.

THE SETUP

Sellers

- ▶ Two initially identical firms S_1, S_2 .
- ▶ Product quality:

$$q_j(t) = \sqrt{t}.$$

- ▶ Development flow cost c until irreversible stopping.
- ▶ Zero marginal production cost.
- ▶ First seller to launch is leader; second is follower.

Buyers

- ▶ Unit mass, $\theta \sim U[0, 1]$.
- ▶ Standalone value: θq_j .
- ▶ Bundle value:

$$\theta(q_L + q_F + \gamma q_L q_F), \quad \gamma \geq 0.$$

- ▶ Utility accrued at acquisition time.
- ▶ Buyers anticipate the continuation game and maximize discounted utility net of prices.

THE GAME

- ▶ At **launch**, each seller posts a single public **take-it-or-leave-it price**.

THE GAME

- ▶ At **launch**, each seller posts a single public **take-it-or-leave-it price**.
- ▶ The **leader** can **commit** to its **launch price** until follower entry.
 - ▶ Compare with Board and Skrzypacz (2016): benchmark for list/reference-price rigidity, posted-price norms, and customer-relations costs of rapid markdowns (Eichenbaum et al., 2011; Anderson and Simester, 2010).

THE GAME

- ▶ At **launch**, each seller posts a single public **take-it-or-leave-it price**.
- ▶ The **leader** can **commit** to its **launch price** until follower entry.
 - ▶ Compare with Board and Skrzypacz (2016): benchmark for list/reference-price rigidity, posted-price norms, and customer-relations costs of rapid markdowns (Eichenbaum et al., 2011; Anderson and Simester, 2010).
- ▶ **Baseline**: buyers decide on each product at its launch date.
 - ▶ Extension allows buyers to wait and observe the follower's price.

THE GAME

- ▶ At **launch**, each seller posts a single public **take-it-or-leave-it price**.
- ▶ The **leader** can **commit** to its **launch price** until follower entry.
 - ▶ Compare with Board and Skrzypacz (2016): benchmark for list/reference-price rigidity, posted-price norms, and customer-relations costs of rapid markdowns (Eichenbaum et al., 2011; Anderson and Simester, 2010).
- ▶ **Baseline**: buyers decide on each product at its launch date.
 - ▶ Extension allows buyers to wait and observe the follower's price.
- ▶ **Simultaneous launch attempts**: random priority assigns leadership; the follower may continue development.
 - ▶ Extension shows robustness by solving the extended-strategy completion.

STANDALONE BENCHMARK

For a given quality q , **monopoly pricing** gives

$$p_S^* = \frac{q}{2}, \quad R_S^* = \frac{q}{4}.$$

STANDALONE BENCHMARK

For a given quality q , **monopoly pricing** gives

$$p_S^* = \frac{q}{2}, \quad R_S^* = \frac{q}{4}.$$

The seller therefore solves

$$\max_t e^{-\beta t} \frac{\sqrt{t}}{4} - \frac{c}{\beta} (1 - e^{-\beta t}).$$

STANDALONE BENCHMARK

For a given quality q , **monopoly pricing** gives

$$p_S^* = \frac{q}{2}, \quad R_S^* = \frac{q}{4}.$$

The seller therefore solves

$$\max_t e^{-\beta t} \frac{\sqrt{t}}{4} - \frac{c}{\beta} (1 - e^{-\beta t}).$$

The **unique solution** and associated **payoff** are

$$t_S^* = \left(\frac{\sqrt{4c^2 + \beta/2} - 2c}{\beta} \right)^2,$$

$$\Pi_S^* = e^{-\beta t_S^*} \frac{\sqrt{t_S^*}}{4} - \frac{c}{\beta} (1 - e^{-\beta t_S^*}).$$

STANDALONE BENCHMARK

For a given quality q , **monopoly pricing** gives

$$p_S^* = \frac{q}{2}, \quad R_S^* = \frac{q}{4}.$$

The seller therefore solves

$$\max_t e^{-\beta t} \frac{\sqrt{t}}{4} - \frac{c}{\beta} (1 - e^{-\beta t}).$$

The **unique solution** and associated **payoff** are

$$t_S^* = \left(\frac{\sqrt{4c^2 + \beta/2} - 2c}{\beta} \right)^2,$$

$$\Pi_S^* = e^{-\beta t_S^*} \frac{\sqrt{t_S^*}}{4} - \frac{c}{\beta} (1 - e^{-\beta t_S^*}).$$

Half of the market purchases each standalone product.

EQUILIBRIUM ANALYSIS

FOLLOWER PRICING: THREE REGIMES

Fix the leader's **owner cutoff** θ_L . Owners value the follower increment at

$$\theta q_F(1 + \gamma q_L),$$

whereas nonowners value it at θq_F .

	Cutoff	Follower price	Follower profit
A: Owner monopoly	$\theta_L < 1/2$	$\frac{q_F(1 + \gamma q_L)}{2}$	$\frac{1 + \gamma q_L}{4} q_F$

FOLLOWER PRICING: THREE REGIMES

Fix the leader's **owner cutoff** θ_L . Owners value the follower increment at

$$\theta q_F(1 + \gamma q_L),$$

whereas nonowners value it at θq_F .

