

The Variety Effect of Trade Liberalization

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Abstract

The model of Melitz (2003) has become central in the literature on heterogeneous firms in trade. It matches empirical findings that trade liberalization raises average productivity in an industry through firm selection. Remarkably, however, for the productivity distribution of greatest empirical relevance, it predicts liberalization unambiguously reduces product variety to domestic consumers. Quantitative studies are left with a choice between matching firm selection with a heterogeneous-firms model or matching variety growth with a homogeneous-firms model. This paper shows that relaxing the Melitz-model's restriction that firms produce a single variety, overturns its anti-variety result. Firm heterogeneity becomes the driving force of both firm selection and variety growth.

Keywords: Trade, Product variety, Firm selection, Heterogeneous firms, Melitz model.

JEL Classification: F12, F15, L11

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1 Introduction

Over the past few years, the model of Melitz (2003) has become the core of a growing literature on heterogeneous firms in international trade (Greenaway and Kneller, 2007). The model is based on firms that differ in productivity and each produce a single horizontally differentiated variety. Exporting involves a sunk cost, which leads to a scale ranking: only the most productive firms export. Then, upon trade liberalization, entry by foreign exporters pushes out the least productive domestic firms, raising the average productivity in the industry. This matches the firm selection effect that, as documented in the surveys of Tybout (2003) and Greenaway and Kneller (2007), receives extensive support from microeconomic studies.

But, remarkably, the Melitz-model misses out on another stylized fact: the increase in product variety available to domestic consumers.¹ Variety growth has been at the heart of trade theory since the seminal work of Krugman (1980). And yet, despite the fact that the Melitz-model is essentially an extension of the Krugman-model to heterogeneous firms, it fails to match the rise in variety. For the firm-size distribution of greatest empirical relevance - the Pareto distribution - Baldwin and Forslid (2006) have proven that the model predicts the exact opposite: trade liberalization unambiguously reduces variety. Arguably, this is the Melitz-model's most serious shortcoming. It implies that quantitative studies are restricted to a choice between matching firm selection with a heterogeneous-firms model (Chaney (2006), Alvarez and Lucas (2004)) or matching the variety channel with a homogeneous-firms model (Klenow and Rodriguez-Clare (1997), Romer (1994)).² Leaving out variety growth can make a large difference: Klenow and Rodriguez-Clare (1997) estimate, for instance, that the welfare gains from trade liberalization are 50% larger when the impact of variety is taken into account.

This paper shows that when the Melitz-model's restriction to one variety per firm is relaxed, its anti-variety effect is reversed. Variety unambiguously rises when trade is liberalized.

¹Klenow and Rodriguez-Clare (1997) estimate, for instance, that a 1% reduction in tariffs leads to a 0.5% increase in variety. Other contributions in the empirical literature on the effect of trade on consumer variety include Chen (2006), Broda and Weinstein (2004) and Funke and Ruhwedel (2003). Case studies, which focus on variety in the car market, include Clerides (2005), Tovar (2004) and Fersthman and Gandal (1998).

²Richardson (1989) provides a survey of earlier calibrations, primarily based on the Krugman-model.

It then becomes the first model capable of explaining both stylized facts of trade liberalization: firm selection and variety growth. The underlying mechanism is simple. Economies of scope come about naturally, as fixed costs can be spread over varieties. Optimal variety is bounded, on the other hand, by the assumption that varieties of a single firm are closer substitutes than varieties of different firms. Hence, additional varieties cannibalize on the demand for the firm's existing line. The most efficient firms, which self-select into export, then also offer the most variety. Upon trade liberalization, entry by variety-rich exporters more than compensates for the drop in the total number of firms. Firm heterogeneity in productivity is now the driving force behind both firm selection and the rise in variety.

The welfare implications of variety growth are more intricate than in previous models, however. Consumers value more variety, but they also value being able to buy from different firms. We prove that parameterizations exist for which the increase in total variety is not sufficient to compensate for the decline in the number of firms.

