

Advanced Topics in Trade

Lecture 4 - Trade Models with Heterogeneous Firms

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Today's Agenda

- ▶ A seminal paper by Melitz (2003) on firm heterogeneity and trade liberalization.
- ▶ Brief discussions of alternative models on firm heterogeneity and trade: Bernard et al. (2004) and Melitz and Ottaviano (2005).
- ▶ Discuss the gains from trade when firm heterogeneity is considered.

Model Set up

- ▶ The model is built on Krugman's seminal (1979, 1980) papers.
- ▶ Demand side is identical to Krugman (there are monopolistic competition and love for variety).
- ▶ Each firm, producing one variety, faces the following demand function:

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

- ▶ It includes most features of the supply side of Krugman (e.g., labor be the numeraire in the economy; $w = 1$) and more:
- ▶ Firms produce varieties under a technology that features a constant marginal cost and fixed overhead cost.
- ▶ The fixed cost, which is denoted by f , is assumed to be identical across firms for simplicity, while marginal costs because of firm heterogeneous productivity, varies across firms.

New Features

- ▶ The marginal cost is assumed to vary across firms, denoted by $\frac{1}{\varphi}$.
- ▶ Total cost of production (= $w (=1)$ * total firm employment)

$$l(\varphi) = f + \frac{q(\varphi)}{\varphi}$$

- ▶ Price

$$p(\varphi) = \left(\frac{\sigma}{\sigma - 1} \right) \frac{1}{\varphi}$$

- ▶ Quantity

$$q(\varphi) = RP^{\sigma-1} \left(\left(1 - \frac{1}{\sigma}\right) \varphi \right)^{\sigma}$$

- ▶ Revenue

$$r(\varphi) = p(\varphi) q(\varphi) = R \left(P \left(1 - \frac{1}{\sigma}\right) \varphi \right)^{\sigma-1}$$

- ▶ Profit

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

Firm Behavior

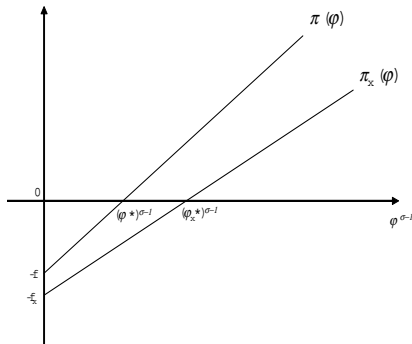
- ▶ Prior to entry, firms face productivity uncertainty. Each firm
 - ▶ produces one variety in the industry;
 - ▶ pays fixed cost of entry of f_e ;
 - ▶ draws its productivity φ from a known distribution with cumulative distribution function $G(\rho)$;
 - ▶ decides whether to exit or produce, after observing φ .
- ▶ If it produces, it will have to incur a fixed cost f every period.
- ▶ Each firm faces a probability δ of exogenous exit (a death shock).

Heterogeneous Firm Behavior

- ▶ Given all the above assumptions, stationarity of distribution of productivity and other variables are guaranteed.
- ▶ Firm with productivity ρ earns profit $\pi(\varphi)$ per period. Its expected value of firm is

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

- ▶ There is a unique productivity cutoff, ρ^* , such that $v(\varphi) > 0$ if and only if $\rho > \rho^*$



Industry Equilibrium (Wonkish)

- ▶ In general equilibrium, there will be a lot of inter-dependence between different macro variables.
- ▶ In particular, the productivity cutoff for entry (ρ^*) is a function of equilibrium prices and number (mass) of firms.
- ▶ Define the (industry equilibrium) weighted average firm productivity as

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

- ▶ Then we can define average firm profits as

$$\begin{aligned} \bar{\pi} &\equiv \frac{1}{1 - G(\varphi^*)} \int_{\varphi^*}^{\infty} \pi(\varphi) g(\varphi) d\varphi \\ &= \pi(\tilde{\varphi}(\varphi^*)) \end{aligned}$$

- ▶ Let us call this function of φ^* the zero cutoff profit (ZCP) curve, as it is derived from the zero profit of the firm that has productivity equal φ^* .

