

Lecture 12: Intraindustry Heterogeneity in Trade Models

14.581: International Economics I

Pol Antràs

Harvard & MIT

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Motivation

- The Helpman-Krugman models feature complete specialization and “universal” exporting:
 - each industry variety is produced by a single firm in just one country, which exports its output everywhere else in the world;
 - adding transport costs could potentially invalidate this, but *not* if transport costs are of the iceberg type (constant-markup pricing).
- This does not provide a good description of reality (see Bernard et al, BEJK).

In the data:

- exporters are in the minority. In 1992, only 21% of U.S. plants reported exporting anything.
- exporters sell most of their output domestically: around 2/3 of exporters sell less than 10% of their output abroad.
- exporters are bigger than non-exporters: they ship on average 5.6 times more than nonexporters (4.8 times more domestically).
- plants are also heterogeneous in measured productivity; see figures 2A and 2B in BEJK.
- exporters' productivity distribution is a shift to the right of the nonexporter's distribution; exporters have, on average, a 33% advantage in labor productivity relative to nonexporters.

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Motivation (cted.)

- This suggests that the most productive firms self-select into export markets, but it could also reflect learning by exporting (Clerides et al., 1998)
- Furthermore, micro-level studies have also found evidence of substantial reallocation effects within an industry following trade liberalization episodes.
 - Exposure to trade forces the least productive firms to exit or shut-down (Bernard and Jensen, 1999; Aw, Chung and Roberts, 2000; Clerides et al., 1998).
 - Trade liberalization leads to market share reallocations towards more productive firms, thereby increasing aggregate productivity (Pavcnik, 2002, Bernard, Jensen and Schott 2003, Trefler, 2004).
- These studies suggest that successful theoretical frameworks for studying firms and the decision to export should include two features:
 - ① Within sectoral heterogeneity in size and productivity.
 - ② A feature that leads *only* the most productive firms to engage in foreign trade:
 - This could be a sunk cost of exporting as documented by Roberts and Tybout (1997) and Bernard and Jensen (2004), and formalized by Melitz (2003);
 - an alternative formulation of competition (as in BEJK 2003); or
 - an alternative demand structure that lead to nonconstant markups (as in Melitz and Ottaviano, 2006).

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Melitz (2003): Closed Economy Model

- The model builds on Krugman's classical (1980) paper.
- The demand side is identical to Krugman's:
 - CES preferences over an endogenous set Ω of differentiated varieties
 - Yields constant elasticity demand function

$$q(\omega) = \frac{R}{P} \left(\frac{p(\omega)}{P} \right)^{-\sigma}, \quad (1)$$

where R is total spending and P is the ideal price index.

- Most elements of the supply side are also as in Krugman (1980):
 - monopolistic competition: each variety is produced by a single firm and there is free entry into the industry.
 - firms produce varieties under a technology that features a constant marginal cost and a fixed overhead cost in terms of the unique composite factor of production (labor), which we take as numeraire.
 - the fixed cost is assumed identical across firms and we denote it by f .

Melitz (2003): New Features

- ① The marginal cost is assumed to vary across firms and is denoted by $1/\varphi$, i.e.

$$TC(\varphi) = f + \frac{q(\varphi)}{\varphi} \quad (2)$$

- Firms with higher φ are therefore more productive. Higher productivity firms also charge lower prices, produce more output, and obtain both higher revenues $r(\varphi)$ and higher profits $\pi(\varphi)$:

$$p(\varphi) = \frac{1}{\rho\varphi}; \quad q(\varphi) = RP^{\sigma-1}(\rho\varphi)^\sigma$$
$$r(\varphi) = p(\varphi)q(\varphi) = R(P\rho\varphi)^{\sigma-1} \quad (3)$$

$$\pi(\varphi) = \frac{1}{\sigma}r(\varphi) - f, \quad (4)$$

- ② Prior to entry, firms face productivity uncertainty:

- firms pay fixed cost of entry of f_e units of labor;
- firm then draws its productivity φ from a known distribution with pdf $g(\varphi)$;
- After observing φ , producer decides whether to exit or produce.

