Technology Upgrading, Exporting and Heterogeneous Firms*

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Abstract

Empirical evidence shows that R&D spending is highly correlated with firm productivity, highly concentrated among large firms, and responsive to trade liberalization. This paper develops a model of product upgrading with heterogeneous firms that captures these characteristics by allowing firms to choose their optimal level of fixed cost spending from a continuum. The endogenous component of fixed costs is assumed to represent R&D or product development that is spent once but reaps demand benefits over all the markets the firm serves. This mechanism encourages firms to export and capture economies of scale in fixed cost spending. The model makes two new predictions. The first prediction is that exporters upgrade while domestic firms cut costs when trade liberalizes. The second prediction is that the selection effect of trade liberalization is weaker in industries characterized by intense upgrading competition between firms.

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1 Introduction

How does technology respond to trade liberalization? Recent empirical research using firm-level data in several countries shows that firms respond to trade liberalization by upgrading technology and investing more in R&D. These studies suggest that these responses are an important aspect of trade liberalization.

This paper derives new predictions about the effect of trade liberalization on technology upgrading in a framework of heterogeneous firms. The model predicts that upgrading by exporters and domestic firms respond differently to trade liberalization, namely that exporters respond to trade liberalization by increasing spending on technology upgrading, while domestic firms respond by cutting costs. A new and somewhat surprising prediction is that the addition of technology upgrading to the Melitz (2003) model does not amplify the selection effect of trade liberalization, but rather reduces its importance.

The model in this paper is motivated by several recent firm-level empirical studies showing a link between exporting and technology investment decisions. Aw, Roberts, and Winston (2007) and Aw, Roberts, and Xu (2008) show that there is a link between the firms’ choice of R&D investment and export market participation using firm-level data from the Taiwanese electronics industry. Lileeva and Treffler (2010) show that Canadian firms that begin exporting due to lower tariffs with the U.S. also make investments in productivity-enhancing technology. Bustos (2010) shows that trade liberalization led Argentinian exporting firms to increase their investments in technology. Teshima (2009) shows that the reduction in tariffs due to the North American Free Trade Agreement on goods produced in Mexican plants induced those plants to increase their total R&D spending.

Firm-level data suggests that firms’ fixed cost spending is heterogeneous and
highly correlated with firm size and firm productivity. To use R&D as an example of fixed cost spending, Cohen and Klepper (1992) report that the correlation coefficient between business-unit sales and R&D spending is 0.78, while Griliches (1998) concludes that there is a high degree of correlation between firm productivity and the level of R&D expenditures. Evidence also suggests that R&D is highly concentrated among very few firms. Survey data from OECD countries suggests that most business R&D is performed by a small number of large firms (OECD 2008).

The theoretical model captures this empirical evidence by assuming that a firm’s capital, non-production workers, R&D spending and the like are embodied in the fixed cost component of firms’ increasing-returns-to-scale technology. This assumption is consistent with the fact that firms’ spending on these costs often considered as fixed and sunk.

This paper describes a particular mechanism of non-price competition in the spirit of Sutton (1991) and Schmalensee (1992) whereby firms compete with each other in a monopolistically competitive environment not only on prices but also on product "quality". An increase in quality shifts out the demand for a firm’s product. The catch is that a firm must pay a larger fixed production cost in order to upgrade its product’s quality and shift out its demand curve, with decreasing returns to fixed cost spending. These costs represent product development or R&D, which provide benefits for all markets the firm serves. Firms with higher productivity are willing to spend more on the fixed cost since their marginal benefit from spending on the fixed cost is greater. Moreover, exporters receive additional revenue in the export market from fixed cost spending compared to domestic firms since higher fixed cost spending increases foreign demand as well. I refer to this mechanism of non-price competition as "upgrading competition" throughout the rest of the paper.

Non-price competition via fixed cost spending is plausible for a variety of in-
dustries, especially those where technology upgrading is associated with fixed costs instead of higher-quality materials. This paper thus examines a different set of circumstances than the Quality-Melitz literature by Baldwin and Harrigan (2009) and others, whereby firms invest in better quality materials in order to increase the price of their product. Firms choose their optimal level of upgrading from a continuum of possibilities, leading to a rich set of predictions. The model closely follows the Melitz (2003) model of trade with heterogeneous firms and is directly comparable to the standard Melitz outcome.

A main prediction of the model is that the distribution of endogenous fixed cost spending is highly concentrated in the largest, most productive firms. It turns out that the more responsive demand is to fixed cost spending, the "tougher" the domestic and export productivity cutoffs are. In addition, upgrading competition has the same effect as trade liberalization in the sense that the domestic and export cutoffs converge, so a higher proportion of surviving firms choose to export. The intuition is that the positive effect of quality improvements on foreign demand make exporting more attractive to surviving firms. While upgrading competition weeds out the low-quality firms and raises aggregate productivity, it also leads to less variety. The net effect of upgrading competition on consumer welfare is positive, however, with the quality effect outweighing the anti-variety effect.