Our work relates to that of Bernard et al. (2006) and Nocke and Yeaple (2006) on multiproduct firms in trade. The latter develop a model with firms that differ in organizational capability, while overall productivity declines in the number of product categories that firms choose to be active in. The model explains why larger firms have lower market-to-book values. In Bernard et al. firms are heterogeneous in both managerial ability and expertise in each product category. Trade liberalization results in higher average productivity due to both market selection between firms and product selection within firms. Neither study is concerned with the variety effect of trade liberalization, however.

The next section presents the model. Section 3 computes the equilibrium solution, from which section 4 derives results on variety growth. Finally, section 5 considers the welfare implications.

2 Model

We first describe demand and then the decision problem that firms face. At the end of the section we demonstrate how the presented model nests the model of Melitz (2003).

2.1 Demand

Preferences are given by a nested CES, in which the domestic representative consumer optimizes over three stages. In the first stage, the consumer optimally allocates expenditure, E , between the quantity index of a differentiated good q (defined below), and an outside composite good, z , which is used as a numeraire. We assume that the numeraire good is produced with identical constant returns to scale technology everywhere and is freely traded. This is a common assumption (Helpman et al. 2004), which brings about international wage equalization. First-stage utility is given by:

$$U = z^\eta q^{1-\eta} \quad (1)$$

with $\eta \in (0, 1)$. By optimization, the consumer spends $y = (1 - \eta) E$ on q , so that we can write the consumer's budget constraint for the differentiated good as

$$y = pq \quad (2)$$

where p is the price index associated with the differentiated good. Second and third stage utility are given by

$$q = \left(\int_{i=0}^n q_i^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}} \quad (3)$$

and

$$q_i = \left(\int_{k=0}^{h_i} q_{ik}^{\frac{\sigma-1}{\sigma}} dk \right)^{\frac{\sigma}{\sigma-1}} \quad (4)$$

where q_{ik} is the demand for each variety k of a given firm i , which produces a number (=mass) h_i of varieties. Then, q_i is the quantity index associated with the sales of a given firm, while n is the number of firms. Importantly, σ is the elasticity of substitution between different varieties of a given firm and θ is the inter-firm elasticity of substitution. We assume that $\sigma > \theta > 1$.

It is well-known that minimizing expenditure subject to the CES aggregator gives the solution for the welfare-based price indices (see Allanson and Montagna (2005) and Obstfeld and Rogoff (1996, pp. 227-228)):

$$p = \left(\int_{i=0}^n p_i^{1-\theta} di \right)^{\frac{1}{1-\theta}} \quad (5)$$

and

$$p_i = \left(\int_{k=0}^{h_i} p_{ik}^{1-\sigma} dk \right)^{\frac{1}{1-\sigma}} \quad (6)$$

and that final demand for varieties can then be expressed as

$$q_{ik} = \left(\frac{p_i}{p} \right)^{-\theta} \left(\frac{p_{ik}}{p_i} \right)^{-\sigma} q \quad (7)$$

2.2 Firms

The firm's problem consists of an entry stage and subsequently, for as many periods as it stays active, sales decisions. To start operating firms have to pay a one-time cost F_e , which entails, among other things, plant setup, initial market research and setting up a distribution network. Only after incurring this cost, firms discover their productivity. Firms draw their productivity, φ , from a time-invariant distribution, $g(\varphi)$. This is an essential building block of the Melitz (2003) model, based on empirical evidence that firms differ widely in their productivities, even within narrowly defined industries.³

Once firms know their productivity, they must decide whether to produce or exit. Those

³See the surveys of Greenaway and Kneller (2007) and Tybout (2003).

who stay set their prices and variety offering. Each period active firms face an exogenous probability, δ , of being hit by a death shock. The industry dynamics of the Melitz-model are essentially a simplified version of Hopenhayn's (1992) work on endogenous entry, exit, and long-run stationary equilibria.

Being active on the domestic market brings about the following costs each period:

$$C_i(\varphi) = a + (b + f_h) h_i + \int_{k=0}^{h_i} \frac{w}{\varphi} q_{ik} dk \quad (8)$$

where a and b are firm-wide and variety-specific fixed costs, respectively. These represent, for instance, advertisement, management time and maintenance of the distribution network. They are the fixed costs required to maintain activity on the domestic market. Both are necessary elements of the model: a generates increasing returns to scale, while a positive b , in conjunction with $\sigma > \theta$, keeps optimal variety bounded. That is, the marginal benefit of variety is decreasing due to $\sigma > \theta$, while its marginal cost is constant and positive.