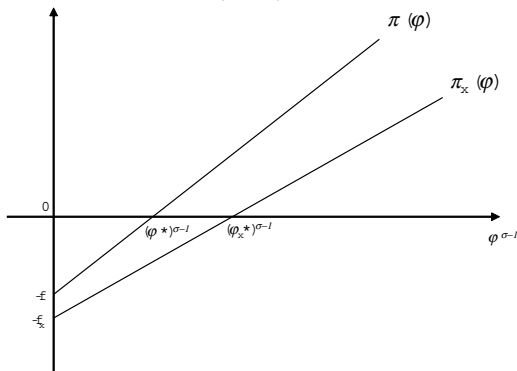
- ③ Each firm faces a probability δ of exogenous exit.

Melitz (2003): Firm Behavior

- Given stationarity, a firm with productivity φ earns profits $\pi(\varphi)$ in each period, until it is hit by a shock. Expected value of the firm:

$$v(\varphi) = \max \left\{ 0, \sum_{t=s}^{\infty} (1-\delta)^{t-s} \pi(\varphi) \right\} = \max \left\{ 0, \frac{1}{\delta} \pi(\varphi) \right\}, \quad (5)$$

- It is clear from (4) and (5) that there is a unique threshold productivity φ^* such that $v(\varphi) > 0$ if and only if $\varphi > \varphi^*$.



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Melitz (2003): Industry Equilibrium

- The threshold φ^* is a function of the equilibrium P and M , so we still have some work to do.
- Notice that $\mu(\varphi)$ is given by:

$$\mu(\varphi) = \begin{cases} \frac{g(\varphi)}{1-G(\varphi^*)} & \text{if } \varphi \geq \varphi^* \\ 0 & \text{otherwise} \end{cases}.$$

- It will be very useful to define the weighted average productivity measure:

$$\tilde{\varphi}(\varphi^*) = \left[\int_0^\infty \varphi^{\sigma-1} \mu(\varphi) d\varphi \right]^{\frac{1}{(\sigma-1)}} = \left[\frac{1}{1-G(\varphi^*)} \int_{\varphi^*}^\infty \varphi^{\sigma-1} g(\varphi) d\varphi \right]^{\frac{1}{(\sigma-1)}}.$$

- Next, we can define average profits $\bar{\pi} \equiv \int_0^\infty \pi(\varphi) \mu(\varphi) d\varphi = \pi(\tilde{\varphi})$ as

$$\begin{aligned} \bar{\pi} &= \frac{r(\tilde{\varphi})}{\sigma} - f = \left(\frac{\tilde{\varphi}(\varphi^*)}{\varphi^*} \right)^{\sigma-1} \frac{r(\varphi^*)}{\sigma} - f \\ &= f \left(\left(\frac{\tilde{\varphi}(\varphi^*)}{\varphi^*} \right)^{\sigma-1} - 1 \right), \quad (\text{ZCP curve}) \end{aligned} \quad (6)$$

where we have used (3), (4) and $\pi(\varphi^*) = 0$.

Melitz (2003): Equilibrium

- Finally, free entry ensures that, in the industry equilibrium, the *expected* discounted value of profits for a potential entrant equal the fixed cost of entry, or

$$\int_0^{\infty} v(\varphi) g(\varphi) d\varphi = f_e \Leftrightarrow \bar{\pi} = \frac{\delta f_e}{1 - G(\varphi^*)}. \quad (\text{FE}) \quad (7)$$

- Notice that (6) and (7) form a system of two equations in two unknowns $\bar{\pi}$ and φ^* .
- Because $G'(\varphi^*) > 0$, it is clear that along the FE schedule $\bar{\pi}$ is an increasing function of φ^* and satisfies $\bar{\pi}(0) = \delta f_e$ and $\lim_{\varphi^* \rightarrow \infty} \bar{\pi}(\varphi^*) = \infty$.
 - Intuitively, for a given expected value of entry f_e , the probability of success should be decreasing in the average profit level $\bar{\pi}$.
- On the other hand, Melitz (2003) shows that the FE curve is cut by the ZCP curve only once from above, thus ensuring the existence and uniqueness of the equilibrium.
 - Furthermore, under common distributions, the ZCP schedule is downward sloping in the space $(\bar{\pi}, \varphi^*)$ (see Figure 2 below).
- This system thus defines $\bar{\pi}$ and φ^* in terms of parameters (no effect of market size).