This paper is related a growing literature of theoretical models that explore the consequences of trade-induced upgrading. Bustos (2010), Bas (2008), Navas and Sala (2007) and Antoniades (2008) develop models whereby firms are heterogeneous with respect to their productivity and self-select not only into exporting but also into investing in productivity-enhancing technology.\(^1\) The main difference between my

\(^1\)My model focuses on the effect of trade liberalization in the output market, in contrast to Bas and Ledezma (2008), who examine the effect of trade liberalization on imported capital goods on technology upgrading. There has also been recent work by Costantini and Melitz (2007) and
paper and the work by other authors is that my model also predicts that domestic firms respond to trade liberalization by downgrading. In contrast, these other papers assume that only exporters make decisions about technology upgrading. The prediction that domestic firms reduce their fixed cost spending as a response to tougher market conditions when trade liberalizes may help to explain the finding by Tybout (2003) that domestic firms respond to trade liberalization by simultaneously reducing output and increasing efficiency. Tybout’s finding may be explained by the downgrading prediction in this model, since firms may respond to trade liberalization by becoming "leaner and meaner" and reducing their costs.

Another main difference between my paper and the work by other authors is that I assume that upgrading shifts out the demand for a firm’s product. In contrast, Bustos (2010) and others assume that upgrading reduces the marginal cost of production. I show that the only difference between these two approaches is the their prediction for prices. My demand-shift approach predicts that a firm’s price is unaffected by upgrading whereas the supply-shift approach predicts that upgrading leads to a lower price.

The prediction that the selection effect of trade liberalization is weak in industries where technology upgrading is important (R&D intense industries, for example) is a new prediction in this literature. The intuition behind this result is that technology upgrading as modeled in this paper results in upgrading competition between firms that weeds out low-productivity firms. This leaves fewer low-productivity firms left to be weeded out by trade liberalization.

The paper is organized as follows. The model in autarky and with trade frictions is provided in sections 2 and 3 respectively. Testable implications follow in section 4, Atkeson and Burstein (2010) that incorporate firm-level upgrading into growth models. These papers investigate the transitional dynamics of trade liberalization and the effect of trade liberalization on variety growth.
and conclusions are drawn in section 5.

2 The Autarky Model

2.1 Set-up

There are two industries: a manufacturing industry $M$ characterized by increasing returns to scale and homogeneous goods industry $A$ characterized by constant returns to scale. One unit of labor is required to produce a unit of the homogeneous good. The homogeneous good is chosen as the numeraire, and assuming free movement of labor between sectors sets the wage equal to unity.

Consumer utility is assumed to be Cobb-Douglas between industries and CES within the manufacturing industry. In the same vein as the earlier work on endogenous sunk costs, starting with Sutton (1991), as well as the more recent quality-Melitz literature, an extra firm-specific quality parameter enters the utility function for manufactures. This parameter, $q_i$, can be influenced by firms’ fixed cost spending in a manner that will be described in the next section. The utility function is specified as:

$$U = C_M^\mu C_A^{1-\mu}, \quad C_M = \left( \int q_i^{\frac{1}{\sigma}} c_i^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$$

where $\mu \in (0, 1)$, $C_A$ is the consumption of the homogeneous good, $C_M$ is the index of consumption for manufactures, $c_i$ is the consumption of manufacturing variety $i$ and $\sigma > 1$ is the elasticity of substitution. Utility is thus increasing and concave in both $q_i$ and $c_i$. Each consumer spends a share $\mu$ on manufactures, and demand for variety $i$ is thus:

$$x_i = \frac{p_i^{-\sigma} q_i}{p_1^{-\sigma} L} \mu L$$
where \( p_i \) is the price of variety \( i \), \( L \) is the number of consumers and \( P \) is the price index, which can be expressed as:

\[
P = \left( \int_{i=0}^{N} p_i^{1-\sigma} q_i \, di \right)^{\frac{1}{1-\sigma}}.
\]

A larger \( q_i \) increases the total quantity demanded of variety \( i \). Labor is the only input to the production process, and costs are composed of a firm-specific marginal labor cost, \( a_i \), an endogenous, firm-specific fixed cost, \( f_i \), and an exogenous beachhead cost, \( F_D \). Since wages are normalized to unity we can write the post-entry cost function for firm \( i \) as:

\[
l_i = x_i a_i + f_i + F_D.
\]

Firms set prices equal to marginal cost multiplied by the CES markup:

\[
p_i = \frac{\sigma}{\sigma - 1} a_i.
\]

### 2.2 Cutoff Conditions

Firm productivity is heterogeneous in this model, following Melitz (2003). Firms’ marginal cost parameter \( a \) is randomly drawn from a continuous probability distribution \( G(a) \) when they are born. All firms face a probability \( \delta \) in each period that they are forced to exit. Dropping the \( i \) subscripts henceforth, the post-entry profit for any firm is:

\[
\pi = \frac{px}{\sigma} - f - F_D
\]

\[
= qa^{1-\sigma} B - f - F_D
\]  

(1)
where

\[
B = \left( \frac{\sigma}{\sigma - 1} \right)^{1-\sigma} \frac{\mu L}{\sigma \delta P^{1-\sigma}}
\]

is a measure of per-firm demand that is independent of firms’ marginal production cost or quality.

