

Bigger is Better: Market Size, Demand Elasticity and Innovation

Klaus Desmet¹ and Stephen L. Parente²

¹Universidad Carlos III and CEPR

²University of Illinois

Spence-Dixit-Stiglitz dominates trade and growth

- Trade literature: Grossman and Helpman (1991), Melitz (2004), Atkeson and Burstein (2007),...
- Growth literature: Romer (1987), Grossman and Helpman (1991), Young (1998),...

Why?

Mainly because of its analytical convenience.

Analytically convenient, but empirically inconsistent

- Spence-Dixit-Stiglitz: price elasticity of demand is constant, and thus independent of market size.
- However, empirical evidence:
 - Bigger markets (in terms of population) are associated with a more elastic demand (Barron et al., 2003; Campbell and Hopenhayn, 2005).
 - Bigger markets (because of trade liberalization) are also associated with a more elastic demand (Tybout, 2003; Hummels and Klenow, 2005; Hummels and Lugovsky, 2005).

Empirical inconsistency: theoretically relevant?

- Helpman and Krugman (1985) said it wasn't.
- We say **it is!**
- Our argument: in models with process and product innovation, Spence-Dixit-Stiglitz (with its constant elasticity) underlies some of the standard results in the trade and growth literature.
 - The absence of a positive effect from trade liberalization on growth: Grossman and Helpman (1991, chapter 9), Atkeson and Burstein (2007),...
 - The absence of a positive scale effect on the rate of growth: Young (1998), Aghion and Howitt (1998, Chapter 12), Dinopoulos and Thompson (1998), Peretto (1998),...

Our paper

- Introduces preferences consistent with a positive relation between market size and elasticity into a model of process and product innovation
- Results:
 - 1 The positive effect of trade on process innovation (and growth) reemerges.
 - 2 The positive scale effect on process innovation (and growth) reemerges.

Outline of rest of talk

1 Intuition for elasticity channel

- Spence-Dixit-Stiglitz.
- Hotelling-Lancaster

2 Static economy

- Model
- Market size: population
- Market size: trade liberalization

3 Dynamic economy

Spence-Dixit-Stiglitz (1)

- Product space is unbounded.
- As population increases, and more varieties enter...
 - The product space does *not* become more crowded.
 - The degree of competition remains the same.
 - The price elasticity of demand and markups remain unchanged.
 - Firm size remains the same because of constant markups.
 - A given price drop has a constant effect on revenues.
 - Larger markets do not make it easier to bear the fixed costs of innovation.

Spence-Dixit-Stiglitz (2)

- Constant firm size implies that number of firms increases proportionately to the population.
- All the additional rents from the increase in market size thus get dissipated through *product innovation*...
- ... with no effect on *process innovation*.
- There is thus NO SCALE EFFECT.

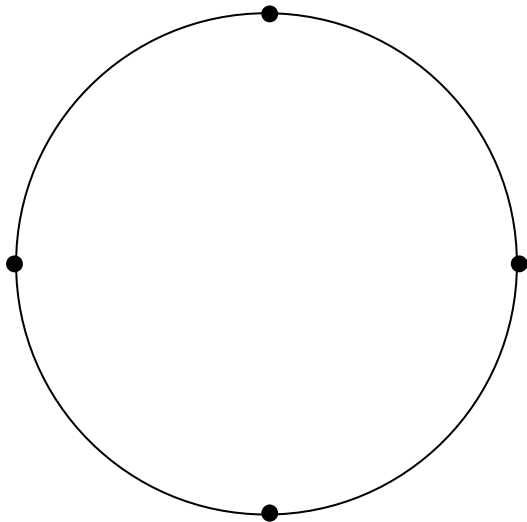
Hotelling-Lancaster (1)

- Product space is bounded, and each product has unique address.
- As population increases, and more varieties enter
 - The product space becomes more crowded.
 - Competition toughens.
 - The price elasticity of demand increases and markups drop.
 - Firm size becomes larger because markups drop.
 - A given price drop has a greater effect on revenues.
 - Larger markets make it easier to bear the fixed costs of innovation.