	Cutoff	Follower price	Follower profit
A: Owner monopoly	$\theta_L < 1/2$	$\frac{q_F(1 + \gamma q_L)}{2}$	$\frac{1 + \gamma q_L}{4} q_F$
B: All owners	$1/2 \leq \theta_L < \bar{\theta}_L$	$\theta_L q_F(1 + \gamma q_L)$	$\theta_L(1 - \theta_L)(1 + \gamma q_L) q_F$

FOLLOWER PRICING: THREE REGIMES

Fix the leader's **owner cutoff** θ_L . Owners value the follower increment at

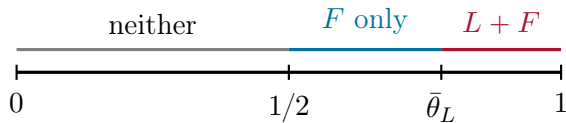
$$\theta q_F(1 + \gamma q_L),$$

whereas nonowners value it at θq_F .

	Cutoff	Follower price	Follower profit
A: Owner monopoly	$\theta_L < 1/2$	$\frac{q_F(1 + \gamma q_L)}{2}$	$\frac{1 + \gamma q_L}{4} q_F$
B: All owners	$1/2 \leq \theta_L < \bar{\theta}_L$	$\theta_L q_F(1 + \gamma q_L)$	$\theta_L(1 - \theta_L)(1 + \gamma q_L) q_F$
C: Mass market	$\theta_L \geq \bar{\theta}_L$	$q_F/2$	$q_F/4$

$$\bar{\theta}_L = \frac{1}{2} \left(1 + \sqrt{\frac{\gamma q_L}{1 + \gamma q_L}} \right) > \frac{1}{2}.$$

THE KEY DECOUPLING

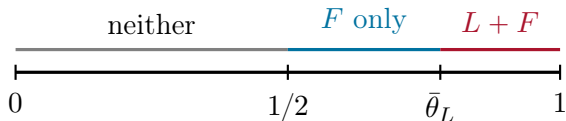


- R_F^* is **independent** of q_L and θ_L .

Regime C

$$p_F^* = \frac{q_F}{2}, \quad R_F^* = \frac{q_F}{4}.$$

THE KEY DECOUPLING



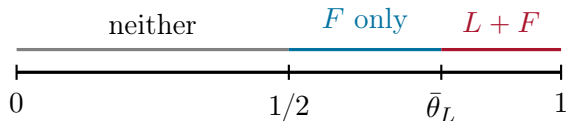
- ▶ R_F^* is **independent** of q_L and θ_L .
- ▶ The follower solves the **standalone stopping problem**:

$$t_F^* = t_S^* \quad \text{if } t_L < t_S^*.$$

Regime C

$$p_F^* = \frac{q_F}{2}, \quad R_F^* = \frac{q_F}{4}.$$

THE KEY DECOUPLING



- ▶ R_F^* is **independent** of q_L and θ_L .
- ▶ The follower solves the **standalone stopping problem**:

$$t_F^* = t_S^* \quad \text{if } t_L < t_S^*.$$

Regime C

$$p_F^* = \frac{q_F}{2}, \quad R_F^* = \frac{q_F}{4}.$$

- ▶ Earlier leader launch changes the **quality gap**, but not the follower's completion date.

LEADER PRICING AND THE SYNERGY PREMIUM

In Regime C, the **marginal owner** values the future synergy. Hence

$$p_L = \theta_L q_L (1 + \delta \gamma q_F), \quad \delta = e^{-\beta(t_F - t_L)}.$$

LEADER PRICING AND THE SYNERGY PREMIUM

In Regime C, the **marginal owner** values the future synergy. Hence

$$p_L = \theta_L q_L (1 + \delta \gamma q_F), \quad \delta = e^{-\beta(t_F - t_L)}.$$

Because Regime-C revenue is decreasing for $\theta_L > 1/2$, the leader chooses the **mass-market boundary**:

$$\theta_L = \bar{\theta}_L, \quad R_L^C = \frac{q_L(1 + \delta \gamma q_F)}{4(1 + \gamma q_L)}.$$

LEADER PRICING AND THE SYNERGY PREMIUM

In Regime C, the **marginal owner** values the future synergy. Hence

$$p_L = \theta_L q_L (1 + \delta \gamma q_F), \quad \delta = e^{-\beta(t_F - t_L)}.$$

Because Regime-C revenue is decreasing for $\theta_L > 1/2$, the leader chooses the **mass-market boundary**:

$$\theta_L = \bar{\theta}_L, \quad R_L^C = \frac{q_L(1 + \delta \gamma q_F)}{4(1 + \gamma q_L)}.$$

The **leader** earns **more than standalone monopoly** profit exactly when

$$R_L^C > \frac{q_L}{4} \quad \Longleftrightarrow \quad \delta q_F > q_L.$$

Follower optimality implies $\delta q_F - q_L > 0$ for every $t_L < t_S^*$.

LEADER PRICING AND THE SYNERGY PREMIUM

In Regime C, the **marginal owner** values the future synergy. Hence

$$p_L = \theta_L q_L (1 + \delta \gamma q_F), \quad \delta = e^{-\beta(t_F - t_L)}.$$

Because Regime-C revenue is decreasing for $\theta_L > 1/2$, the leader chooses the **mass-market boundary**:

$$\theta_L = \bar{\theta}_L, \quad R_L^C = \frac{q_L(1 + \delta \gamma q_F)}{4(1 + \gamma q_L)}.$$

The **leader** earns **more than standalone monopoly** profit exactly when

$$R_L^C > \frac{q_L}{4} \quad \Longleftrightarrow \quad \delta q_F > q_L.$$

Follower optimality implies $\delta q_F - q_L > 0$ for every $t_L < t_S^*$.