The survival cutoff in autarky, \( a_{aut}^{a} \), is defined as the marginal cost of the firm whose operating profits equal fixed costs:

\[
q \left( a_{aut}^{a} \right) \left( a_{aut}^{a} \right)^{1-\sigma} B = f \left( a_{aut}^{a} \right) + F_D
\]

where \( f \left( a_{aut}^{a} \right) \) is the cutoff firm-specific fixed cost and \( F_D \) is the exogenous fixed "beachhead" cost to serve the domestic market.

### 2.3 Endogenous Sunk Costs

This model departs from the standard Melitz formulation by assuming that firm-specific fixed costs, \( f \), influence firm-specific quality, \( q \). This assumption closely follows the seminal work of Sutton (1991) on endogenous sunk costs in the Industrial Organization literature. This assumption is consistent with fixed cost spending that enhances the attractiveness of a product to a consumer, such as product development, R&D, or advertising expenditures that are not country-specific. This formulation is essentially a heterogeneous-firm version of the Schmalensee (1992) model of endogenous sunk costs.

Firms choose their optimal fixed cost spending by equating the marginal revenue of increasing \( q \) with its associated marginal cost. A firm’s optimal choice of \( q \) is the
solution to the following profit maximization problem:

\[ \max_q \pi = qa^{1-\sigma} B - f(q) - F_D. \]

A firm’s optimal technology upgrading choice can be characterized by the following first order condition:

\[ \frac{\partial f(q)}{\partial q} = a^{1-\sigma} B. \quad (3) \]

As long as \( \partial^2 f / \partial q^2 > 0 \), a lower marginal cost draw leads to higher marginal revenue from an increase in \( q \), which means a higher equilibrium \( q \).

At this point it is useful to make an assumption about the cost of technology upgrading. I assume a functional form with increasing and convex costs:

\[ f(q) = q^{\frac{1}{\theta}}, \quad \theta \in [0, 1] \quad (4) \]

where \( \theta \) is a parameter common to all firms that determines the convexity of the cost to upgrade. The larger is \( \theta \), the easier it is for firms to affect consumer demand by spending more on fixed costs. I henceforth refer to differences in \( \theta \) as differences in "upgrading intensity" throughout the rest of the paper. It turns out that \( \theta \) equals the equilibrium industry ratio of fixed cost spending to output.

**2.4 Equilibrium Product Upgrading**

One can solve for each firm’s equilibrium quality and its associated fixed cost by combining (2), (3) and (4):

\[ q(a) = \left( \frac{\theta}{1-\theta} F_D \right)^\theta \left( \frac{a}{a^{aut}_D} \right)^{\frac{\theta}{1-\sigma} (1-\sigma)}, \quad \forall a \in (0, a^{aut}_D], \quad (5) \]
\[ f(a) = \frac{\theta}{1 - \theta} F_D \left( \frac{a}{a_{aut}^D} \right)^{\frac{1-\sigma}{\sigma}}, \forall a \in (0, a_{aut}^D]. \] (6)

Inspection of (5) and (6) reveals that a firm’s equilibrium quality and fixed cost spending is increasing in its own productivity, \( a^{-1} \), since a firm with higher productivity has a higher marginal revenue from technology upgrading. However, quality and fixed cost spending is also decreasing in the productivity of the cutoff firm, \((a_{aut}^D)^{-1}\), since a tougher cutoff leads to a lower price index, which reduces all firms’ marginal revenue from technology upgrading. Fixed cost spending is increasing in \( \theta \). Inspection of both (5) and (6) reveals that fixed cost spending for the cutoff firm \((a = a_{aut}^D)\) is independent of the marginal cost draw, and only depends on the exogenous beachhead cost, \(F_D\), and the intensity of upgrading. Note that the expressions above assume no particular probability distribution for the firms’ marginal cost draws.

2.5 Free Entry Condition

Firms must pay a fixed cost \(F_E\) to enter the market prior to finding out their respective marginal production costs. Firms enter until the expected profit from entry equals zero:

\[ E(\pi - F_E) = 0 \]

\[ \iff F_E = \int_0^{a_{aut}^D} [qa^{1-\sigma}B - f(a) - F_D] g(a) \, da. \] (7)

Substituting (5) and (6) into (7), assuming a Pareto distribution, \(G(a) = a^k\) for firm marginal costs, where \(k\) is the shape parameter, and integrating over all surviving firms provides an analytical solution for the cutoff firm marginal cost in autarky:

\[ (a_{aut}^D)^k = \frac{F_E \left[\beta (1 - \theta) - 1\right]}{F_D} \] (8)
where $\beta \equiv k (\sigma - 1)^{-1}$. Note in (8) that $\partial (a^\text{aut}_D)^k / \partial \theta < 0$, so more intense technology upgrading (larger $\theta$) makes the cutoff "tougher". The solution for the Melitz model without upgrading competition, such as Helpman, Melitz, and Yeaple (2004) and Baldwin and Forslid (2010), is obtained when $\theta = 0$. Non-price competition thus disappears when technology upgrading becomes prohibitively expensive. One must assume that $\beta > (1 - \theta)^{-1}$ in order to obtain a solution for the cutoff. Intuitively, if $\theta$ is too high (or $\beta$ is too low) then fixed cost spending becomes so large that the number of firms becomes zero. This can be seen in the expression for the equilibrium number of firms in autarky:

$$n^\text{aut} = \frac{\beta (1 - \theta) - 1}{\beta} \frac{\mu L}{F_D}. \quad (9)$$

One can see in (9) that $\partial n^\text{aut} / \partial \theta < 0$, so more intense technology upgrading (higher $\theta$) leads to fewer firms. This occurs because firms spend more on fixed costs and experience higher demand for their products, which pushes marginal, low productivity firms out of the market.