Melitz (2003): More on the Shape of the ZCP schedule

- We see from equation (6) that there are two effects of φ^* on $\bar{\pi}$
 - First, an increase in φ^* will increase the average productivity of the surviving firms

$$\tilde{\varphi}(\varphi^*)' = \frac{g(\varphi^*) \tilde{\varphi}^{2-\sigma}}{(\sigma-1)(1-G(\varphi^*))^2} \int_{\varphi^*}^{\infty} (\varphi^{\sigma-1} - (\varphi^*)^{\sigma-1}) g(\varphi) d\varphi > 0.$$

- But because firm profits are decreasing in the productivity of rivals, there is also an additional effect that goes in the opposite direction.
- If the distribution $G(\varphi)$ has a fat enough right tail, the latter effect will dominate and the ZCP will be downward sloping. An interesting case is that of a Pareto distribution, i.e., $G(\varphi) = 1 - \left(\frac{b}{\varphi}\right)^k$, which yields a flat ZCP schedule.

Melitz (2003): Other Equilibrium Variables

- With the equilibrium values of φ^* and $\bar{\pi}$ at hand, we can easily solve for the remaining endogenous variables
- The ideal price index is given by:

$$P^{1-\sigma} = \int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega = \int_0^{\infty} (\rho\varphi)^{\sigma-1} M\mu(\varphi) d\varphi = M(\rho\tilde{\varphi})^{\sigma-1},$$

and hence,

$$\bar{\pi} = \frac{1}{\sigma} \frac{R}{M} - f.$$

- But because of the equality of income and expenditure ($R = L$) we have:

$$M = \frac{L}{\sigma(\bar{\pi} + f)}, \quad (8)$$

which completes the characterization of the stationary equilibrium of the closed economy.

- Welfare is given by $U = LM^{1/(\sigma-1)}\rho\tilde{\varphi}$ (similar to Krugman but with $\tilde{\varphi}$ replacing φ).

Melitz (2003): Open-Economy Model

- With this machinery at hand, we can now move to the open economy version of the model and analyze the exporting decision as well as the reallocation effects generated by trade.
- If trade opening is just an increase in the relevant size of the economy, then we know that all firms will export and that trade will have no impact on average productivity (importance of CES).
- Melitz (2003) thus introduces trade frictions. These are of two types:
 - ① A standard per-unit iceberg costs, so that τ units need to be shipped for 1 unit to make it to any foreign country;
 - ② An initial fixed cost of f_{ex} units of labor to start exporting, *which is incurred once the firm has learned φ* .
- It is also assumed that the domestic economy can trade with $n \geq 1$ other countries and that all countries are of equal size, which implies that factor price equalization will hold and the wage will equal 1 everywhere.

Melitz (2003): Firm Behavior Revisited

- Firms will charge constant markups in both domestic and foreign sales, so domestic revenues are:

$$r_d(\varphi) = R(P\rho\varphi)^{\sigma-1}$$

where as revenues from foreign sales in country k are:

$$r_x(\varphi) = \tau^{1-\sigma} R_k (P_k \rho \varphi)^{\sigma-1}.$$

- As we will see later, the assumption of factor price equalization will imply that $RP^{\sigma-1} = R_k P_k^{\sigma-1}$ for all k , so following Melitz we can express firm revenues by export status as

$$r(\varphi) = \begin{cases} r_d(\varphi) & \text{if the firm does not export} \\ (1 + n\tau^{1-\sigma}) r_d(\varphi) & \text{if the firm exports to all countries.} \end{cases}$$

- The corresponding profit levels are

$$\pi_d(\varphi) = \frac{r_d(\varphi)}{\sigma} - f, \quad (9)$$

$$\pi_x(\varphi) = \frac{r_x(\varphi)}{\sigma} - f_x = \frac{\tau^{1-\sigma} r_d(\varphi)}{\sigma} - f_x, \quad (10)$$

where f_x is amortized per-period portion of the initial fixed cost (i.e., δf_{ex}).