The premium persists on an open set of cutoffs with strict mass-market response.

STRATEGIC UNDERINVESTMENT

Theorem 1

A designated leader chooses

$$t_L^* < t_S^* \quad \text{with} \quad \Pi_L^* > \Pi_S^*.$$

STRATEGIC UNDERINVESTMENT

Theorem 1

A designated leader chooses

$$t_L^* < t_S^* \quad \text{with} \quad \Pi_L^* > \Pi_S^*.$$

Let $f(t) = e^{-\beta t} \sqrt{t}$. The leader payoff factorizes as

$$L(t) = V_S(t) + \frac{\gamma \sqrt{t}}{4(1 + \gamma \sqrt{t})} [f(t_S^*) - f(t)].$$

STRATEGIC UNDERINVESTMENT

Theorem 1

A designated leader chooses

$$t_L^* < t_S^* \quad \text{with} \quad \Pi_L^* > \Pi_S^*.$$

Let $f(t) = e^{-\beta t} \sqrt{t}$. The leader payoff factorizes as

$$L(t) = V_S(t) + \frac{\gamma \sqrt{t}}{4(1 + \gamma \sqrt{t})} [f(t_S^*) - f(t)].$$

- ▶ $V_S(t)$ is the standalone payoff.
- ▶ The second term is the **leader's share** of the **discounted quality gap**.
- ▶ For every $t < t_S^*$, this gap is **strictly positive**.

STRATEGIC UNDERINVESTMENT (PROOF SKETCH)

At the standalone optimum,

$$V'_S(t_S^*) = 0, \quad f'(t_S^*) = 4ce^{-\beta t_S^*} > 0.$$

STRATEGIC UNDERINVESTMENT (PROOF SKETCH)

At the standalone optimum,

$$V'_S(t_S^*) = 0, \quad f'(t_S^*) = 4ce^{-\beta t_S^*} > 0.$$

Because the quality gap vanishes at t_S^* ,

$$L'(t_S^*) = -\frac{\gamma\sqrt{t_S^*}}{4(1 + \gamma\sqrt{t_S^*})} f'(t_S^*) < 0.$$

STRATEGIC UNDERINVESTMENT (PROOF SKETCH)

At the standalone optimum,

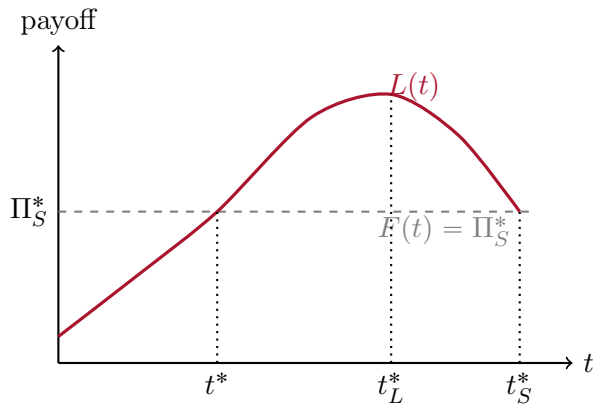
$$V'_S(t_S^*) = 0, \quad f'(t_S^*) = 4ce^{-\beta t_S^*} > 0.$$

Because the quality gap vanishes at t_S^* ,

$$L'(t_S^*) = -\frac{\gamma\sqrt{t_S^*}}{4(1 + \gamma\sqrt{t_S^*})} f'(t_S^*) < 0.$$

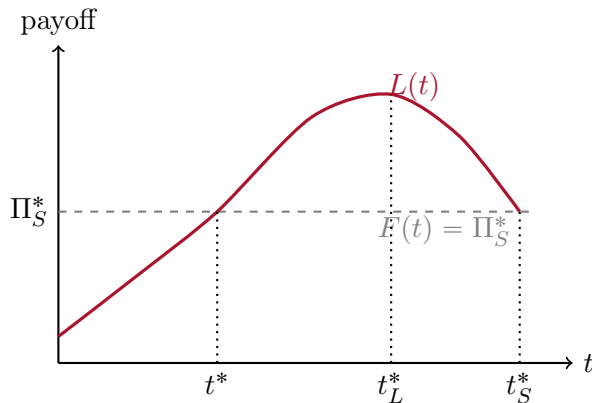
- ▶ Moving left lowers the leader's own quality.
- ▶ The follower still completes at t_S^* , so follower quality is unchanged.
- ▶ **Revenue arrives earlier** and accumulated **development costs fall**.

ENDOGENOUS LEADERSHIP



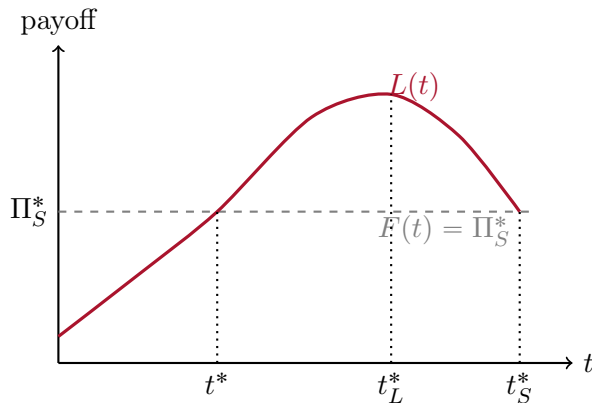
- $F(t) = \Pi_S^*$ for all $t \leq t_S^*$.