Distinct from these is f_h , which is the cost of creating a new variety. Once we introduce exports, it will be clear why these must be kept distinct. In fact, it costs F_h to set up a new variety. But firms are indifferent between paying this F_h up front, or paying the amortized fixed cost $\delta F_h = f_h$ each period.⁴ The last term in the equation captures the variable costs of production. Marginal costs are inversely proportional to the productivity parameter, φ , and w is the wage. We normalize $w = 1$.

Simultaneously with its domestic sales decision a firm also chooses whether to become an exporter, how many of its varieties to export, and which prices to charge abroad. Yet, in order to export, firms face an additional hurdle. As in Melitz (2003), they must pay a so-called beachhead cost, f_x , associated to setting up a new trade line.⁵ For simplicity, we let the fixed costs of maintaining activity on a market, a and b , be the same in the domestic and foreign markets. The model's outcomes are not sensitive to larger costs abroad, however. To

⁴See the discussion in Melitz (2003, p.1708) on rewriting fixed costs to per-period notation.

⁵Tybout (2003) discusses the empirical relevance of these fixed costs to commence export.

export a good, furthermore, a firm pays tariff and transport costs $\tau > 1$ per shipped unit.

The firm's per period profit function becomes:

$$\pi_i(\varphi) = \int_{k=0}^{h_i} \left(p_{ik} - \frac{1}{\varphi} \right) q_{ik} dk - a - (b + f_h) h_i + \max \left\{ 0, \int_{k=0}^{h_i^X} \left(p_{ik}^X - \frac{\tau}{\varphi} \right) q_{ik}^X dk - (a + f_x) - b h_i^X \right\} \quad (9)$$

where the second term in the max operator represents the profits from exporting. If these are smaller than zero, the firm will not export. The terms h_i^X , p_{ik}^X and q_{ik}^X stand for, respectively, the number of varieties exported, the price of variety k charged in the foreign market and the quantity of variety k sold abroad. Countries are identical and the trading cost τ is the same to each destination.⁶ In the above equation, it is implicit that firms do not develop new varieties only for export. That is, $h_i \geq h_i^X$, and firms export a subset of their domestic varieties. Equation (13) below states the required parameter restriction for this to hold. This condition is necessary for an interior solution.

The first stage decision of the firm can now be summarized by a free-entry condition:

$$E [\max \{[\pi_i(\varphi)], 0\}] \geq f_e \quad (10)$$

where we have rewritten $\delta F_e = f_e$. Firms will enter as long as the expected net present value of positive future profits covers the entry cost. After having drawn φ , moreover, firms have a cutoff productivity level, $\hat{\varphi}$, for which they are indifferent between continuing and ceasing production:

$$\pi_i(\hat{\varphi}) = 0 \quad (11)$$

Similarly, the model contains a cutoff productivity for exporting, $\hat{\varphi}^X$, which is the productivity draw for which a firm is indifferent between exporting and not exporting.

$$\int_{k=0}^{h_i^X} \left(p_{ik}^X - \frac{\tau}{\hat{\varphi}^X} \right) q_{ik}^X dk - (a + f_x) - b h_i^X = 0 \quad (12)$$

⁶It then makes no difference whether the model is termed a 2-country or a multi-country model: if a firm exports to any destination it exports to all.

As in Melitz (2003), however, we require a condition that ensures $\widehat{\varphi}^X \geq \widehat{\varphi}$:

$$\frac{b(\tau^{\theta-1} - 1)}{f_h} \geq 1 \quad (13)$$

After all, the fact that only the most productive fraction of active firms become exporters is the driving force of firm selection. The above condition is also necessary and sufficient for $h_i \geq h_i^X$. This is verifiable in the next section.