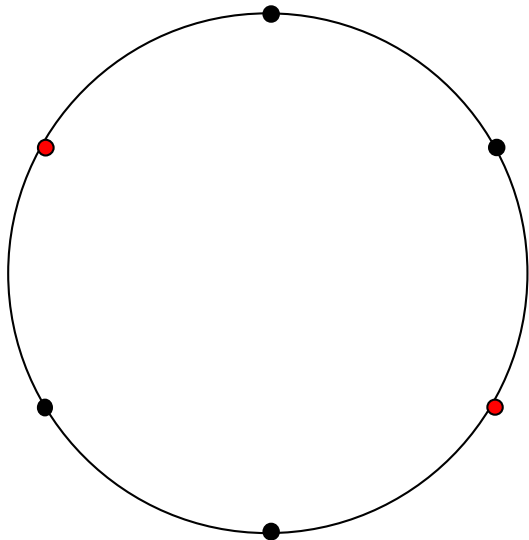
Hotelling-Lancaster (2)

- Larger firm size implies that the number of firms increases less-than-proportionately to the population.
- Only part of the additional rents from the increase in market size dissipate through *product innovation*...
- ... so that there is a positive effect on *process innovation*.
- The POSITIVE SCALE EFFECT reemerges.
- *Note: any preference structure which generates a positive relation between market size and demand elasticity would give the same result (Ottaviano, Tabuchi and Thisse, 2004).*

Hotelling-Lancaster preferences



Hotelling-Lancaster preferences



The model economy

- **Two countries:** Home (H) and Foreign (F). To deliver 1 unit of a good overseas requires a shipment of $\tau \geq 1$ units.
- **Household sector:** L households in each country, uniformly distributed on the unit circle.
- **Business sector:** monopolistically competitive.
 - Each firm produces a unique variety, located on the unit circle.
 - Firm chooses between a continuum of increasing returns technologies.
 - Both product and process innovation.

Household sector

- Utility of a household located at \tilde{v}

$$u(c_v) = \frac{c_v}{1 + d_{v\tilde{v}}^\beta}$$

- $d_{v\tilde{v}}$: shortest arc distance between variety v and the household's ideal variety \tilde{v}
- $1 + d_{v\tilde{v}}^\beta$: Lancaster's compensation function, i.e., the quantity of variety v that gives a household the same utility as 1 unit of its ideal variety \tilde{v} .

Household demand

- Each household buys the variety v that minimizes the cost of a quantity equivalent to 1 unit of its ideal variety \tilde{v} :

$$v' = \operatorname{argmin}[p_v(1 + d_{v\tilde{v}}^\beta) | v \in V]$$

[In a symmetric equilibrium with no transportation costs, this would imply each household buys the closest located variety.]

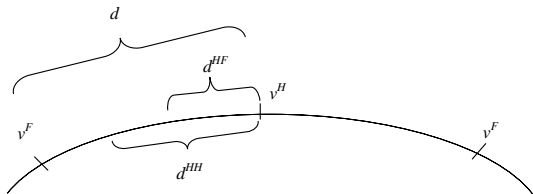
- Each household spends its entire income on that one good

$$c_{v'}^i = w^i / p_{v'}^i$$

Aggregate demand (1)

- Focus exclusively on symmetric equilibria: each Home variety has two Foreign varieties as closest neighbors.
- The aggregate demand for a Home variety comes from both Home households and Foreign households.
- Start with Home households.
- Determine Home household that is indifferent between buying Home variety and neighboring Foreign variety.

Aggregate demand (2)



- Home household that is indifferent between v^H and v^F :

$$p^{FH}[1 + (d - d^{HH})^\beta] = p^{HH}[1 + (d^{HH})^\beta]$$

where p^{HH} is price of Home variety in Home market, and p^{FH} is price of Foreign variety in the Home market.

- Aggregate consumption of v^H by Home households:

$$C^{HH} = \frac{2d^{HH}w^HL}{p^{HH}}$$

Aggregate demand (3)

- By analogy, aggregate consumption of v^H by Foreign households:

$$C^{HF} = \frac{2d^{HF} w^F L}{p^{HF}}$$

- Because of transportation costs, aggregate production is not the same as aggregate consumption:

$$Q^{HH} = C^{HH}$$
$$Q^{HF} = \tau C^{HF} = \frac{\tau 2d^{HF} w^F L}{p^{HF}}$$

Business sector

- Goods are horizontally differentiated.
- Choice between a continuum of increasing returns to scale technologies, indexed by $\gamma \geq 0$.

$$Q_v = A(1 + \gamma)[L_v - \kappa e^{\phi\gamma}]$$

- $\gamma = 0$ is referred to as the 'benchmark' technology
- Upgrading to a higher γ and a higher marginal productivity requires a higher fixed cost.