Solving the Closed-economy Equilibrium (Wonkish)

- ▶ Recall that there is a sunk entry cost.
- ▶ In equilibrium, the expected discounted value of profits for a potential entrant equal the fixed cost of entry:

$$[1 - G(\varphi^*)] \frac{\bar{\pi}}{\delta} = f_e$$

$$\Rightarrow \bar{\pi} = \frac{\delta f_e}{1 - G(\varphi^*)}$$

- ▶ This is the free entry (FE) curve in Melitz.
- ▶ Since $G(\varphi^*)$ is increasing in φ^* , the FE curve is upward-sloping with respect to φ^* .
- ▶ Under a wide range of distribution functions of φ , the ZP curve is downward-sloping.
- ▶ Thus, the ZP curve and the FE curve will intersect (and Melitz shows that there is a unique intersection).

Equilibrium productivity cutoff and average firm profit

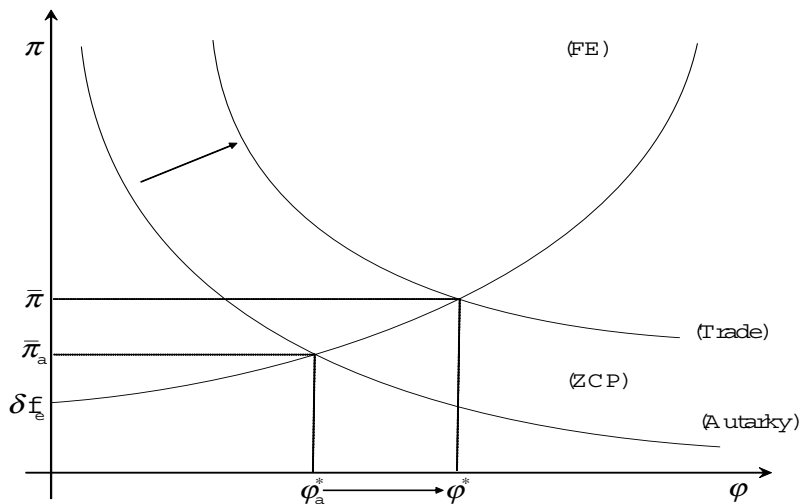


Figure: The Impact of Trade on the Industry Equilibrium

Other equilibrium variables

- ▶ With equilibrium φ^* and $\bar{\pi}$ solved, we can solve for other endogenous variables.
- ▶ The aggregate price index (over all variety prices), $P^{1-\sigma}$, is

$$\begin{aligned}\int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega &= \frac{M}{1 - G(\varphi^*)} \int_{\varphi^*}^{\infty} \left(\frac{\sigma - 1}{\sigma} \varphi \right)^{\sigma-1} g(\varphi) d\varphi \\ &= M \left(\frac{\sigma - 1}{\sigma} \tilde{\varphi} \right)^{\sigma-1}\end{aligned}$$

- ▶ Rearranging the definition of the average firm profit:

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

yields the number (mass) of firms in the market:

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

Other equilibrium variables (cont')

- ▶ Finally, welfare (consumer utility) can be expressed as:

$$U = \frac{w}{P} = LM^{\frac{1}{\sigma-1}} \left(1 - \frac{1}{\sigma}\right) \tilde{\varphi}$$

- ▶ New source of gains from trade: increased average productivity, in addition to increased variety and increasing returns, as in Krugman (1979).

An Open Economy Version

Set-up

- ▶ We can now move to the open-economy version of the model.
- ▶ If trade opening is just like an expansion of the market, like Krugman (1979), then all firms serve both the domestic market and the foreign market (i.e., export).
- ▶ Melitz (2003) introduces trade costs. There are two kinds:
 - ▶ A standard per-unit iceberg cost (i.e., to have 1 unit of goods absorbed in the foreign market, $\tau > 1$ units of goods need to be shipped.)
 - ▶ A initial sunk cost to export, f_{ex} , in addition to f_e .