Finally, if we set $\sigma = \theta$ and fix $h_i = h_i^X = 1$ we obtain a model with heterogeneous, single-variety firms that is equivalent to Melitz's. An alternative way to put it is that in the standard Melitz-model $f_h = 0$ for $h_i \in [0, 1]$ and $f_h \rightarrow \infty$ for $h_i > 1$: the R&D cost function is discontinuous at one variety. In addition, the model presented above nests the contribution of Allanson and Montagna (2005), who develop a closed-economy model of homogeneous, multi-variety firms. Their model is obtained by fixing $\varphi = \bar{\varphi}$ for all firms and taking away firms' possibility to export.

3 Equilibrium

In this section we compute a closed-form equilibrium solution for the Pareto distribution. This distribution is central in applied work on heterogeneous firms (Helpman et al. (2004), Chaney (2006)), while the standard Melitz-model unambiguously fails to match variety growth when it is applied (Baldwin and Forslid, 2006).

To solve for the price setting of the firms, we replace q_{ik} from equation (7) into equation (9) and set $\frac{\partial \pi_i(\varphi)}{\partial p_{ik}} = 0$. Likewise, noting that $q_{ik}^X = \left(\frac{p_i^X}{p}\right)^{-\theta} \left(\frac{p_{ik}^X}{p_i^X}\right)^{-\sigma} q$ - where p_i^X is the price index of domestic consumers' purchases from a foreign firm - we set $\frac{\partial \pi_i(\varphi)}{\partial p_{ik}^X} = 0$ to obtain prices charged by exporters. Subsequently, $\frac{\partial \pi_i(\varphi)}{\partial h_i} = 0$ and $\frac{\partial \pi_i(\varphi)}{\partial h_i^X} = 0$ give us equations for h_i and h_i^X . Replacing terms, equations (11) and (12) provide solutions for the cutoff productivity levels for activity on the domestic and foreign markets, $\widehat{\varphi}$ and $\widehat{\varphi}^X$.

To solve for the firms' free-entry condition in equation (10), we rewrite the max operators

in the profit function to probabilistic terms. That is, with the probability that $\varphi \geq \widehat{\varphi}$ the firm will remain active in the domestic market after discovering its productivity. This probability is simply $\int_{\widehat{\varphi}}^{\infty} g(\varphi) d\varphi$. Similarly, before entering the market, the firm has a chance of $\int_{\widehat{\varphi}^X}^{\infty} g(\varphi) d\varphi$ of becoming an exporter. Finally, we rewrite the aggregate price level from equation (5) to

$$p = \frac{\sigma}{\sigma - 1} \left(n \int_{\widehat{\varphi}}^{\infty} \varphi^{\theta-1} (h_i)^{\frac{\theta-1}{\sigma-1}} g(\varphi | \varphi \geq \widehat{\varphi}) d\varphi + n^X \int_{\widehat{\varphi}^X}^{\infty} \left(\frac{\varphi}{\tau}\right)^{\theta-1} (h_i^X)^{\frac{\theta-1}{\sigma-1}} g(\varphi | \varphi \geq \widehat{\varphi}^X) d\varphi \right)^{\frac{1}{1-\theta}} \quad (14)$$

where $g(\varphi | \varphi \geq \widehat{\varphi})$ is the conditional distribution of φ . That is, the distribution of productivities among only active firms. While $g(\varphi | \varphi \geq \widehat{\varphi}^X)$ is that distribution among exporters. Furthermore, n^X is the number of foreign firms from which domestic consumers purchase. By the symmetry of countries this is equal to the number of domestic exporters. Formally,

$$n^X = n \frac{\int_{\widehat{\varphi}^X}^{\infty} g(\varphi) d\varphi}{\int_{\widehat{\varphi}}^{\infty} g(\varphi) d\varphi} \quad (15)$$

This gives us enough to solve the free-entry condition and obtain an equation for n . For the Pareto distribution, the probability density function takes the form

$$g(\varphi) = c d^c \varphi^{-c-1} \quad (16)$$

where $g(\varphi)$ has support on $[d, \infty)$, and c is the parameter that measures heterogeneity. A smaller c implies a wider distribution and, thus, a more heterogeneous population of firms. As is common in the literature, we normalize $d = 1$. Moreover, as in Helpman et al. (2004) and Chaney (2006), we require a parameter restriction

$$c > \max \left\{ 2, \frac{(\sigma - 1)(\theta - 1)}{\sigma - \theta} \right\} \quad (17)$$