### 2.6 Frictionless Free Trade

The effect of free trade without trade frictions can be seen by simply increasing the market size, $L$, in the model presented above. One can see that an increase in market size leads to a proportional increase in the number of firms, but does not affect fixed cost spending or the marginal cost cutoffs. The increase in the number of firms lowers the price index and increases consumer welfare in the same way as previous models of trade with CES preferences.
2.7 Marginal Cost-Reducing Technology Upgrading

The model in this paper departs slightly from the other recent papers by assuming that fixed cost spending increases consumer demand for a good in the spirit of Sutton (1991). Other authors, such as Bustos (2010), assume that firms spend fixed costs in order to reduce their marginal cost of production. It can be shown, however, that the model I present here can easily be expressed as a model of marginal cost-reducing technology upgrading and many of the results remain the same. The result is summarized in the following proposition:

**Proposition 1** The model described by equations (1) - (8) can be attained in a model of marginal cost-reducing technology upgrading with the following assumptions for the utility function and costs:

\[
\bar{U} = \bar{C}_M \bar{C}_A^{1-\mu}, \quad \bar{C}_M = \left( \int_{i=0}^{\tilde{N}} \tilde{c}_i^{\frac{\sigma}{\sigma-1}} \, di \right)^{\frac{\sigma}{\sigma-1}}, \\
\bar{l}_i = \bar{x}_i \left( \tilde{q}_i^{\frac{1}{\sigma-1}} a_i \right) + \tilde{f}_i + F_D.
\]

**Proof.** The utility function and cost function given above yields the following expression for the demand for variety \(i\) and its price:

\[
\bar{x}_i = \frac{\tilde{p}_i^{-\sigma}}{P^{1-\sigma}} \mu L \\
\tilde{p}_i = \frac{\sigma}{\sigma-1} \left( \tilde{q}_i^{\frac{1}{\sigma-1}} a_i \right)
\]
where the price index can be expressed as:

\[ \tilde{P} = \left( \tilde{N} \int_{\tilde{p}_i}^{\tilde{p}_1} d\tilde{p}_i \right)^{\frac{1}{1-\sigma}}. \]

This formulation yields the following expression for post-entry profit:

\[ \tilde{\pi}_i = \tilde{q}_i \alpha_i^{1-\sigma} \tilde{B} - \tilde{f}_i - F_D \]

where

\[ \tilde{B} = \left( \frac{\sigma}{\sigma-1} \right)^{1-\sigma} \tilde{P}^{1-\sigma} \mu L \]

This expression for post-entry profit is identical to (1). It follows that the equilibrium fixed cost spending, quality and marginal cost cutoff in this case are identical to the expressions given in equations (2) - (8).

The only difference between these two cases is the implication for prices. Prices are unaffected by the model I present in equations (1) - (8), whereas technology upgrading that lowers the marginal cost of production would predict that upgrading lowers a firm’s price. The effect of upgrading on prices can thus be used to identify whether upgrading is occurring via a reduction in marginal cost or an outward shift of the demand curve.

### 3 Two Country Model with Trade Frictions

The autarky model can easily be extended to two countries with variable and fixed trade costs. Two new assumptions are necessary, however, to incorporate technology upgrading with international trade. The first assumption is that the fixed cost of
technology upgrading, \( f \), is not country-specific. The second assumption is that each firm’s quality parameter, \( q \), affects consumers symmetrically in all countries. These assumptions mean that a firm pays for technology upgrading only once and its benefits are spread over all of its markets. This contrasts with the fixed beachhead costs, which are country-specific. These assumptions are consistent with fixed costs such as R&D that are spent once and then provide benefits in every market that the firm serves.

Consumers have identical utility functions in both countries, dubbed \textit{Home} and \textit{Foreign}. Costless trade in the homogeneous goods industry sets the wage in both countries equal to unity. Variable trade costs are assumed to be of the "iceberg" form, so \( \tau > 1 \) units of a variety must be shipped in order for one unit to arrive in the other country. The probability distribution for marginal costs is the same for both countries. All variables that refer to \textit{Foreign} market are denoted with an asterisk.