An Open Economy Version

Firm outcomes

- ▶ Firm will charge constant markups over marginal costs ($\frac{w}{\varphi}$) for both domestic and foreign markets. (Strong results?)
- ▶ Revenues (home market and market k):

$$r_d(\varphi) = R \left[\left(1 - \frac{1}{\sigma} \right) \varphi P \right]^{\sigma-1}$$

$$r_k(\varphi) = \tau^{1-\sigma} R_k \left[\left(1 - \frac{1}{\sigma} \right) \varphi P_k \right]^{\sigma-1}$$

- ▶ Under the assumption of symmetric countries (same P and R everywhere), a firm's total revenue (either non-exporter or exporter):

$$r(\varphi) = \begin{cases} r_d(\varphi) \\ (1 + n\tau^{1-\sigma}) r_d(\varphi) \end{cases}$$

- ▶ Corresponding profits:

$$\pi_x(\varphi) = \frac{r_x(\varphi)}{\sigma} - f_x; \quad \pi_d(\varphi) = \frac{r_d(\varphi)}{\sigma} - f$$

The Impact of Trade

- ▶ We can then derive the ZCP and FE conditions to pin down the equilibrium entry cutoffs (domestic and each foreign market), average firm productivity, and average firm profit in the industry.

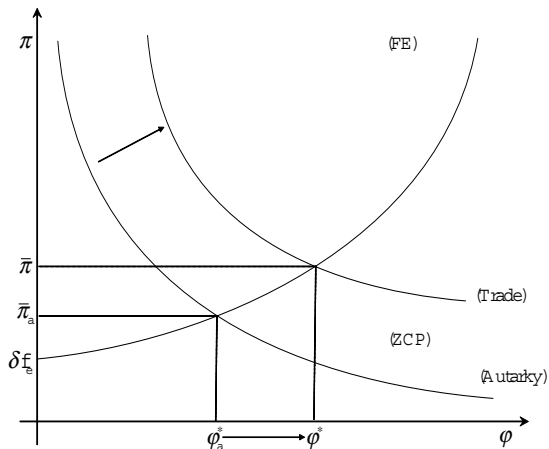


Figure: The Impact of Trade on the Industry Equilibrium

The Intuition of the Impact of Trade

- ▶ Notice that $\varphi^* > \varphi_a^* \Rightarrow \tilde{\varphi} > \tilde{\varphi}_a$, where the subscript a stands for autarky.
 - ▶ Firms with productivity between φ_a^* and φ^* can no longer make profits and exit.
 - ▶ This is consistent with previous findings that trade liberalization will weed out the least productive firms.
- ▶ But what is the mechanism here? And is it consistent with what previous studies have conjectured?
 - ▶ The fall in profit for firms that only sell in the domestic market is not driven by import competition, which has been the conventional wisdom and certainly matters.
 - ▶ In Melitz (2003), the channel operates through the rise in real wages (a general equilibrium effect)!
 - ▶ Recall that labor is the numeraire. So when P goes down (due to variety and productivity effects), w/P rises.

Reallocation of resources after trade liberalization

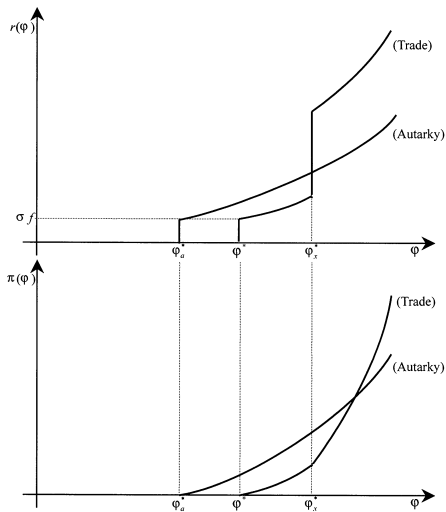


FIGURE 2.—The reallocation of market shares and profits.