to ensure finite variance of the distribution of productivity draws $g(\varphi)$ and the conditional

productivity distribution of active firms $g(\varphi \mid \varphi \geq \widehat{\varphi})$. If this condition is violated, productivity cutoffs are indeterminate. Implementing the Pareto distribution and solving algebraically, gives us the closed-form solution:

$$\begin{aligned}
q &= \frac{y}{p} \\
p &= \frac{1}{\widehat{\varphi}} \frac{\sigma}{\sigma-1} \left[\frac{\sigma(\sigma-1)}{y} \right]^{\frac{1}{\theta-1}} \left[\frac{b+f_h}{\theta-1} \right]^{\frac{1}{\sigma-1}} \left[\frac{a}{\sigma-\theta} \right]^{\frac{\sigma-\theta}{(\theta-1)(\sigma-1)}} \\
\widehat{\varphi} &= \left[\frac{a}{f_e} \frac{(\theta-1)(\sigma-1)}{(\sigma-\theta)c - (\sigma-1)(\theta-1)} \left(1 + \frac{1 + \frac{f_x}{a}}{\Psi(\tau)} \right) \right]^{\frac{1}{c}} \\
\widehat{\varphi}^X &= \left[\frac{a}{f_e} \frac{(\theta-1)(\sigma-1)}{(\sigma-\theta)c - (\sigma-1)(\theta-1)} \left(1 + \frac{f_x}{a} + \Psi(\tau) \right) \right]^{\frac{1}{c}} \\
n &= \frac{y(\sigma-\theta)c - (\sigma-1)(\theta-1)}{a} \frac{\Psi(\tau)}{\sigma(\sigma-1)c} \frac{1}{1 + \frac{f_x}{a} + \Psi(\tau)} \\
n^X &= \frac{y(\sigma-\theta)c - (\sigma-1)(\theta-1)}{a} \frac{1}{\sigma(\sigma-1)c} \frac{1}{1 + \frac{f_x}{a} + \Psi(\tau)}
\end{aligned}$$

where we have defined

$$\Psi(\tau) = \left(\tau \left[\frac{b}{b+f_h} \right]^{\frac{1}{\sigma-1}} \left[\frac{a+f_x}{a} \right]^{\frac{\sigma-\theta}{(\theta-1)(\sigma-1)}} \right)^c \quad (18)$$

to make things visually easier to absorb. Moreover, for a given firm with productivity draw φ we also have the following equations governing price setting and the optimal scope at home and abroad:

$$p_{ik} = \frac{\sigma}{\sigma-1} \frac{1}{\varphi} \quad (19)$$

$$p_{ik}^X = \frac{\sigma}{\sigma-1} \frac{\tau}{\varphi} \quad (20)$$

$$h_i = \frac{\theta-1}{\sigma-\theta} \frac{a}{b+f_h} \left(\frac{\varphi}{\widehat{\varphi}} \right)^{\frac{(\sigma-1)(\theta-1)}{\sigma-\theta}} \quad (21)$$

$$h_i^X = \left[\frac{b+f_h}{b} \right]^{\frac{\sigma-1}{\sigma-\theta}} \frac{\theta-1}{\sigma-\theta} \frac{a}{b+f_h} \left(\frac{1}{\tau} \frac{\varphi}{\widehat{\varphi}} \right)^{\frac{(\sigma-1)(\theta-1)}{\sigma-\theta}} \quad (22)$$

It is interesting to observe here that the inter-firm elasticity of substitution, θ , does not affect

price setting. Rather, firms set markups purely according to their intra-firm elasticity, σ , and adjust for θ completely along the variety margin.