ENDOGENOUS LEADERSHIP



- ▶ $F(t) = \Pi_S^*$ for all $t \leq t_S^*$.
- ▶ $L(t)$ is strictly single-peaked and maximized at t_L^* .

ENDOGENOUS LEADERSHIP



- ▶ $F(t) = \Pi_S^*$ for all $t \leq t_S^*$.
- ▶ $L(t)$ is strictly single-peaked and maximized at t_L^* .
- ▶ Unique first crossing $t^* < t_L^*$:
 - ▶ $t < t^*$: follower preferred;
 - ▶ $t = t^*$: rent equalization;
 - ▶ $t \in (t^*, t_S^*)$: leader preferred.

PREEMPTION

Theorem 2

Every pure-strategy SPE has the same calendar-time outcome. In the symmetric equilibrium,

$$t^* < t_L^* < t_S^*$$

both sellers attempt to launch at t^* , random priority assigns leadership, and the follower continues to t_S^* .

PREEMPTION

Theorem 2

Every pure-strategy SPE has the same calendar-time outcome. In the symmetric equilibrium,

$$t^* < t_L^* < t_S^*$$

both sellers attempt to launch at t^* , random priority assigns leadership, and the follower continues to t_S^* .

- ▶ Before t^* , launching yields less than the follower outside option Π_S^* .

PREEMPTION

Theorem 2

Every pure-strategy SPE has the same calendar-time outcome. In the symmetric equilibrium,

$$t^* < t_L^* < t_S^*$$

both sellers attempt to launch at t^* , random priority assigns leadership, and the follower continues to t_S^* .

- ▶ Before t^* , launching yields less than the follower outside option Π_S^* .
- ▶ After t^* , a seller can gain by launching slightly before the rival.

PREEMPTION

Theorem 2

Every pure-strategy SPE has the same calendar-time outcome. In the symmetric equilibrium,

$$t^* < t_L^* < t_S^*$$

both sellers attempt to launch at t^* , random priority assigns leadership, and the follower continues to t_S^* .

- ▶ Before t^* , launching yields less than the follower outside option Π_S^* .
- ▶ After t^* , a seller can gain by launching slightly before the rival.
- ▶ At t^* , leader and follower roles both yield Π_S^* .

PREEMPTION

Theorem 2

Every pure-strategy SPE has the same calendar-time outcome. In the symmetric equilibrium,

$$t^* < t_L^* < t_S^*$$

both sellers attempt to launch at t^* , random priority assigns leadership, and the follower continues to t_S^* .

- ▶ Before t^* , launching yields less than the follower outside option Π_S^* .
- ▶ After t^* , a seller can gain by launching slightly before the rival.
- ▶ At t^* , leader and follower roles both yield Π_S^* .
- ▶ The endogenous leader premium determines timing but is **fully dissipated**:

$$E[\Pi_1] = E[\Pi_2] = \Pi_S^*.$$

WELFARE

COORDINATED BENCHMARKS

For synchronized quality $q = \sqrt{t}$, bundle value is

$$V(t) = 2\sqrt{t} + \gamma t.$$

Benchmark	Objective	Cutoff	Time
First Best	Maximize total surplus	$\theta_{FB} = 0$	t_{FB}
Second Best	Maximize welfare subject to $PS \geq 0$	$0 < \theta_{SB} < 1/2$	t_{SB}
Joint Monopoly	Maximize joint producer surplus	$\theta_M = 1/2$	t_M

COORDINATED BENCHMARKS

For synchronized quality $q = \sqrt{t}$, bundle value is

$$V(t) = 2\sqrt{t} + \gamma t.$$

Benchmark	Objective	Cutoff	Time
First Best	Maximize total surplus	$\theta_{FB} = 0$	t_{FB}
Second Best	Maximize welfare subject to $PS \geq 0$	$0 < \theta_{SB} < 1/2$	t_{SB}
Joint Monopoly	Maximize joint producer surplus	$\theta_M = 1/2$	t_M

$$0 = \theta_{FB} < \theta_{SB} < \theta_M = \frac{1}{2},$$

$$t_S^* < t_M < t_{SB} < t_{FB}.$$

TWO MARKET FAILURES

Dynamic Inefficiency

$$t^* < t_L^* < t_F^* = t_S^* < t_M.$$

The leader launches before both its own unconstrained optimum and the coordinated benchmark.

Static Inefficiency

$$\bar{\theta}_L > \theta_F = \theta_M = \frac{1}{2}.$$

The leader excludes buyers solely to manipulate the follower's pricing and stopping decision.

TWO MARKET FAILURES

Dynamic Inefficiency

$$t^* < t_L^* < t_F^* = t_S^* < t_M.$$

The leader launches before both its own unconstrained optimum and the coordinated benchmark.

Static Inefficiency

$$\bar{\theta}_L > \theta_F = \theta_M = \frac{1}{2}.$$

The leader excludes buyers solely to manipulate the follower's pricing and stopping decision.

- ▶ **Producer surplus:** $PS_{SB} = 0 < PS^* < PS_M$.
- ▶ **Consumer surplus:** $CS^* < CS_M < CS_{SB} < CS_{FB}$.
- ▶ **Total welfare:** $W^* < W_M < W_{SB} < W_{FB}$.

