Spatial Competition with Heterogeneous Firms

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Introduction

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- Two branches of product differentiation literature

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- Two branches of product differentiation literature
- Economists tend to hold product characteristics fixed when considering pricing decisions and firm behavior more generally $\Longrightarrow$ endogeneity bias

- Estimate the change in domestic-firm profit resulting from an increase in a tariff

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$$\begin{bmatrix} \text{market shares} \\ \text{prices} \\ \text{product characteristics} \end{bmatrix} \Longrightarrow \begin{bmatrix} \text{demand system} \\ \text{marginal costs} \end{bmatrix}$$

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- Counter-factual exercise

$$\begin{bmatrix} \text{demand system} \\ \text{NEW marginal costs} \\ \text{FIXED product characteristics} \end{bmatrix} \Longrightarrow \begin{bmatrix} \text{market shares} \\ \text{prices} \end{bmatrix}$$

Introduction

Endogenous differentiation and firm heterogeneity

- Markets are rarely perfectly competitive
  ——Spence (1976), Dixit Stiglitz (1977), Salop (1979)
- Firm productivity differs significantly both within and across industries
  ——Jovanovic (1982), Hopenhayn (1992)
- Models studying firm heterogeneity in monopolistically competitive industries abstract from or treat as exogenous product placement
  ——Melitz (2002), Syverson (2004), Melitz Ottaviano (2005)

- Spatial competition models are ideally suited to answer: How does firm heterogeneity affect product placement in product space or firm location in geography?
- Spatial competition literature dates back to Hotelling (1929)
  - Two-stage model of Bertrand competition in which location differentiates otherwise homogeneous goods

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- Either assume that firms are homogeneous or abstract from location choice

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  - Will a firm locate closer to its relatively less productive neighbor?
  - Does opening the black box of differentiation yield new insight into the mechanism linking productivity to profit and market share?
  - How does the productivity of direct competitors affect outcomes such as profit, market share, and the ease with which consumers substitute between goods?

1. A set of SPNE to a standard Hotelling-style model generalized in two ways:
    1. firm heterogeneity
    2. horizontal and vertical differentiation (vertical not in presentation)
2. Firms use pure strategies along the equilibrium path
3. There is a unique economic outcome in any strict SPNE under a simple refinement

Setup
Consumers

- A mass L of consumers uniformly distributed along a unit circumference

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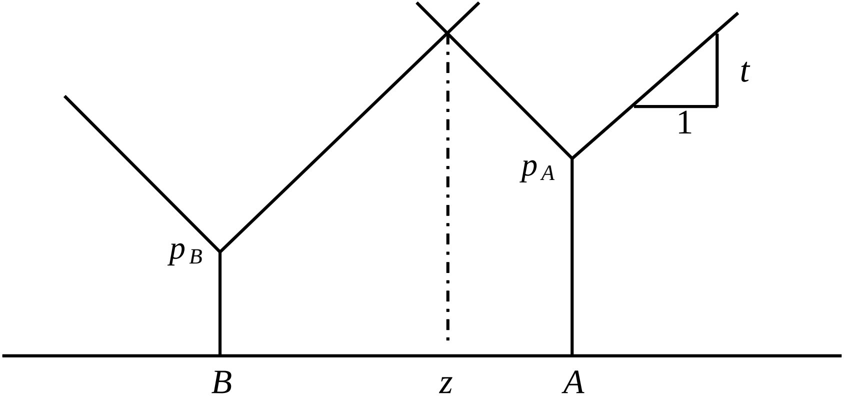
- A mass L of consumers uniformly distributed along a unit circumference
- Each consumer inelastically demands one good
- A consumer located at point z buys from firm i if

$$p_i + t \|z - i\| \leq \min_j \{p_j + t \|z - j\|\}$$

where $t > 0$

Setup
Consumer preferences



A graphical representation of consumer preferences

Setup

Firms: costs

- Firm i is associated with a constant marginal cost of production k_i

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- Additionally, firm incurs a "shipping cost" of $2\tau d$, with $\tau \in [0, t)$, to ship a good to a consumer located a distance d from its location