Details of the Reallocation Effects

- ▶ Recall the following empirical regularities in most countries:
 - ▶ Exporters are larger;
 - ▶ Less productive firms exit;
 - ▶ Some firms expand while others contract due to trade liberalization.
- ▶ Melitz (2003) has the following prediction about sales volume for a given firm:

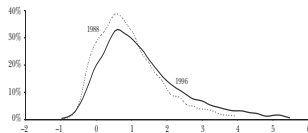
$$r_d(\varphi) < r_a(\varphi) < r_d(\varphi) + nr_x(\varphi) \text{ for all } \varphi \geq \varphi^*$$

- ▶ How do we know that the portion of domestic sales, and thus firms that only sell in the domestic market, will shrink in size?
- ▶ Argument: From the perspective of a firm, nothing has changed besides real wages, which increase after liberalization.
- ▶ Proving the second inequality is trickier as it involves a careful analysis about the magnitude of the change in real wages and the benefits of gaining access to a foreign market (See the appendix in the paper for details). Melitz (2003) shows that it is the second force that dominates.

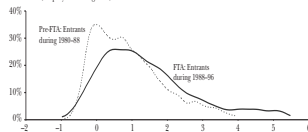
Evidence? Melitz and Trefler (2012)

Distribution of Productivity across Canadian Manufacturing Plants before and after the Canada-U.S. Free Trade Agreement

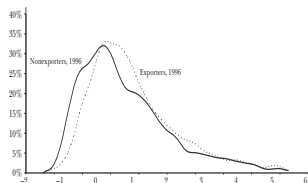
A: Labor productivity distribution of all Canadian manufacturing plants 1988 and 1996 (employment weighted)



B: Labor productivity distribution of entering Canadian manufacturing plants 1980-1988 and 1988-1996 (employment weighted)



C: Labor productivity distribution of exporters and nonexporters, 1996 (employment weighted)



Summary of Melitz (2003)

- ▶ In addition to Krugman's insights, there is an additional source of the gains from trade, through a reallocation of resources (labor in the paper) from the less productive firms to the more productive ones.
- ▶ Average (aggregate) productivity of the industry increases because
 - ▶ Low-productivity firms exit;
 - ▶ Medium-productivity firms only sell in the domestic market and shrink;
 - ▶ High-productivity, which were already large before trade liberalization, further increase in size after trade liberalization.
- ▶ The paper shows that the main source through which this reallocation happens is due to rising (real) wages in equilibrium.

Extensions?

- ▶ Multi-product firms? (Bernard et al., 2010)
- ▶ Heckscher-Ohlin forces (Bernard et al., 2007, and Ma, Tang, and Zhang, 2014).
- ▶ Inequality (Amiti and Davis, 2011).
- ▶ Dynamics, growth, innovation, mis-allocation of resources in developing countries, etc.

Introduction to Melitz and Ottaviano (2008)

- ▶ A strong assumption made by Melitz (2003) is **constant elasticity of substitution between varieties**.
- ▶ While allowing firm heterogeneity in productivity and thus prices, CES pins down a constant mark-up over marginal costs across firms (a very standard feature in trade models, for convenience).
- ▶ In reality, mark-ups certainly vary across firms, but how much more insight do we get by allowing it to vary in the model?
- ▶ This is what Melitz and Ottaviano (2008) aims to achieve.
- ▶ Similar to Melitz, it also emphasize firm heterogeneity in productivity, firm entry and exit, and the associated reallocation effects.
- ▶ Different from Melitz, it allows firms to set different markups.
- ▶ More importantly, competitive pressure, due to trade liberalization, would limit the ability of firms to charge prices over marginal costs.
- ▶ Low (average) markups after trade liberalization will immediately become another source of the welfare and efficiency gains from trade.