TWO MARKET FAILURES

Dynamic Inefficiency

$$t^* < t_L^* < t_F^* = t_S^* < t_M.$$

The leader launches before both its own unconstrained optimum and the coordinated benchmark.

Static Inefficiency

$$\bar{\theta}_L > \theta_F = \theta_M = \frac{1}{2}.$$

The leader excludes buyers solely to manipulate the follower's pricing and stopping decision.

- ▶ **Producer surplus:** $PS_{SB} = 0 < PS^* < PS_M$.
- ▶ **Consumer surplus:** $CS^* < CS_M < CS_{SB} < CS_{FB}$.
- ▶ **Total welfare:** $W^* < W_M < W_{SB} < W_{FB}$.

Joint monopoly Pareto-dominates decentralized development.

► accounting

THE DICHOTOMOUS SYNERGY EFFECT

- ▶ **Coordination:**

- stronger

- complementarity leads
to longer development.

THE DICHOTOMOUS SYNERGY EFFECT

- ▶ **Coordination:**

stronger

complementarity leads
to longer development.

- ▶ **Competition:**

stronger

complementarity
accelerates preemption
near zero.

THE DICHOTOMOUS SYNERGY EFFECT

► **Coordination:**

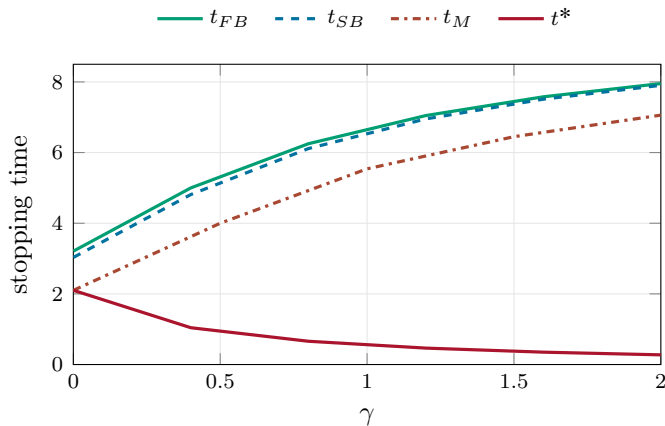
stronger
complementarity leads
to longer development.

► **Competition:**

stronger
complementarity
accelerates preemption
near zero.

► **Welfare reversal:**

direct gains can be
dominated by worse
timing and broader
exclusion.



EXTENSIONS

ENDOGENOUS PRODUCT DESIGN

Before development, sellers choose interoperability investments:

$$\gamma = \gamma_0 + x_1 + x_2, \quad K'(0) = 0, \quad K'' > 0.$$

ENDOGENOUS PRODUCT DESIGN

Before development, sellers choose interoperability investments:

$$\gamma = \gamma_0 + x_1 + x_2, \quad K'(0) = 0, \quad K'' > 0.$$

Decentralized Market

$$E[\Pi_j \mid \gamma] = \Pi_S^*$$

is independent of γ . Hence

$$x_1^* = x_2^* = 0.$$

Coordinated Benchmarks

Optimized surplus is strictly increasing in γ .
Convexity implies

$$x_1 = x_2 > 0.$$

ENDOGENOUS PRODUCT DESIGN

Before development, sellers choose interoperability investments:

$$\gamma = \gamma_0 + x_1 + x_2, \quad K'(0) = 0, \quad K'' > 0.$$

Decentralized Market

$$E[\Pi_j \mid \gamma] = \Pi_S^*$$

is independent of γ . Hence

$$x_1^* = x_2^* = 0.$$

Coordinated Benchmarks

Optimized surplus is strictly increasing in γ .
Convexity implies

$$x_1 = x_2 > 0.$$

Preemption eliminates private investment in complementarity.

BUYER DELAY

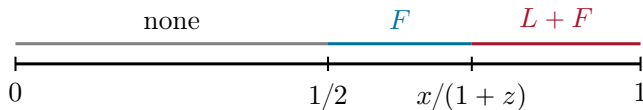
- Buyers may wait until follower entry and observe both prices; the leader's launch offer remains available.

BUYER DELAY

- Buyers may wait until follower entry and observe both prices; the leader's launch offer remains available.
- At the boundary $t_L \uparrow t_S^*$, write

$$q = \sqrt{t_S^*}, \quad z = \gamma q, \quad p_L = xq.$$

If $x > m(z) \equiv 2 + z - \sqrt{2 + z}$, the follower uniquely chooses $p_F = q/2$.

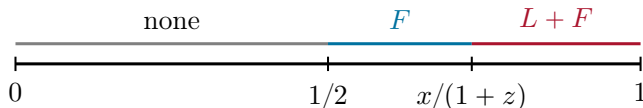


BUYER DELAY

- Buyers may wait until follower entry and observe both prices; the leader's launch offer remains available.
- At the boundary $t_L \uparrow t_S^*$, write

$$q = \sqrt{t_S^*}, \quad z = \gamma q, \quad p_L = xq.$$

If $x > m(z) \equiv 2 + z - \sqrt{2 + z}$, the follower uniquely chooses $p_F = q/2$.



- For a nonempty primitive interval of z , the designated price leader earns more than Π_S^* .
- Every buyer who obtains L waits until p_F is observed.

The premium does not rely on forcing buyers to purchase early.