Profit maximization (1)

- A home firm maximizes profits with respect to p^{HH} , p^{HF} and γ , taking all decision variables of other firms as given, and taking aggregate variables as given:

$$\Pi^H = p^{HH} Q^{HH} + p^{HF} \frac{Q^{HF}}{\tau} - w^H \left[\kappa e^{\phi\gamma} + \frac{Q^{HH} + Q^{HF}}{A(1 + \gamma)} \right]$$

- This gives the following FOCs

$$\begin{aligned} p^{HH} &= \frac{w^H}{A_s} \frac{\varepsilon^{HH}}{\varepsilon^{HH} - 1} \\ \frac{p^{HF}}{\tau} &= \frac{w^H}{A_s} \frac{\varepsilon^{HF}}{\varepsilon^{HF} - 1} \\ -\phi\kappa e^{\phi\gamma} + \frac{Q^{HH} + Q^{HF}}{A(1 + \gamma)^2} &\leq 0 \end{aligned}$$

where the inequality in the last expression corresponds to a corner solution $\gamma = 0$.

Profit maximization (2)

Note that

$$\epsilon^{HH} = 1 + \frac{[1 + (d^{HH})^\beta]p^{HH}}{[p^{HH}\beta(d^{HH})^{\beta-1} + p^{FH}\beta(d - d^{HH})^{\beta-1}]d^{HH}}$$

$$\epsilon^{HF} = 1 + \frac{[1 + (d^{HF})^\beta]p^{HF}}{[p^{HF}\beta(d^{HF})^{\beta-1} + p^{FF}\beta(d - d^{HF})^{\beta-1}]d^{HF}}$$

Zero profit condition

- Free entry and exit
- No cost to move address
- Zero profit condition:

$$p^{HH}Q^{HH} + p^{HF}\frac{Q^{HF}}{\tau} - w^H[\kappa_s + (Q^{HH} + Q^{HF})/A_s] = 0$$

- This determines the number of varieties in equilibrium.

Symmetric equilibrium

- Households maximize utility.
- All firms maximize profits.
- There is free entry and exit: zero profit condition.
- All markets (labor and goods) clear.

Market size and innovation

- Experiment 1: Effect of an increase in population size on innovation.
- Experiment 2: Effect of a decrease in trade costs on innovation.

Population size (1)

Proposition 1. *In the absence of transportation costs, for each population size L there is a unique symmetric equilibrium.*

- The FOC with respect to γ is

$$-\phi\kappa e^{\phi\gamma} + \frac{Q^{HH} + Q^{HF}}{A(1 + \gamma)^2} \leq 0$$

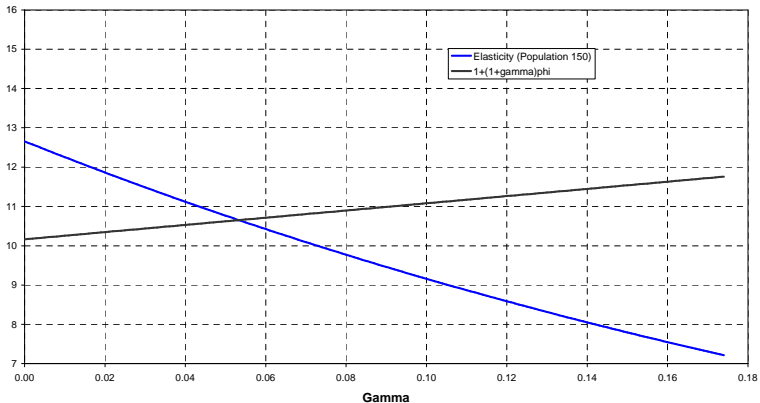
- This expression can be simplified to

$$\varepsilon \begin{cases} = 1 + (1 + \gamma)\phi & \text{if } \gamma > 0 \\ < 1 + (1 + \gamma)\phi & \text{if } \gamma = 0 \end{cases} \quad (1)$$

LHS is decreasing in γ ; RHS is increasing in γ .

Population size (2)

Equilibrium Technology



Population size (3)

Proposition 2. *In a symmetric equilibrium with zero iceberg costs, γ is increasing in the size of the population L .*

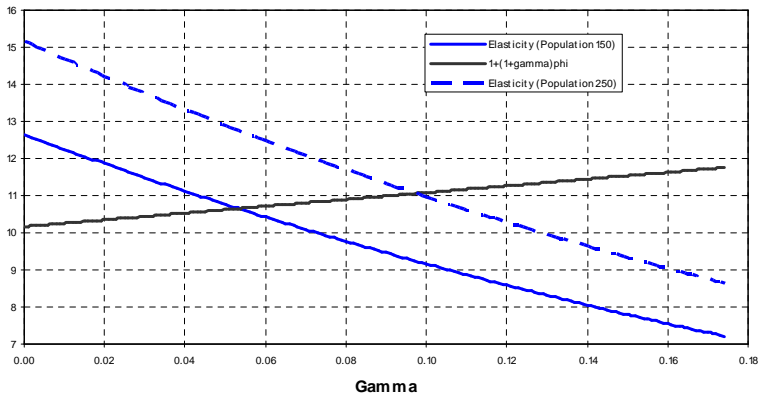
- Take the FOC condition of technology adoption:

$$\varepsilon \begin{cases} = 1 + (1 + \gamma)\phi & \text{if } \gamma > 0 \\ < 1 + (1 + \gamma)\phi & \text{if } \gamma = 0 \end{cases} \quad (2)$$