### 3.1 Cutoff Conditions

The post-entry profits for a domestic firm and exporter situated in \textit{Home} are:

\[
\pi = qa^{1-\sigma}B - f - F_D,
\]

\[
\pi_X = qa^{1-\sigma}(B + \phi B^*) - f_x - F_D - F_X
\]

where \( \phi = \tau^{1-\sigma} \in [0, 1] \),

\[
B^* = \frac{\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}}{\sigma \delta P^* \mu L^*}
\]

and \( f_x \) is the exporter’s fixed cost spending and \( F_X \) is the exogenous fixed beachhead cost to serve the export market. The post-entry profits for domestic firms and
exporters situated in *Foreign* are:

\[ \pi^* = qa^{1-\sigma}B^* - f^* - F_D, \]

\[ \pi_X^* = qa^{1-\sigma} (B^* + \phi B) - f^*_x - F_D - F_X \]

where \( f^*_x \) is the exporter’s fixed cost spending.

Since an exporting firm at *Home* or *Foreign* spreads its technology upgrading costs, \( f \) and \( f^* \) respectively, over both markets, one cannot express the export cutoff marginal cost as a function of export profits alone. The export cutoff, \( a_X \) or \( a^*_X \), is defined as the marginal cost of the firm whose net profits from serving both markets equals the net profits from only serving the domestic market. The domestic and export cutoffs for *Home* and *Foreign* are:

\[ q (a_D) a_D^{1-\sigma} B = f (a_D) + F_D, \]  \hspace{1cm} (10)

\[ [q_x (a_X) - q (a_X)] a_X^{1-\sigma} B + [q_x (a_X)] a_X^{1-\sigma} \phi B^* = f_x (a_X) - f (a_X) + F_X, \] \hspace{1cm} (11)

\[ q^* (a^*_D) a_D^{*(1-\sigma)} B^* = f^* (a^*_D) + F_D, \] \hspace{1cm} (12)

\[ [q^*_x (a^*_X) - q^* (a^*_X)] a_X^{*1-\sigma} B^* + [q^*_x (a^*_X)] a_X^{*1-\sigma} \phi B = f^*_x (a^*_X) - f (a^*_X) + F_X. \] \hspace{1cm} (13)

Firms’ trade-off between exporting and remaining as a domestic firm can be seen by comparing (10) and (11) or (12) and (13). On the one hand an exporter gains operating profits from the export market and thus is induced to upgrade to a level \( q_x \) and \( q^*_x \) instead of \( q \) and \( q^* \). On the other hand, an exporter is induced to spend more on fixed costs ( \( f_x \) and \( f^*_x \) instead of \( f \) and \( f^* \)). The domestic and export cutoff conditions for *Home* are illustrated graphically in figure 1.

A parameter restriction is required to ensure that the marginal cost cutoff for
exporting is lower than the domestic firm cutoff, which is given later in the paper. In addition, the case where the firm serves the export market only can be ruled out by parameter restrictions discussed in the appendix. As in Helpman, Melitz, and Yeaple (2004), the free entry condition means that both countries share the same cutoffs \( a_D = a_D^* \), \( a_X = a_X^* \) and the same demand levels \( B = B^* \). This implies that both countries share the same cutoff fixed costs \( f(a_D) = f^*(a_D) \), \( f(a_X) = f^*(a_X) \), and quality levels \( q(a_D) = q^*(a_D) \), \( q(a_X) = q^*(a_X) \).

3.2 Endogenous Sunk Costs and the Decision to Export

As in the autarky model described earlier, firms each choose their quality and its associated fixed cost to maximize post-entry profits. This decision is made jointly with the decision to export or not. The firm thus compares the profits from exporting or not, given that they choose the optimal amount of technology upgrading in either case. The optimal spending on technology upgrading will differ between exporters and domestic firms, since exporters receive a demand response from both markets, which gives them a stronger incentive to invest in technology upgrading.

A domestic firm’s quality investment problem is identical to the autarky case, with the solution given by (3). The exporter problem differs from the domestic firm problem because it considers the additional operating profit in the export market when it chooses its optimal technology upgrading. An exporter solves the following problem:

\[
\max_{q_x} \left[ q_x a^{1-\sigma} B (1 + \phi) - f_x (q_x) - F_D - F_X \right]
\]

An exporting firm’s optimal decision is determined by the following first order condition:

\[
\frac{\partial f_x (q_x)}{\partial q_x} = a^{1-\sigma} B (1 + \phi)
\]
I assume the same functional form as the autarky model for the cost of technology upgrading:

\[ f(q) = q^{\frac{1}{3}}, \quad (15) \]

\[ f_x(q_x) = q_x^{\frac{1}{3}}. \quad (16) \]

### 3.3 Equilibrium Product Upgrading

Each domestic firm’s equilibrium quality and its associated fixed cost are found by combining (3), (10) and (15), which provides the same solutions as in the autarky model, (5) and (6). Each exporter’s equilibrium quality and its associated fixed cost are found by combining (5), (6), (10), (11), (12), (14) and (16):

\[ q_x(a) = \left( \frac{\theta}{1-\theta} F_X \Phi \right) \left( \frac{a}{a_X} \right)^{\frac{\theta}{1-\sigma}(1-\sigma)}, \quad \forall a \in (0, a_X] \quad (17) \]

\[ f_x(a) = \frac{\theta}{1-\theta} F_X \Phi \left( \frac{a}{a_X} \right)^{\frac{1-\sigma}{1-\theta}}, \quad \forall a \in (0, a_X] \quad (18) \]

where

\[ \Phi \equiv \frac{(1 + \phi)^{\frac{1}{3-\tau}}}{(1 + \phi)^{\frac{\theta}{3-\tau}} - 1}. \]

One can see in (17) and (18) that an exporter’s equilibrium quality and fixed cost spending is increasing in own productivity, \( a^{-1} \), since a firm with higher productivity has a higher marginal revenue from technology upgrading. However, exporter technology upgrading is decreasing in the productivity of the cutoff exporter, \( a_X^{-1} \).