The game

- Firms play a two-stage game of complete information

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1. Location stage

The game

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1. Location stage
2. Price stage

The game

Stage one: location stage

- There is a set of $n \geq 2$ firms
- The vector of marginal costs $(k_1, ..., k_n)$ is common knowledge
- All firms simultaneously choose locations along the circumference of the circle

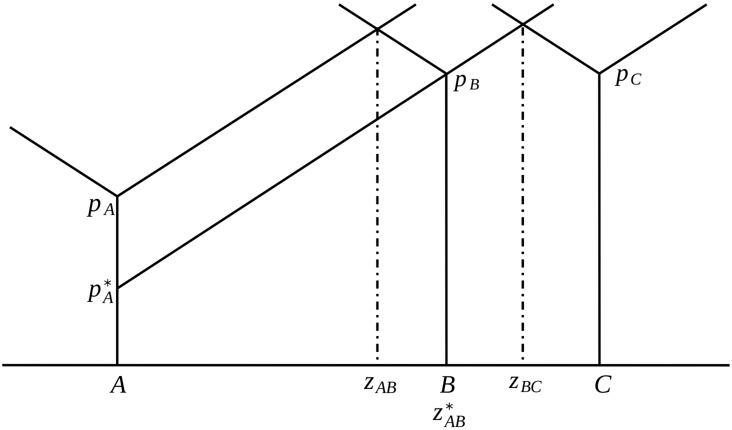
The game

Stage two: price stage

- All locations and marginal costs are common knowledge at the beginning of the price stage
- All firms simultaneously choose their prices

No SPNE

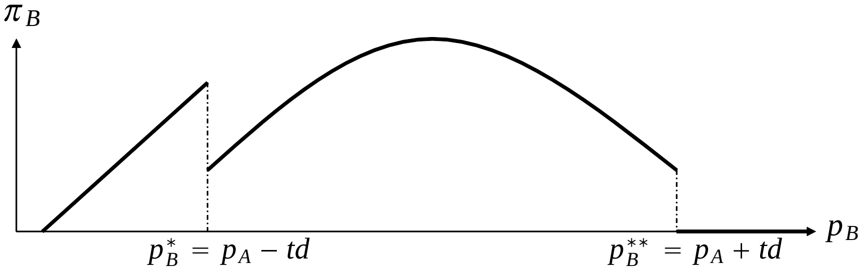
A simple game without a simple solution



Market share is discontinuous in price

No pure-strategy equilibrium

Profits are not globally continuous or quasi-concave



Firm B's profit as a function of its price (with $n = 2$)

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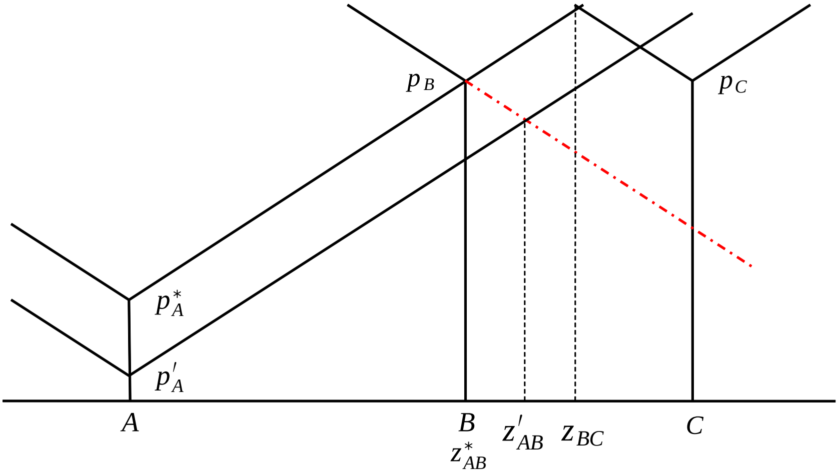
- Suppose firm i unilaterally deviates in the location stage from conjectured equilibrium and in subsequent price stage there exists no pure strategy equilibrium in prices
- Upper bound on i's profit strictly less than profit had it not deviated