Melitz and Ottaviano (2008)

Demand Side

- ▶ The model uses a specific utility function:

$$U = q_0^C + \alpha \int_{i \in \Omega} q_i^C di - \frac{1}{2} \gamma \int_{i \in \Omega} (q_i^C)^2 di - \frac{1}{2} \eta \left(\int_{i \in \Omega} q_i^C di \right)^2$$

- ▶ γ is an index of product differentiation. When γ is high, the gains from variety is high; when $\gamma = 0$, varieties become perfect substitutes.
- ▶ α and γ govern the substitutability of varieties with the numeraire ('outside') good (q_0^C). High α or low γ reduces the demand for differentiated varieties.
- ▶ It can be shown that the marginal utility is bounded (never infinity even when consumption is zero), so there exists a 'choked' price above which demand for a variety drops to zero.

$$q_i^C = \frac{1}{\gamma} (\alpha - p_i - \eta Q^C); \quad Q^C = \int_{i \in \Omega} q_i^C di$$

- ▶ Given L consumers, aggregate demand for a differentiated variety is $q_i = Lq_i^C$

Melitz and Ottaviano (2008)

Firm Equilibrium Outcomes

- ▶ The 'outside' good is produced one-to-one with labor.
- ▶ For differentiated varieties, production technology is similar to Melitz (2003).
- ▶ Firms pay sunk cost f_E to enter, before which their unit costs, c , are unknown.
- ▶ Firm productivity is revealed (drawn) from a common cost distribution $G(c)$ with support on $[0, c_M]$.
- ▶ Different from Melitz, there is no per-period fixed cost of production.
- ▶ Due to monopolistic competition, firms maximize profits taking number of firms N and prices as given. There is free entry in the long run.

Melitz and Ottaviano (2008)

Firm Equilibrium Outcomes

- ▶ Let $c_D \equiv \alpha - \eta Q^C$, firm outcomes can be solved as follows:

$$\text{prices} : p(c) = \frac{1}{2}(c_D + c)$$

$$\text{markups} : \mu(c) = p(c) - c = \frac{1}{2}(c_D - c)$$

$$\text{revenue} : r(c) = \frac{L}{4\gamma} [(c_D)^2 - c^2]$$

$$\text{profits} : \pi(c) = \frac{L}{4\gamma} [c_D - c^2]$$

Melitz and Ottaviano (2008)

Industry Equilibrium

- ▶ Relative to other firms, more productive firms (lower c)
 - ▶ set lower prices but higher markups (thus, efficiency dominates the markup effects);
 - ▶ are bigger (in terms of sales, exports, and employment);
 - ▶ earn higher profit.
- ▶ Imposing Pareto distribution for $1/c$ with shape parameter k , one can use the free-entry condition to pin down the cost parameter of the marginal firm:

$$c_D = \left(\frac{\gamma\phi}{L} \right)^{\frac{1}{k+2}}$$

where $\phi = 2(k+1)(k+2)c_M^k f_E$.

- ▶ c_D is lower and thus the market is more competitive with higher average productivity if
 - ▶ L is higher (i.e., the market is larger);
 - ▶ γ is lower, varieties are closer substitutes;
 - ▶ f_M is lower (i.e., lower entry cost or barriers).

Melitz and Ottaviano (2008)

Impact of Trade

- ▶ An integrated world economy implies a larger market and:
 - ▶ Lower average markups and prices;
 - ▶ Bigger firms;
 - ▶ More profitable firms;
 - ▶ Lower variance of productivity, prices, and markups;
 - ▶ Higher variance in firm size (output and sales).
- ▶ Welfare Impact: In addition to Melitz (2003), there is an additional pro-competitive effect.
- ▶ Extensions:
 - ▶ add iceberg transport costs;
 - ▶ asymmetric country size;
 - ▶ unilateral vs. multilateral liberalization.

Conclusions of the Models with Heterogeneous Firms

- ▶ Although through different channels, both Melitz (2003) and Melitz-Ottaviano (2006) emphasize the same but previously overlooked aspect of the gains from trade:
 - ▶ aggregate productivity of an economy increases through (re)allocation of resources from the less efficient firms to the more efficient ones.
- ▶ Both of these seminal papers ignore within-firm upgrading (e.g., technology upgrading, innovation, quality upgrading, capital deepening, etc.) in response to trade liberalization and expanded market access.
- ▶ The review paper by Melitz and Trefler (2012) has a summary of those studies, and those will be our focus next time.