The distribution of fixed cost spending by firms with different marginal costs is illustrated in figure 2. The curved lines represent the pattern of spending in the model described in this paper. The curve for marginal costs between \( a_D \) and \( a_X \) corresponds to equation (6), while the curve between \( a_X \) and \( a = 0 \) corresponds to equation (18).
The pattern of fixed costs spending predicted by Bustos (2010) is illustrated by the horizontal line, \( f_{\text{Bustos}} \). The pattern of fixed cost spending predicted by Antoniades (2008) is linear in marginal cost and upward sloping, denoted by \( f_{\text{Antoniades}} \). The advantage of the model in this paper is that it clearly captures the concentration of fixed cost spending in the high-productivity firms while not ruling out small amounts of fixed cost spending by other surviving firms. In contrast, only firms with marginal cost lower than \( a_h < a_X \) spend on technology upgrading in the models of Bustos (2010) and Antoniades (2008).

3.4 Free Entry Condition

Firms must pay a fixed cost \( F_E \) to enter the market prior to finding out their marginal cost. Firms enter until the expected profits from entry equal zero:

\[
E (\pi_i - F_E) = 0
\]

\[
\Leftrightarrow F_E = \int_{a_X}^{a_D} \left[ qa^{1-\sigma} B - f (a) - F_D \right] g (a) \, da
\]

\[
+ \int_0^{a_X} \left[ q_x a^{1-\sigma} B (1 + \phi) - f_x (a) - F_D - F_X \right] g (a) \, da.
\]

Substituting (5), (6), (17) and (18) into (19), assuming a Pareto distribution for firm marginal costs and integrating provides analytical solutions for the domestic and export cutoff firm marginal cost:

\[
a_D^k = \frac{F_E \beta (1 - \theta) - 1}{F_D} \frac{1 + \Theta}{1 + \Theta},
\]

18
\[ a_X^k = \frac{F_E}{F_X} \Theta \beta (1 - \theta) - 1 \]
\[ 1 + \Theta \]

where
\[ \Theta \equiv \left( (1 + \phi)^{\frac{1}{1-\beta}} - 1 \right)^{(1-\theta)\beta} \left( \frac{F_X}{F_D} \right)^{1-(1-\theta)\beta} \in [0, 1]. \]

The domestic cutoff with trade frictions, (20), closely resembles the cutoff in the autarky model, (8). The only difference is the additional term \( \Theta \) that appears in the denominators of (20). The term \( \Theta \) is a measure of trade freeness that includes the effect of fixed and variable trade frictions, plus the intensity of upgrading competition. The term \( \Theta \) increases with trade liberalization and with the intensity of upgrading competition:
\[ \frac{\partial \Theta}{\partial F_X} < 0, \frac{\partial \Theta}{\partial \phi} > 0, \frac{\partial \Theta}{\partial \theta} > 0. \]

Substituting (5), (6), (17) and (18) into (10) and (11) provides the parameter restriction ensuring that exporters have lower marginal costs than domestic firms:
\[ \left( \frac{a_X}{a_D} \right)^{1-\sigma} = \left( \frac{F_X}{F_D} \right)^{1-\theta} > 1. \]

The number of firms assuming symmetric country size is:
\[ n|_{L=L^*} = \frac{\beta (1 - \theta) - 1}{\beta} \frac{\mu L}{F_D (1 + \Theta)}. \]

Just as in the autarky case, variety is decreasing as upgrading competition becomes more intense. In addition, variety decreases due to trade liberalization:
\[ \frac{\partial n}{\partial \phi} < 0, \frac{\partial n}{\partial F_X} > 0, \frac{\partial n}{\partial \theta} < 0. \]
3.5 Welfare Effects

The "anti-variety" effect of trade liberalization may have implications for welfare, since welfare is increasing with variety. However, upgrading intensity and trade liberalization also increase quality-adjusted aggregate productivity in the economy, which has a beneficial effect on welfare. One can use the price index in order to ascertain the net effect of upgrading intensity and trade liberalization on consumer welfare. The price index assuming symmetric country size is:

$$P^{1-\sigma}|_{L=L^*} = \sum_{j} \frac{\mu L}{F_D} (1 - \theta) \left( \frac{\theta}{1 - \theta} F_D \right)^{\phi} a_D^{1-\sigma}$$  \hspace{1cm} (23)$$

It can be shown that, in the symmetric case, welfare is increasing with trade liberalization and with the intensity of upgrading:

$$\frac{\partial P^{1-\sigma}}{\partial \phi} > 0, \quad \frac{\partial P^{1-\sigma}}{\partial F_X} < 0.$$  

These comparative statics are given in the appendix. The beneficial productivity effect outweighs the negative anti-variety effect, meaning that both more intense upgrading and trade liberalization lead to welfare gains.

