Public and Private Infrastructure Investment in Mixed Duopoly

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Problem

Point of Departure

- In many industries, both **private** and **public** firms make **demand-enhancing infrastructure investments**.
- The **interaction** of private and public infrastructure investments is **not very well understood**.

Example: Fibre Optics

Investment in the deployment of fiber optics is key for enhancing demand for broadband communication services.

Natural Question

What is the **impact** of **public** demand-enhancing **investment on private firms**?

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Duopoly Model

- Imperfect **price competition** between private and public firm.
- Firms produce **horizontally differentiated products**.
- **No a priori assumptions on relative efficiency** of private and public firm.

Main Results

(1) The **impact of public investment** depends on its **direct effect on private demand**: It may **increase** (no direct effect) or **decrease** (strong direct negative effect) **private investment**.

(2) With **linear demand**, public investment **improves** the **private firm's price-investment ratio**.

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Related Literature

Mixed Oligopoly with Price Competition
Cremer et al. (1991), *IJIO*; Chowdhury (2008), unpublished WP.

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Assumptions

Demand

A1 Products are **imperfect substitutes** and **strategic complements**, i.e., $\partial D_i(\mathbf{p},\boldsymbol{\theta})/\partial p_i < 0$, $\partial D_i(\mathbf{p},\boldsymbol{\theta})/\partial p_j \geq 0$ and $\partial^2 D_i(\mathbf{p},\boldsymbol{\theta})/\partial p_i \partial p_j \geq 0$, with $\mathbf{p} = (p_i, p_j)$ and $\boldsymbol{\theta} = (\theta_i, \theta_j)$.

A2 **Quality** is **demand-enhancing** for own product, $\partial D_i(\mathbf{p},\boldsymbol{\theta})/\partial \theta_i > 0$, and may be **demand-reducing** for competing product, $\partial D_i(\mathbf{p},\boldsymbol{\theta})/\partial \theta_j \leq 0$.

A3 **Direct** price and quality **effects dominate indirect effects** (vaguely speaking).

Timing

- **Stage 1**: Firms invest in infrastructure qualities (θ_i, θ_j).
- **Stage 2**: Firms set product market prices (p_i, p_j).

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Market Configurations $k = \{S, M, W\}$

Standard Duopoly $(k = S)$

- **Stage 2**: $\max_{p_i} \pi_i(\mathbf{p}, \boldsymbol{\theta}) \rightarrow p_i^S(\boldsymbol{\theta})$
- **Stage 1**: $\max_{\theta_i} \pi_i(p_i(\boldsymbol{\theta}), p_j(\boldsymbol{\theta}), \boldsymbol{\theta}) \rightarrow \theta_i^S$

Mixed Duopoly $(k = M)$

- **Stage 2**: $\max_{p_1} \pi_1(\mathbf{p}, \theta)$ and
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Pricing

Result 1: Equilibrium Pricing

- Lerner index under **profit maximization**

$$\frac{p_i - c_i}{p_i} = \frac{1}{\varepsilon_{ii}}$$

- Lerner index under **welfare maximization**

$$\frac{p_i - c_i}{p_i} = \frac{1}{\varepsilon_{ii}} \left(\frac{\int_{p_j}^{\infty} \frac{\partial D_j}{\partial p_i} d\tilde{p}_j}{D_i} - \frac{(p_j - c_j)\varepsilon_{ij} D_j}{R_i} \right)$$

Intuition

- **Profit-maximizing** pricing is **standard**.
- **Welfare-maximizing** pricing also accounts for **cross-effects** on consumer and producer surplus on other market.

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Investment

Result 2: Equilibrium Investment

- Investment incentive under **profit maximization**

$$\frac{\partial F_i}{\partial \theta_i} = (p_i - c_i)\left(\frac{\partial D_i}{\partial p_j}\frac{\partial p_j}{\partial \theta_i} + \frac{\partial D_i}{\partial \theta_i}\right)$$

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- **Profit maximization**: Investment incentive equals **marginal revenue**.
- **Welfare maximization**: Investment incentive accounts for marginal impact on **producer** and **consumer surplus** in **both markets**.

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Crowding Out?

Result 3: Private vs. Public Investment

- If public investment has **no direct effect** on private demand, a marginal increase in public investment (weakly) increases private investment (**complementarity**).
- If public investment has a **direct negative effect** on private demand, the impact of a marginal increase in public investment on private investment is generally **ambiguous**.

Intuition

Without a direct negative effect on private demand, public investment increases retail prices (**strategic complementarity**). A direct negative effect on private demand may overcompensate this (**strategic substitutability**).

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Demand Function

Suppose demand is given by

$$D_i(p_i, p_j, \theta_i) = \alpha - \beta p_i + \gamma p_j + \theta_i$$

with $\alpha > 0, \beta > \gamma > 0$.

Goal

Compare equilibrium prices p_i^k and investments θ_i^k across market configurations k. For simplicity, we focus on the **price-investment ratios** $r_i^k \equiv p_i^k / \theta_i^k$.

Note

- Products are **imperfect substitutes**.
- If $\gamma \to \beta$, products become **closer substitutes**.
- There is **no direct effect** of θ_j on $D_i(\cdot)$.

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Price-Investment Ratios

Result 4: Private Price-Investment Ratios

For all admissible (β, γ)-combinations, the price-investment ratio offered by the private firm is strictly **lower** if the public firm maximizes **social welfare** rather than profits ($r_1^M < r_i^S$).

Note

- **Smaller price-investment ratios** reflect **lower prices and/or higher investments**.
- The welfare benchmark does **not** always deliver the lowest price-investment ratio.
- In the **mixed scenario**, for instance, the welfare-maximizing public firm provides an even **lower** ratio than in the welfare scenario for some (β, γ)-combinations to **manipulate demand**.

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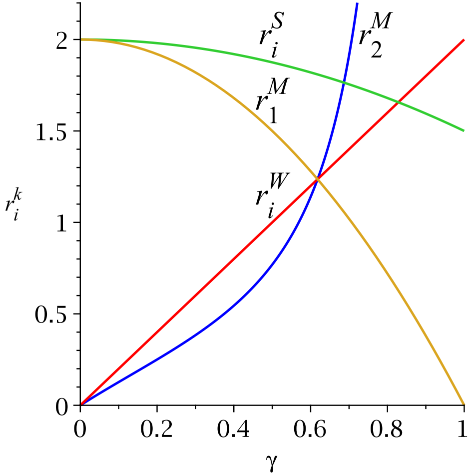

Conclusion

Key Insights

- The impact of public investment depends on its **direct effect on private demand**: It may either **increase** (no direct effect) or **decrease** (strong direct negative effect) private investment.
- With **linear demand** (and no direct negative effect on private demand), public investment unambiguously **improves the private firm's price-investment ratio**.

Future Research

- Find the minimal set of assumptions supporting the reduced-form analysis.
- Study the impact of public investment on prices and investments (rather than price-investment ratios).
- Compare analysis to real-world examples.

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Feedback

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