EXTENDED STRATEGIES AND GENERALIZATIONS

- ▶ **No pure-strategy tie-breaker.**
 - ▶ If forced simultaneous launch is no more attractive than the follower role on $[t^*, t_S^*]$, and strictly worse at t^* ,
 - ▶ the Fudenberg–Tirole extended-strategy equilibrium resolves the race at the same calendar time t^* , with exact ties occurring with probability zero.

EXTENDED STRATEGIES AND GENERALIZATIONS

- ▶ **No pure-strategy tie-breaker.**

- ▶ If forced simultaneous launch is no more attractive than the follower role on $[t^*, t_S^*]$, and strictly worse at t^* ,
- ▶ the Fudenberg–Tirole extended-strategy equilibrium resolves the race at the same calendar time t^* , with exact ties occurring with probability zero.

- ▶ **Production technologies.**

- ▶ Strategic underinvestment holds for general increasing, concave technologies satisfying standard boundary (Inada) conditions.
- ▶ Preemption follows under a primitive single-crossing condition on the induced leader payoff.

EXTENDED STRATEGIES AND GENERALIZATIONS

- ▶ **No pure-strategy tie-breaker.**

- ▶ If forced simultaneous launch is no more attractive than the follower role on $[t^*, t_S^*]$, and strictly worse at t^* ,
- ▶ the Fudenberg–Tirole extended-strategy equilibrium resolves the race at the same calendar time t^* , with exact ties occurring with probability zero.

- ▶ **Production technologies.**

- ▶ Strategic underinvestment holds for general increasing, concave technologies satisfying standard boundary (Inada) conditions.
- ▶ Preemption follows under a primitive single-crossing condition on the induced leader payoff.

- ▶ **Buyer types.**

- ▶ Both main results extend when the monopoly revenue curve $\theta[1 - F(\theta)]$ is strictly single-peaked.

DISCUSSION

TAKEAWAYS

- ▶ I build a model in which **independent sellers** develop **complementary products**, i.e., products that exhibit **synergies** when used together.
-

TAKEAWAYS

- ▶ I build a model in which **independent sellers** develop **complementary products**, i.e., products that exhibit **synergies** when used together.
-
- ▶ Invoking an **exclusionary pricing** strategy, the **leader free-rides** on the follower's product quality, who addresses the mass market.
 - ▶ **Premature product launch** and **exclusionary pricing** as elements of the **leader's rent-extraction** strategy (recall the **quality gap**) establish ecosystem dominance.
 - ▶ Complementarities **increase feasible surplus**, but the ensuing **preemption game** to determine the leader dissipates the synergy premium **lowering welfare**.
-

TAKEAWAYS

- ▶ I build a model in which **independent sellers** develop **complementary products**, i.e., products that exhibit **synergies** when used together.
-
- ▶ Invoking an **exclusionary pricing** strategy, the **leader free-rides** on the follower's product quality, who addresses the mass market.
 - ▶ **Premature product launch** and **exclusionary pricing** as elements of the **leader's rent-extraction** strategy (recall the **quality gap**) establish ecosystem dominance.
 - ▶ Complementarities **increase feasible surplus**, but the ensuing **preemption game** to determine the leader dissipates the synergy premium **lowering welfare**.
-
- ▶ Formally, the **main findings** are **robust** to endogenous complementarity, extended strategies, buyer delay, general production functions and buyer distributions.
-

TAKEAWAYS

- ▶ I build a model in which **independent sellers** develop **complementary products**, i.e., products that exhibit **synergies** when used together.
-
- ▶ Invoking an **exclusionary pricing** strategy, the **leader free-rides** on the follower's product quality, who addresses the mass market.
 - ▶ **Premature product launch** and **exclusionary pricing** as elements of the **leader's rent-extraction** strategy (recall the **quality gap**) establish ecosystem dominance.
 - ▶ Complementarities **increase feasible surplus**, but the ensuing **preemption game** to determine the leader dissipates the synergy premium **lowering welfare**.
-
- ▶ Formally, the **main findings** are **robust** to endogenous complementarity, extended strategies, buyer delay, general production functions and buyer distributions.
-
- ▶ **Selling synergies** can **destroy** the **synergies being sold**.

[illegible]

APPENDIX

STANDALONE BENCHMARK: DERIVATION

Given $p^* = q/2$ and $q(t) = \sqrt{t}$,

$$V_S(t) = e^{-\beta t} \frac{\sqrt{t}}{4} - \frac{c}{\beta} (1 - e^{-\beta t}).$$

The first-order condition is

$$\frac{1}{8\sqrt{t}} - \frac{\beta\sqrt{t}}{4} - c = 0 \quad \Longleftrightarrow \quad 2\beta t + 8c\sqrt{t} - 1 = 0.$$

Solving the quadratic in $\sqrt{t}$ yields

$$t_S^* = \left(\frac{\sqrt{4c^2 + \beta/2} - 2c}{\beta} \right)^2.$$

Strict concavity of the discounted revenue term and linearity of discounted cost imply uniqueness.

FOLLOWER PRICING: CANDIDATE REVENUES

Let $\alpha^O = q_F(1 + \gamma q_L)$ denote owners' incremental valuation scale.

$$R_F^A = \max_y \alpha^O y(1 - y) = \frac{\alpha^O}{4},$$

$$R_F^B = \alpha^O \theta_L(1 - \theta_L),$$

$$R_F^C = \frac{q_F}{4}.$$

- ▶ Regime A is feasible when the owner cutoff lies below $1/2$.
- ▶ Regime B serves every owner.
- ▶ Regime C serves the standalone mass market.