- LHS is increasing in L ; RHS is independent of L .
- Therefore, γ^* is increasing in L .

Population size (4)

Equilibrium Technology



Population size (5)

- Higher population leads to more firms.
- More firms leads to tougher competition, higher demand elasticity and lower markups.
- Because of the lower markups, firms must be larger to break even.
- For a given technology, the number of firms increases less-than-proportionately with population.

Population size (6)

Larger firms endogenously choose higher values of γ .

- Effect #1 (NEGATIVE): An increase in γ raises a firm's fixed cost.
- Effect #2 (POSITIVE): An increase in γ lowers a firm's marginal cost.
- Effect #1 (NEGATIVE) does not change with a firm's size, whereas Effect #2 (POSITIVE) increases with the size of a firm.
- Therefore, larger firms endogenously choose a higher γ .

Population size (7)

- The positive relation between population and innovation is due to the positive relation between population and elasticity.
- Remember the FOC of technology adoption:

$$\varepsilon \begin{cases} = 1 + (1 + \gamma)\phi & \text{if } \gamma > 0 \\ < 1 + (1 + \gamma)\phi & \text{if } \gamma = 0 \end{cases} \quad (3)$$

- If the elasticity were independent of population (as in Spence-Dixit-Stiglitz), then neither the LHS nor the RHS would depend on L , and γ^* would be independent of L .
- This explains the absence of a positive scale effect in the endogenous growth literature.

Trade liberalization (1)

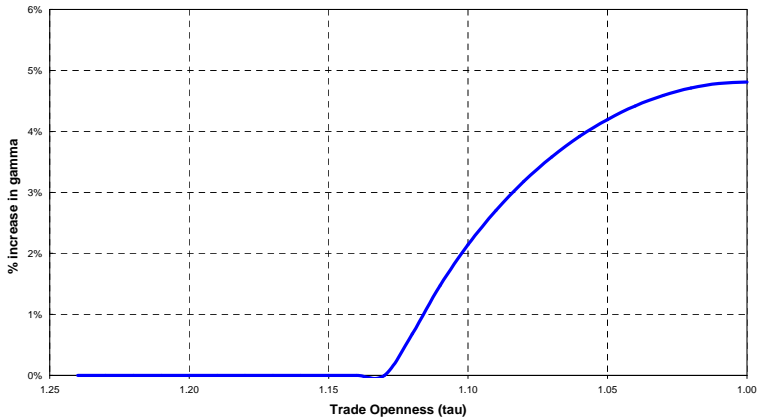
- Going from autarky to free trade is equivalent to doubling the population.
- Instead: focus on incremental reduction in trade costs.
- Keep population fixed, and lower τ .
- Explore how trade liberalization affects technology adoption.

Trade liberalization (2)

- $\beta = 0.55$ (consistent with positive relation between trade liberalization and elasticity)
- $A = 20$ (marginal labor input benchmark technology)
- $\kappa = .40$ (fixed labor input benchmark technology)
- $\phi = 9.2$ (parameter that determines how the fixed cost increases in γ)
- $L = 100$ (population)

Trade liberalization (3)

Trade Liberalization and Technological Progress



Trade liberalization (4)

- As trade is liberalized, competition between neighboring varieties increases.
- The elasticity of demand goes up, and markups fall.
- To recover fixed costs, firms need to sell more, and become larger.
- Trade liberalization leads to more process innovation but a lowering in the total number of varieties.
- Contrast with Atkeson and Burstein (2007), where trade liberalization affects neither process nor product innovation. Again: Spence-Dixit-Stiglitz!

Market size and innovation: summary

- Increase in population leads to technology adoption.

Reason: elasticity channel (through the entry of more varieties)

- Trade liberalization leads to technology adoption.