Mixing

Auxiliary game



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    3. Either $\pi_i^{A\prime} \geq E\left[\pi_i^{\prime}\right]$ or $\pi_i^* > E\left[\pi_i^{\prime}\right]$
- $\Longrightarrow$ Either $\pi_i^* > E\left[\pi_i^{\prime}\right]$ or $\pi_i^* = \pi_i^{A^*} \geq \pi_i^{A\prime} \geq E\left[\pi_i^{\prime}\right]$

- Firm i's strategy space is Ω_i and a strategy is $\omega_i \in \Omega_i$
  Let $\Omega^n \equiv \Omega_1 \times ... \times \Omega_n$ and denote $\vec{\omega} \in \Omega^n$ by a *strategy vector*

Proposition

Suppose $\tau \geq 0$. *For any set of parameters* $\theta \equiv (n, t, \tau, L)$ *and* $k \geq 0$ *there exists a* $\phi(\theta, k) > 0$ *such that if* $k_i \in [k, k + \phi(\theta, k)]$ *for all* i, *then there is a non-empty set* $O^* \in \Omega^n$ *such that any* $\vec{\omega} \in O^*$ *is a SPNE and strategies are pure along the equilibrium path for all* $\vec{\omega} \in O^*$.

Proposition

For an arbitrary order in which firms locate, label any firm 0 and label subsequent firms in a clockwise direction (to firm $n-1$). This order corresponds to an equilibrium in O^*. For any $\vec{\omega} \in O^*$ the distance between each pair of neighbors, firms i and $i+1$, is

$$d^*_{i,i+1} = \frac{1}{n} + \frac{2}{3t+2\tau}\left(\bar{k} - \frac{k_i + k_{i+1}}{2}\right)$$

Firm i's price, market share, and profit are

$$\begin{aligned} p_i^* &= (t+\tau)\left(\frac{1}{n} + \frac{2}{3t+2\tau}\bar{k}\right) + \frac{t}{3t+2\tau}k_i \\ x_i^* &= \frac{1}{n} + \frac{2}{3t+2\tau}\left(\bar{k} - k_i\right) \\ \pi_i^* &= Lt\left(x_i^*\right)^2 \end{aligned}$$

Equilibrium description

Distance adjusts

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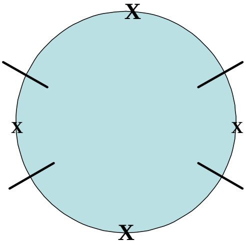

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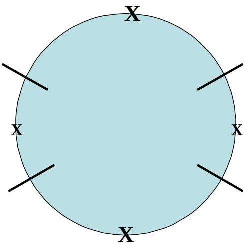
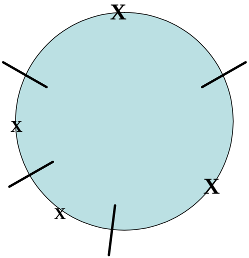


    - The two productive firms could neighbor each other:



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   Novel mechanism linking productivity to firm size

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2. More productive firms have larger market shares; a firm's market share is greater than average if and only if $k_i < \bar{k}$
   Novel mechanism linking productivity to firm size
3. Firm i earns more profit than average if and only if $k_i < \bar{k}$

Uniqueness

- A SPNE is *strict* if a unilateral deviation along the equilibrium path by firm i strictly decreases firm i's profit
  - This is not the standard definition of strict. A more accurate term would be "strict along the equilibrium path"

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Proposition

If $\tau > 0$ *and* $k_i \in [k, k + \phi(\theta, k)]$ *then* $\vec{\omega}$ *is a strict SPNE if and only if* $\vec{\omega} \in O^*$.