FOLLOWER PRICING: REGIME BOUNDARY

The upper boundary solves

$$q_F(1 + \gamma q_L)\bar{\theta}_L(1 - \bar{\theta}_L) = \frac{q_F}{4}.$$

Hence

$$\bar{\theta}_L = \frac{1}{2} \left(1 + \sqrt{\frac{\gamma q_L}{1 + \gamma q_L}} \right) > \frac{1}{2}.$$

Because $\theta(1 - \theta)$ is strictly decreasing above $1/2$,

$$\theta_L > \bar{\theta}_L \implies R_F^B(\theta_L) < R_F^C.$$

Thus mass-market pricing is uniquely optimal above the boundary.

BOUNDARY SELECTION AND STRICT RESPONSES

At $\theta_L = \bar{\theta}_L$:

$$R_F^B(\bar{\theta}_L) = q_F(1 + \gamma q_L)\bar{\theta}_L(1 - \bar{\theta}_L) = \frac{q_F}{4} = R_F^C.$$

The lower revenue-maximizing price is $q_F/2$, so the follower selects the mass market.

BOUNDARY SELECTION AND STRICT RESPONSES

At $\theta_L = \bar{\theta}_L$:

$$R_F^B(\bar{\theta}_L) = q_F(1 + \gamma q_L)\bar{\theta}_L(1 - \bar{\theta}_L) = \frac{q_F}{4} = R_F^C.$$

The lower revenue-maximizing price is $q_F/2$, so the follower selects the mass market.

For every $\theta_L > \bar{\theta}_L$,

$$R_F^B(\theta_L) < \frac{q_F}{4},$$

so the mass-market response is strict.

BOUNDARY SELECTION AND STRICT RESPONSES

At $\theta_L = \bar{\theta}_L$:

$$R_F^B(\bar{\theta}_L) = q_F(1 + \gamma q_L)\bar{\theta}_L(1 - \bar{\theta}_L) = \frac{q_F}{4} = R_F^C.$$

The lower revenue-maximizing price is $q_F/2$, so the follower selects the mass market.

For every $\theta_L > \bar{\theta}_L$,

$$R_F^B(\theta_L) < \frac{q_F}{4},$$

so the mass-market response is strict.

Because leader payoff is continuous in θ_L and

$$\Pi_L^* > \Pi_S^*,$$

there is an open right-neighborhood of $\bar{\theta}_L$ in which the follower strictly chooses the mass market and the leader still earns more than standalone profit.

STRATEGIC UNDERINVESTMENT: PROOF

Let

$$f(t) = e^{-\beta t} \sqrt{t}, \quad K(t, \gamma) = \frac{\gamma \sqrt{t}}{4(1 + \gamma \sqrt{t})}.$$

In Regime C,

$$L(t) = V_S(t) + K(t, \gamma)[f(t_S^*) - f(t)].$$

Since t_S^* maximizes V_S ,

$$V'_S(t_S^*) = 0, \quad f'(t_S^*) = 4ce^{-\beta t_S^*} > 0.$$

Therefore

$$L'(t_S^*) = -K(t_S^*, \gamma)f'(t_S^*) = -\frac{\gamma \sqrt{t_S^*}}{1 + \gamma \sqrt{t_S^*}} ce^{-\beta t_S^*} < 0.$$

Thus $L(t) > L(t_S^*) = \Pi_S^*$ for $t < t_S^*$ sufficiently close to t_S^* , and continuity plus $L(0) = 0$ gives an interior maximizer $t_L^* < t_S^*$.

PREEMPTION: EQUILIBRIUM LOGIC

- ▶ A seller can guarantee Π_S^* by waiting to become the follower or launching at t_S^* .
- ▶ No first launch can occur before t^* because $L(t) < \Pi_S^*$ there.
- ▶ No first launch can occur after t^* :
 - ▶ if one seller launches at $T > t^*$, the other can launch at $t \in (t^*, T)$ and earn $L(t) > \Pi_S^*$;
 - ▶ if both launch at $T < t_S^*$, either can move slightly earlier and replace $S(T)$ by approximately $L(T) > S(T)$;
 - ▶ if both wait to t_S^* , a launch in (t^*, t_S^*) yields more.
- ▶ At t^* , $L = F = S = \Pi_S^*$, so the prescribed simultaneous attempt is sequentially rational.

For symmetric mixed strategies, any support above t^* creates a profitable move just below the upper support; no support below t^* is compatible with the Π_S^* guarantee. Hence the symmetric distribution is degenerate at t^* .

WELFARE ACCOUNTING

For synchronized stopping t and common cutoff θ_c , define

$$V(t) = 2\sqrt{t} + \gamma t, \quad C(t) = \frac{c}{\beta}(1 - e^{-\beta t}).$$

Then

$$\begin{aligned} CS(t, \theta_c) &= e^{-\beta t} \frac{(1 - \theta_c)^2}{2} V(t), \\ PS(t, \theta_c) &= e^{-\beta t} \theta_c (1 - \theta_c) V(t) - 2C(t), \\ W(t, \theta_c) &= e^{-\beta t} \frac{1 - \theta_c^2}{2} V(t) - 2C(t). \end{aligned}$$

The coordinated solutions satisfy

$$0 = \theta_{FB} < \theta_{SB} < \theta_M = \frac{1}{2}, \quad t_S^* < t_M < t_{SB} < t_{FB}.$$

Together with $t^* < t_S^*$ and $\bar{\theta}_L > 1/2$, these orderings yield the dynamic and allocative distortions in the main text.