4 Testable Implications

It is important to first note that trade liberalization causes the export and domestic marginal cost cutoffs to converge, as is customary in Melitz models without upgrading competition:

$$\frac{\partial a^k_D}{\partial \phi} < 0, \quad \frac{\partial a^k_X}{\partial \phi} > 0,$$
The model's most interesting testable implications center around the effect of upgrading competition and the interaction between trade liberalization and upgrading competition. First, more intense upgrading competition results in tougher marginal cost cutoffs for both domestic survival and exporting:

\[ \frac{\partial a_D^k}{\partial F_X} > 0, \frac{\partial a_X^k}{\partial F_X} < 0. \]

Combining (10) and (11) provides an expression for the share of surviving firms that export in equilibrium:

\[ \frac{a_X^k}{a_D^k} = \Theta \frac{F_D}{F_X}. \]  \hspace{1cm} (24)

Comparative statics on (24) reveal that more intense upgrading competition encourages a greater proportion of surviving firms to export:

\[ \frac{\partial \left( \frac{a_X}{a_D} \right)^k}{\partial \theta} > 0. \]

More intense upgrading competition thus causes the domestic and export cutoffs to converge. This prediction is novel and results from the implementation of the intensity-of-upgrading parameter \( \theta \) and allowing firms to choose their level of upgrading from a continuum. Non-price competition thus has a similar effect to trade liberalization in the sense that it causes the domestic and export cutoffs to converge.

Changes in the domestic and export marginal cost cutoffs will affect aggregate
productivity in the manufacturing sector. Aggregate productivity is defined as

$$\Psi = \left( s_D \int_0^{a_D} a^{1-\sigma} dG (a|a < a_D) + s_X \int_0^{a_X} a^{1-\sigma} dG (a|a < a_D) \right)^{\frac{1}{1-\sigma}} $$

(25)

where $s_D = a_D^k \left( a_D^k + a_X^k \right)^{-1}$ and $s_X = a_X^k \left( a_D^k + a_X^k \right)^{-1}$ are the share of firms selling domestically and exporting respectively. Equation (25) can be rewritten as a function of the domestic firm cutoff and the ratio of exporters to domestic firms:

$$\Psi = \left( \frac{\beta}{\beta - 1} \right)^{\frac{1}{1-\sigma}} a_D^{-1} \left( 1 + \left( \frac{a_X}{a_D} \right)^k \left( \left( \frac{a_X}{a_D} \right)^{k+1-\sigma} - 1 \right) \right)^{\frac{1}{1-\sigma}} $$

From this expression it can be seen that aggregate productivity is increasing with trade liberalization and with the intensity of upgrading competition:

$$\frac{\partial \Psi}{\partial \phi} > 0, \frac{\partial \Psi}{\partial F_X} < 0, \frac{\partial \Psi}{\partial \theta} > 0.$$  

The positive effect upgrading competition on aggregate productivity is a new result. The intuition behind the result is that more intense upgrading competition increases fixed cost spending and leads to larger firms. This means that there is room for fewer firms in the manufacturing industry, thus weeding out the lowest productivity firms.

The model in this paper delivers two new predictions regarding the interaction between trade liberalization and upgrading. The first new prediction is that exporters upgrade and domestic firms "downgrade" when trade liberalizes. The effect on domestic firms can be seen in (6) and when the domestic cutoff becomes tougher due to trade liberalization:

$$\frac{\partial f (a)}{\partial \phi} < 0.$$
Domestic firms reduce their fixed costs spending because trade liberalization reduces demand for their product and thus weakens their incentives to invest in quality. The effect of trade liberalization on exporter upgrading is derived by substituting (21) and (22) into (18):

\[ \frac{\partial f_x(a)}{\partial \phi} > 0. \]

The intuition behind the upgrading and downgrading results can be seen in the first order conditions for upgrading, equations (3) and (14). Trade liberalization affects the upgrading decision via two countervailing channels. First, trade liberalization reduces the price index, which reduces per-firm demand for all firms in the economy. Second, trade liberalization increases export demand by reducing trade frictions. Domestic firms are only affected by the price index effect and respond by downgrading. Exporters are affected through both channels, and it turns out that the positive effect of reduced frictions outweighs the negative price index effect, so they respond to trade liberalization by upgrading.