Melitz (2003): Firm Behavior Revisited (cted.)

- Notice that eq. (10) is independent of the importing country k , and hence a firm does not export at all or it exports to all countries.
- Defining per period profits as $\pi(\varphi) = \pi_d(\varphi) + \max\{0, n\pi_x(\varphi)\}$, the value of the firm is again

$$v(\varphi) = \max\left\{0, \frac{1}{\delta}\pi(\varphi)\right\}.$$

- But we now have two relevant thresholds:

$$\varphi^* = \inf\{\varphi : v(\varphi) > 0\}$$

and

$$\varphi_x^* = \inf\{\varphi : \varphi \geq \varphi^* \text{ and } \pi_x(\varphi) > 0\}.$$

- Because $RP^{\sigma-1}$ is identical in all country, φ^* will also be identical everywhere.
- Firms with $\varphi \geq \varphi^*$ will remain in the market after learning their productivity, while those with $\varphi \geq \varphi_x^*$ will not only produce domestically, but also export.
- So long as $\varphi_x^* > \varphi^*$, the model is able to replicate the micro-level findings. This will hold true whenever $\tau^{\sigma-1}f_x > f$, a case illustrated in Figure 1.

Melitz (2003): Actual vs. Measured Productivity

- It is clear that, in the model, a higher φ is associated with a higher productivity level.
- But is it also associated with a higher *measured* productivity level? Consider value-added per worker.
- A naive measure of productivity would be the firm's markup, which by definition is equal to value added pq divided by variable costs q/φ . In Melitz's (2003) model this is independent of φ !
- But one needs to take into account the workers hired to of the fixed costs.

Then we have

$$\frac{r_d(\varphi) + nr_x(\varphi)}{q_d(\varphi) / \varphi + n\tau q_x(\varphi) / \varphi + f + f_x} > \frac{r_d(\varphi)}{q_d(\varphi) / \varphi + f} \text{ if and only if } \tau^{\sigma-1} f_x > f,$$

and hence the model is consistent with the evidence that uses the available measures of productivity.

- Notice that fixed costs are crucial for this.
 - An alternative route explored by BEJK (2003) and Melitz and Ottaviano (2003) is to dispense with fixed costs but introduce a theory that generates variable markups.

Melitz (2003): Industry Equilibrium

- To solve for the equilibrium, let us proceed as before and express all the relevant equilibrium conditions in terms of the cut-off φ^* .
- From (3), (10) and the definition of these thresholds, we immediately get

$$\varphi_x^* = \varphi^* \tau \left(\frac{f_x}{f} \right)^{1/(\sigma-1)}.$$

- The equilibrium distribution of productivity levels for incumbent firms $\mu(\varphi)$ is again given by $\mu(\varphi) = g(\varphi) / [1 - G(\varphi^*)]$ for $\varphi \geq \varphi^*$, while the probability that a surviving firm exports is given by $p_x = [1 - G(\varphi_x^*)] / [1 - G(\varphi^*)]$.
- Next, we can define average expected profits as

$$\begin{aligned} \bar{\pi} &= \pi_d(\tilde{\varphi}) + p_x n \pi_x(\tilde{\varphi}_x) = \\ &= f \left(\left(\frac{\tilde{\varphi}(\varphi^*)}{\varphi^*} \right)^{\sigma-1} - 1 \right) + p_x n f_x \left(\left(\frac{\tilde{\varphi}_x(\varphi^*)}{\varphi_x^*} \right)^{\sigma-1} - 1 \right), \quad (\text{ZCP}_t) \end{aligned} \quad (11)$$

which is the open-economy analog to (6).

Melitz (2003): Industry Equilibrium (cted.)

- Finally, the free entry condition requires the *expected* operating profits for a potential entrant to equal the sunk entry cost

$$\int_0^{\infty} v(\varphi) g(\varphi) d\varphi = f_e \Leftrightarrow \bar{\pi} = \frac{\delta f_e}{1 - G(\varphi^*)}, \quad (\text{FE}_t) \quad (12)$$

and hence this relationship remains unaltered in the open economy.