Reason: elasticity channel (through the tougher competition between Home and Foreign varieties)

Dynamic model: motivation

- **Question: Is the scale effect in our model in terms of the steady state GROWTH rate or in terms of the state income LEVEL?**
- Jones (1995) found no relation between R&D inputs and growth, and concluded there was no growth scale effect.
- Second generation endogenous growth literature: growth scale effect can be eliminated by endogenizing product innovation in a Spence-Dixit-Stiglitz framework (Young, 1998).
- Since this result is due to the absence of an elasticity channel, it suggests that with Hotelling-Lancaster preferences the growth scale effect should re-emerge.

Dynamic model: motivation

- **Issue: while being consistent with the micro-evidence on elasticity and market size, are Hotelling-Lancaster preferences inconsistent with the macro-evidence on the absence of a growth scale effect?**
- Answer: depends on whether we assume complete intertemporal spillovers or not.
- In addition: not all the evidence is supportive of the absence of a growth scale effect (Sachs and Warner, 1995; Alcalá and Ciccone, 2005; Alesina et al., 2005).

Dynamic model: setup

- Time is discrete.
- No population growth. Everyone lives for one period.
- Each period firms have a choice between using a benchmark technology or upgrading to a more productive technology.

Dynamic model: complete intertemporal spillovers (1)

- Benchmark technology in period t is the technology used in period $t - 1$. Denote this technology by A_t .
- Complete knowledge spillovers.
 - Fixed cost of the benchmark technology is constant in every period.
 - Upgrading the marginal productivity by a certain fraction γ_t requires the same fixed cost in terms of labor in every period.
 - In other words, to upgrade to a marginal productivity $A_t(1 + \gamma_t)$ requires a fixed labor cost $\kappa e^{\phi\gamma_t}$.

Dynamic model: complete intertemporal spillovers (2)

Proposition 3. *With complete intertemporal knowledge spillovers, the equilibrium γ is (i) constant over time; (ii) equal to the growth rate of GDP per capita; and (iii) increasing in the size of the population*

- Complete intertemporal spillovers imply that in **PERIOD** t the fixed cost required to use a certain technology depends on its improvement relative to the benchmark technology of **PERIOD** t .
- The price elasticity of demand therefore does not change with time either.
- The incentive to innovate and adopt more productive technologies is therefore the same in each period.

Dynamic model: incomplete spillovers

- To keep things simple: assume no intertemporal knowledge spillovers.
- In that case the fixed cost to operate a certain technology in **PERIOD** t depends on how much it has improved relative to the benchmark technology of the **FIRST PERIOD**.

Proposition 4. *With no intertemporal knowledge spillovers and zero iceberg costs, an increase in the population increases the steady state levels of technology and GDP per capita, but not their steady state growth rate.*

Concluding remarks (1)

- Introduce Hotelling-Lancaster preferences into model of process and product innovation.
- Elasticity channel leads to positive scale effects.
- Whether this is a level or a growth effect depends on the strength of intertemporal knowledge spillovers.
- This novel mechanism applies to both an increase in population and an increase in trade openness.
- Often the trade and the growth literatures seem to have divergent agendas regarding scale effects.
- There should be no dichotomy between those two literatures.

Concluding remarks (2)

- Future work: Industrial Revolution.
- Endogenous switch from Malthus to Solow.
- Explain the start of the Revolution, the demographic transition, and the structural transformation.

Concluding remarks (2)

Empirical debate

- Scale effect on growth:
 - **NO**: Jones (1995)
 - **YES**: Kremer (1993)
- Trade effect on growth:
 - **YES**: Sachs and Warner (1995), Wacziarg and Welch (2003), Alcalá and Ciccone (2004)
 - **AMBIGUOUS**: Rodríguez and Rodrik (2000).
- Being small only matters when being closed: Alesina, Spolaore and Wacziarg (2000).

Concluding remarks (3)

Theoretical debate

- Endogenous growth literature:

GET RID OF SCALE EFFECT

Young (1998), Aghion and Howitt (1998), Dinopolous and Thompson (1998), Peretto (1998)

- Trade literature:

RECOVER POSITIVE TRADE EFFECT

Holmes and Schmitz (1995, 2001), Herrendorf (2005), Atkeson and Burstein (2007), Segerstrom and Gustafsson (2007)

Concluding remarks (4)

Theoretical debate

- **What is the difference between interregional and international trade?** If the US and Canada were to join and become one country, then NO growth effect, but if the US and Canada were to remain separate countries and liberalize trade, then YES effect on growth...
- **Maybe the difference is the existence of fixed export costs?** But then only incomplete liberalization favors growth, whereas complete liberalization does not...
- **What about the absence of the elasticity channel in these two literatures?**

Concluding remarks (5)

NEEDED: A UNIFIED THEORY OF TRADE AND GROWTH