The downgrading prediction is new because the previous literature assumes that it is only exporters that make decisions about upgrading. The prediction that domestic firms reduce their fixed cost spending as a response to tougher market conditions when trade liberalizes may help to explain the finding by Tybout (2003) about domestic firms’ response to trade liberalization. He found that domestic firms respond to trade liberalization by reducing output but did not find that their efficiency was also reduced. Instead he found that domestic firms increased their efficiency in response to trade liberalization, despite their reduced output. Tybout’s finding may be explained by the downgrading prediction in this model, since firms may respond to trade liberalization by becoming "leaner and meaner" and reducing their costs.
The prediction that domestic firms and exporters have opposite upgrading responses to trade liberalization has not been tested in the existing empirical literature. The recent empirical studies on trade-induced upgrading analyze the heterogeneous responses along different dimensions. Bustos (2010) compares the upgrading response across firms size quartiles, and finds that firms in the third size quartile respond to trade liberalization by upgrading their technology. Bustos (2010) also shows that both continuing exporters and new exporters increase their spending on technology, but no results for continuing domestic firms are reported. Lileeva and Trefler (2010) compare the upgrading responses across firms that differ in their predicted probability to export, and find that it is the low- to medium-productivity firms that begin exporting that invest in new technologies. The results in both of these papers agree with the predictions this paper, since the model predicts a large increase in upgrading for firms that begin exporting due to trade liberalization. Teshima (2009) reports the effect of tariff changes on firm-level upgrading for all firms in the sample and does not differentiate between firms on the basis of size, productivity or exporter status.

The second new prediction is the effect of trade liberalization on the extensive margin. Starting with (24) one can show that trade liberalization has a smaller effect on the extensive margin when fixed cost intensity is high:

$$\frac{\partial \varepsilon_{a,\phi}}{\partial \theta} < 0, \quad \frac{\partial \varepsilon_{a,F_X}}{\partial \theta} > 0$$

where $\varepsilon_{a,\phi}$ and $\varepsilon_{a,F_X}$ are elasticities of the response of the exporter-domestic firm ratio to variable and fixed trade costs:

$$\varepsilon_{a,\phi} \equiv \frac{\partial \left( \frac{a_X}{a_D} \right)^k}{\partial \phi} \frac{\phi}{( \frac{a_X}{a_D} )^k}, \quad \varepsilon_{a,F_X} \equiv \frac{\partial \left( \frac{a_X}{a_D} \right)^k}{\partial F_X} \frac{F_X}{( \frac{a_X}{a_D} )^k}.$$
The intuition behind this result is that more intense technology upgrading encourages a greater proportion of firms to export prior to trade liberalization, so trade liberalization does not have such a large effect on the proportion of firms that export. Bas and Ledezma (2008) elude to this idea in their numerical simulations, whereas the model in this paper yields an analytical result for this comparative static. This result may have important implications for predicting the effect of trade liberalization across industries that differ in their fixed cost intensity.

The volume of one-way trade assuming symmetric country size is given by the following expression:

\[ V|_{L=L^*} = \mu L \phi \Phi \frac{\Theta}{1 + \Theta}. \]  

(26)

If countries are symmetric then the comparative statics for trade will share the same properties as the extensive margin comparative statics above:

\[ \frac{\partial V|_{L=L^*}}{\partial \phi} > 0; \quad \frac{\partial \varepsilon_{V,\phi}|_{L=L^*}}{\partial \theta} < 0, \]

\[ \frac{\partial V|_{L=L^*}}{\partial F_X} < 0, \quad \frac{\partial \varepsilon_{V,F_X}|_{L=L^*}}{\partial \theta} > 0, \]

where \( \varepsilon_{V,\phi} \equiv \partial V/\partial \phi \cdot \phi/V \) and \( \varepsilon_{V,F_X} \equiv \partial V/\partial F_X \cdot F_X/V \). In other words, trade is increasing as trade liberalizes and the effect of trade liberalization is diminished in fixed cost-intense industries.

5 Conclusions

Empirical evidence shows that R&D spending is highly correlated with firm productivity, highly concentrated among large firms, and responsive to trade liberalization. This paper develops a model of product upgrading with heterogeneous firms that
captures these characteristics by allowing firms to choose their optimal level of fixed cost spending from a continuum.

The model provides a rich new set of predictions that help to better understand the interaction of upgrading with international trade. The first new prediction is that exporters upgrade while domestic firms reduce their fixed cost spending when trade liberalizes. The second new prediction is that industries where upgrading is important respond less elastically to trade liberalization along the extensive margin.
Appendix

Ruling out the Export-Only Case

There are three potential cases to rule out. The case first is that the export-only cutoff is the easiest cutoff. The second case is that exporting-only is performed by firms with intermediate marginal cost. The third case is that exporting-only is performed by firms with the lowest marginal cost.

The first case is ruled out by the following parameter assumption:

$$\left( \frac{a_{X_{only}}}{a_D} \right)^{1-\sigma} = \frac{1}{\phi} \left( \frac{F_X}{F_D} \right)^{1-\theta} > 1$$

where $a_{X_{only}}$ is the marginal cost of the firm exporting only and earning zero profits.

The second case can be ruled out because the profits from serving the domestic market exceed the profits from serving the export market only, for any $a \in [a_X, a_D]$. This is intuitive because export profits are always lower than domestic profits, for any given marginal cost level.

The third case can be ruled out because the profits from serving both markets exceed the profits from serving the export market only for any $a \in [0, a_X]$. This is intuitive since any firm that can survive in the export market can make more profits by serving the domestic market as well.
Figure 1: Domestic and Export Cutoff Conditions

Figure 2: Graphical Representation of Firms’ Endogenous Sunk Cost Choice for a Given Marginal Cost
References