[► back](#)

COMPARATIVE STATICS

Primitive	t^*	t_S^*	Economic force
Complementarity $\gamma \uparrow$	$\downarrow$	unchanged	Larger leadership prize intensifies preemption; equilibrium payoffs remain Π_S^* .
Development cost $c \uparrow$	$\downarrow$	$\downarrow$	Development becomes more expensive; leadership becomes relatively more attractive.
Discount rate $\beta \uparrow$	ambiguous	$\downarrow$	Earlier revenue favors preemption; weaker discounted free-riding can delay it.

BUYER DELAY: REVENUE COMPARISON

At the boundary, leader revenue under the mass-market continuation is

$$R_L^W(x, z) = q \left(x - \frac{x^2}{1+z} \right).$$

It is decreasing for $x \geq m(z)$, where

$$m(z) = 2 + z - \sqrt{2+z}.$$

At $x = m(z)$, let $y = \sqrt{2+z}$. Then

$$\frac{R_L^W(m(z), z)}{q} = \frac{y(y-1)}{y+1}.$$

Hence the leader beats standalone revenue $q/4$ whenever

$$4y^2 - 5y - 1 > 0.$$

BUYER DELAY: PRIMITIVE REGION

The positive root of $4y^2 - 5y - 1 = 0$ implies

$$\underline{z} = \frac{5\sqrt{41} - 31}{32}.$$

The feasibility condition $m(z) < 1$ is equivalent to

$$\bar{z} = \frac{\sqrt{5} - 1}{2}.$$

Therefore, for every

$$z \in (\underline{z}, \bar{z}),$$

continuity gives an $x \in (m(z), 1)$ that

- ▶ induces strict mass-market pricing,
- ▶ makes all leader buyers wait until the follower price is observed, and
- ▶ gives the designated price leader more than Π_S^* .

GENERALIZATIONS

General production functions. Let q be increasing, strictly concave, differentiable, $q(0) = 0$, with standard boundary conditions. Then

$$L(t) = V_S(t) + \frac{\gamma q(t)}{4(1 + \gamma q(t))} [f(t_S^*) - f(t)], \quad f(t) = e^{-\beta t} q(t),$$

so

$$L'(t_S^*) < 0.$$

Regular type distributions. If

$$m(\theta) = \theta[1 - F(\theta)]$$

is strictly single-peaked, the monopoly quantile replaces $1/2$ and the same mass-market decoupling obtains. With $q(t) = \sqrt{t}$, both strategic underinvestment and preemption continue to hold.

REFERENCES I

- E. T. Anderson and D. I. Simester. Price Stickiness and Customer Antagonism. *The Quarterly Journal of Economics*, 125(2):729–765, 2010.
- S. Board and A. Skrzypacz. Revenue Management with Forward-Looking Buyers. *Journal of Political Economy*, 124(4):1046–1087, 2016.
- C. Bobtcheff, J. Bolte, and T. Mariotti. Researcher’s Dilemma. *The Review of Economic Studies*, 84(3):969–1014, 2017.
- J. D. Carrillo and G. Tan. Platform competition with complementary products. *International Journal of Industrial Organization*, 77:102741, 2021.
- Z. Chen and P. Rey. Competitive cross-subsidization. *The RAND Journal of Economics*, 50(3):645–665, 2019.
- P. K. Dutta and A. Rustichini. A Theory of Stopping Time Games with Applications to Product Innovations and Asset Sales. *Economic Theory*, 3(4):743–763, 1993.

REFERENCES II

- N. Economides and S. C. Salop. Competition and Integration Among Complements, and Network Market Structure. *The Journal of Industrial Economics*, 40(1):105–123, 1992.
- M. Eichenbaum, N. Jaimovich, and S. Rebelo. Reference Prices, Costs, and Nominal Rigidities. *American Economic Review*, 101(1):234–262, 2011.
- D. Fudenberg and J. Tirole. Preemption and Rent Equalization in the Adoption of New Technology. *The Review of Economic Studies*, 52(3):383–401, 1985.
- J. R. Green and S. Scotchmer. On the Division of Profit in Sequential Innovation. *The RAND Journal of Economics*, 26(1):20–33, 1995.
- H. C. Hoppe and U. Lehmann-Grube. Innovation timing games: A general framework with applications. *Journal of Economic Theory*, 121(1):30–50, 2005.
- M. L. Katz and C. Shapiro. Technology Adoption in the Presence of Network Externalities. *Journal of Political Economy*, 94(4):822–841, 1986.
- C. Matutes and P. Regibeau. “Mix and Match”: Product Compatibility Without Network Externalities. *The RAND Journal of Economics*, 19(2):221–234, 1988.

REFERENCES III

- B. Nalebuff. Bundling as an Entry Barrier. *The Quarterly Journal of Economics*, 119(1): 159–187, 2004.
- J. F. Reinganum. On the Diffusion of New Technology: A Game Theoretic Approach. *The Review of Economic Studies*, 48(3):395–405, 1981.
- S. Scotchmer. Standing on the Shoulders of Giants: Cumulative Research and the Patent Law. *Journal of Economic Perspectives*, 5(1):29–41, 1991.