4 Matching variety growth

We can now obtain a closed-form expression for the total variety available to domestic consumers, $H = n \int_{\hat{\varphi}}^{\infty} h_i g(\varphi \mid \varphi \geq \hat{\varphi}) d\varphi + n^X \int_{\hat{\varphi}^X}^{\infty} h_i^X g(\varphi \mid \varphi \geq \hat{\varphi}^X) d\varphi$:

$$H = \frac{y(\theta-1)}{\sigma(\sigma-1)} \frac{1}{b} \frac{1 + \frac{f_x}{a} + \left[\frac{b}{b+f_h} \right] \Psi(\tau)}{1 + \frac{f_x}{a} + \Psi(\tau)} \quad (23)$$

Taking the derivative of this expression towards tariffs and replacing $\Psi'(\tau) = \frac{c}{\tau} \Psi(\tau)$ yields

$$\frac{\partial H}{\partial \tau} = -\frac{c y}{\tau \sigma} \frac{1}{b+f_h} \frac{(\theta-1)}{(\sigma-1)} \frac{a+f_x}{a} \frac{f_h}{b} \frac{\Psi(\tau)}{\left[1 + \frac{f_x}{a} + \Psi(\tau)\right]^2} < 0 \quad (24)$$

from which:

Proposition 1 *Total variety available to domestic consumers unambiguously rises when trade is liberalized: $\frac{\partial H}{\partial \tau} < 0$.*

On the one hand, the total number of firms that domestic consumers can purchase from decreases in liberalization. This can be seen from.

$$N = n + n^X = \frac{y(\sigma-\theta)c - (\sigma-1)(\theta-1)}{\sigma(\sigma-1)c} \frac{1}{a} \left[\frac{1 + \Psi(\tau)}{1 + \frac{f_x}{a} + \Psi(\tau)} \right] \quad (25)$$

and

$$\frac{\partial N}{\partial \tau} = \frac{f_x y(\sigma-\theta)c - (\sigma-1)(\theta-1)}{\tau \sigma(\sigma-1)c} \frac{1}{a^2} \frac{\Psi(\tau)}{\left[1 + \frac{f_x}{a} + \Psi(\tau)\right]^2} > 0 \quad (26)$$

On the other hand, efficient foreign entrants offer more variety than the domestic firms that exit: $[h_i^X \mid \varphi = \hat{\varphi}^X] > [h_i \mid \varphi = \hat{\varphi}]$ by equations (21) and (22). This unambiguously dominates the decrease in the number of firms. In this manner firm heterogeneity drives both firm selection and variety growth.

5 Welfare implications

The question remains, however, whether the increase in variety from liberalization always implies higher welfare. After all, by $\sigma > \theta$ consumers care about how many firms they can buy from. We ask, therefore, whether the increase in variety is sufficient to compensate for the loss of firms.⁷

Proposition 2 *There exist parameterizations for which the increase in variety from trade liberalization implies higher welfare. There also exist parameterizations for which it implies lower welfare.*

Proof. It suffices to consider the cases $f_x \rightarrow 0$ and $f_h \rightarrow 0$ (neither of which violates the condition in equation (13)). When entry costs to export vanish, $f_x \rightarrow 0$, all firms export at least some varieties and liberalization ceases to affect the number of firms: $N \rightarrow \frac{y}{\sigma} \frac{(\sigma-\theta)c - (\sigma-1)(\theta-1)}{(\sigma-1)c} \frac{1}{a}$ and $\frac{\partial N}{\partial \tau} \rightarrow 0$ from equations (25) and (26). But by equation (24) $\frac{\partial H}{\partial \tau}$ does not go to zero, since exporters expand their variety offering when tariffs are lower, $\frac{\partial h_i^X}{\partial \tau} < 0$ (equation (22)). More variety with the same number of firms implies an unambiguous welfare gain. Conversely, for $f_h \rightarrow 0$ economies of scope from exporting domestically developed varieties vanish, and $H \rightarrow \frac{y}{\sigma} \frac{(\theta-1)}{(\sigma-1)} \frac{1}{b}$ so that $\frac{\partial H}{\partial \tau} \rightarrow 0$. At the same time, $\frac{\partial N}{\partial \tau}$ does not go to zero. The same amount of variety from fewer firms implies an unambiguous welfare loss. ■

Thus, though the adjusted Melitz-model is the first model capable of matching both firm selection and variety growth, its welfare implications for variety are more intricate than in the previous literature.

⁷Even when the variety effect is negative in welfare terms, however, the gains from firm selection more than compensate. From our closed-form solution it is apparent that $\frac{\partial q}{\partial \tau} < 0$ and total welfare unambiguously increases in liberalization.

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