- We again have a system of two equations in two unknowns $\bar{\pi}$ and φ^* , which we plot in Figure 2.
- To solve for the equilibrium number of firms M , M_x and M_t notice that the M domestic producers together collect a revenue equal to R , while their average revenue is given by

$$\bar{r} = \int_0^{\infty} r(\varphi) \mu(\varphi) d\varphi = \sigma(\bar{\pi} + f + p_x n f_x)$$

and thus, imposing the equality of income and spending, we get

$$M = \frac{R}{\bar{r}} = \frac{L}{\sigma(\bar{\pi} + f + p_x n f_x)} \quad (13)$$

and $M_t = (1 + np_x) M$.

- Finally, we have $P^{1-\sigma} = M_t (\rho \tilde{\varphi}_t)^{\sigma-1}$, where $\tilde{\varphi}_t$ is average productivity.

Melitz (2003): The Impact of Trade

- Comparing the closed-economy and open-economy equilibria is straightforward.
- From simple inspection of (6) and (11), it follows that the ZCP schedule in the open economy is an upward shift of the ZCP schedule under autarky.
- It thus follows that $\varphi^* > \varphi_a^*$ and $\tilde{\varphi} > \tilde{\varphi}_a$, as illustrated in Figure 2.
 - Firms with productivity between φ_a^* and φ^* are not able to earn positive operating profits under trade.
 - Consistently with the findings in the empirical literature, exposure to trade thus forces the least productive firms to exit or shut-down.
- Intuition:
 - The fall in profit for domestic producers is not explained by a fall in mark-ups driven by increased foreign competition.
 - The *actual* channel operates through the domestic factor market.
 - Trade translates into increased profitable opportunities for the relatively productive firms \rightarrow more entry \rightarrow increased labor demand \rightarrow rise in the real wage (w/P) \rightarrow least productive firms can no longer afford to produce.
- Welfare: new source of gains from trade (increased average productivity).

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Melitz (2003): Open-Economy Model

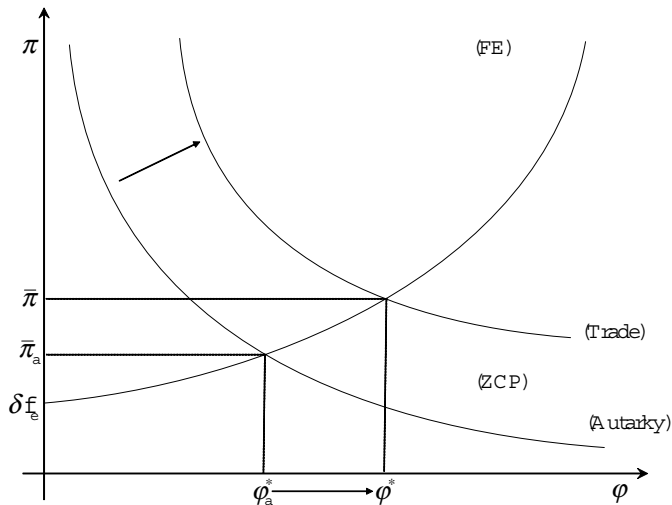


Figure: The Impact of Trade on the Industry Equilibrium

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Melitz (2003): Open-Economy Model

- Finally, we are interested in showing that the model can replicate the type of market shares reallocations found in the data. In particular, we want to show that:

$$r_d(\varphi) < r_a(\varphi) < r_d(\varphi) + nr_x(\varphi) \text{ for all } \varphi \geq \varphi^*.$$

- Notice that since $\varphi^* > \varphi_a^*$, we have

$$r_d(\varphi) = \sigma f \left(\frac{\varphi}{\varphi^*} \right)^{\sigma-1} < \sigma f \left(\frac{\varphi}{\varphi_a^*} \right)^{\sigma-1} = r_a(\varphi),$$

which proves the first inequality.

- The second inequality is more cumbersome to establish as its proof requires an analysis of the elasticity of the equilibrium φ^* with respect to τ (see Appendix E in the paper for details).
- In the last section, Melitz demonstrates that similar reallocation effects arise in response to smooth variations in τ and n .
 - important because there is some tension between the previous comparison of steady states equilibria (which captures long-run consequences of trade) and the type of short-run adjustments unveiled by the empirical literature.