- Given locations, firm's i's best-response in prices is

$$\frac{2\left(\tau+2t\right)}{\left(t+\tau\right)}p_i = p_{i-1} + p_{i+1} + t\left(d_{i-1,i} + d_{i,i+1}\right) + \frac{2t}{t+\tau}k_i$$

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- This implies the system

$$A\vec{p}' = \vec{b}'$$

where

$$A \equiv \begin{bmatrix} \frac{2(2t+\tau)}{t+\tau} & -1 & 0 & 0 & -1 \\ -1 & \frac{2(2t+\tau)}{t+\tau} & -1 & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots \\ -1 & 0 & 0 & -1 & \frac{2(2t+\tau)}{t+\tau} \end{bmatrix}$$

and

$$b_i \equiv t\left(d_{i-1,i}+d_{i,i+1}\right)+\frac{2t}{t+\tau}k_i$$

- In the auxiliary game firm i's price is:

$$\begin{aligned} p_i &= \beta_1 \left(d_{i-1,i} + d_{i,i+1}\right) + \beta_2 \left(d_{i-2,i-1} + d_{i+1,i+2}\right) + \ldots \\ &\quad + \delta_0 k_i + \delta_1 \left(k_{i-1} + k_{i+1}\right) + \ldots \end{aligned}$$

Its market share and profit are

$$x_i = \frac{1}{2t}\left(p_{i-1} + p_{i+1} - 2p_i + t\left(d_{i-1,i} + d_{i,i+1}\right)\right)$$

$$\pi_i = L\left[x_i\left(p_i - k_i\right) - \tau\left(x_{i,i-1}^2 + x_{i,i+1}^2\right)\right]$$

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- Refinement intuition: want to be "centered in market share"

Extensions

- Consider both horizontal differentiation and (arbitrarily many dimensions of) vertical differentiation

$$p_i + t\,\|z - i\| - \sum_{k=1}^{K} q_{k,i}^{\gamma} \leq \min_j \left\{ p_j + t\,\|z - j\| - \sum_{k=1}^{K} q_{k,j}^{\gamma} \right\}$$

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- Allow consumers to vary in value they place on quality, θ, where $\theta \in [\theta_L, \theta_H]$:

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- Prove that there exist equilibria when the cost of transportation is convex (concave) that limit to my class of equilibria as the convexity (concavity) limits to linearity

Empirical implementation

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  2. differentiated good industry
- Examples of industries:

  ——ready-mixed concrete (Syverson (2004) and Collard-Wexler (2006))

  ——movie theaters (Davis (2005))

  ——motels (Mazzeo (2002))

  ——video retail (Seim (2001))

  ——eyeglass retail (Watson (2004))

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- Relevance of frameworks to industries
  1. Mill pricing appropriate for modeling differentiation in geographic and product-characteristics space
  2. SPD most appropriate for geographic differentiation and for differentiation of intermediate inputs that must be tailored to exact specifications of final good producers

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Spatial Price Discrimination

SPD relative to mill pricing: results

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- Similarities
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Spatial Price Discrimination

SPD relative to mill pricing: results

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  1. All economically relevant firm outcomes are uniquely determined across all SPNE in undominated strategies
  2. Firm's neighbor has no stronger effect on its market share and profit than a distant firm
  3. More productive firms are more isolated in product or geographic space, all else equal
- Differences
  1. Results hold not only in a neighborhood of symmetry, but for arbitrary distribution of m.c.'s
  2. A unique characterization of SPNE in undominated, pure strategies without imposing any assumptions on the allocation of transportation costs
  3. Equilibria with SPD are all welfare maximizing (solve social planner's prob)

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- Whether predictions are borne out remains to be seen