Productivity Improvements and Falling Trade Costs: Boon or Bane?*

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Abstract

This paper looks at two features of globalization, namely, productivity improvements and falling trade costs, and explores their effect on welfare in a monopolistic competition model with heterogenous firms and technological asymmetries. Contrary to received wisdom, and for reasons unrelated to adverse terms of trade effects, it is shown that improvements in a partner's productivity must hurt us. Moreover, with technological asymmetries, the more productive country gains significantly more from falling trade costs than does the backward one.

1 Introduction

Should a country welcome productivity improvements in its trading partners or should it be apprehensive? Should all countries welcome falling trading costs or are their welfare effects asymmetric across countries with some gaining and others losing? This is a question of fundamental importance today as globalization results in the spread of technology and concomitant productivity improvements from the North to the South, while concurrently falling trade costs and trade barriers improve market access. The standard mantra from trade economists has been that, by and large, such changes are beneficial for the economy as a whole, though some segments of society gain and others lose. *It is argued below, that though there are always gains from trade, improvements in a partner's productivity hurt us (for a new and different reason). Falling trade costs help the*

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advanced country but by less than they help the backward one. This paper also provides new reasons for a country to invest in its infrastructure: more on this below.

A monopolistic competition model with heterogeneous firms based on Melitz (2003) is used to identify a new effect, the technological potential effect.[1] The technological potential of a country consists of the distribution of productivities its firms draw from and the impact of this on its competitiveness in the marketplace. The technology a firm has access to interacts with market conditions to determine the equilibrium distributions of productivity, the extent of competition and variety in equilibrium. If countries have different technologies available to them, i.e., their firms draw from different distributions which are ordered in terms of hazard rate stochastic dominance (HRSD)[2], and there is no specialization, then productivity improvements in one country raise welfare there but reduce that of its trading partner. The intuition behind the results is that there is a monopoly distortion in the differentiated good sector so price exceeds marginal costs. As a result, the price of the differentiated goods relative to the competitively produced numeraire exceeds the ratio of their marginal costs. Hence, too little is produced and consumed of the differentiated goods. Anything that makes this distortion worse reduces welfare.

An improvement in the technological potential, which occurs when firms can draw from a "better" distribution of productivities, results in more entrants in the home country, and fewer abroad. Domestic entrants are drawn by the higher expected profits from being an exporter. Competition intensifies and the cutoff productivity level rises so that average domestic firm productivity rises. Though the number of foreign producers exporting to the home market falls, the surge in the entry of domestic firms overwhelms it. As a result, consumption of the differentiated goods at home rises and consumers gain, though the import of the differentiated goods from abroad decreases. As for the foreign country, a fall in its domestic production is not fully compensated for by the increase in the export of home firms and its differentiated good consumption and welfare falls. Note that the

[1] In the existing literature (see, for instance, Melitz (2003), Melitz and Ottaviano (2003), Baldwin and Forslid (2004)) all firms are assumed to draw from the same distribution. As a result, this effect has been neglected.

[2] Or in the case of a Pareto distribution, ordered in terms of the usual (first order) notion of stochastic dominance. Note that the case of the Pareto distribution with a difference in the supports is considered in Falvey, Greenaway and Yu (2005).

results are not coming from a terms of trade effect. If anything, a terms of trade effect should work in the opposite direction. The technological leader is a net exporter of the differentiated good. If its firms draw from an even better distribution, relative supply should shift out and its terms of trade should worsen which should raise the welfare of its partner, not reduce it!

Similarly, a fall in trade costs across the board makes it more advantageous to draw from the better productivity distribution enhancing the technological potential of the advanced country. The gains from falling trade costs accrue disproportionately to the advanced country. Firms are attracted to it and its output and consumption of the differentiated good rises. On the other hand, the backward country looks less attractive and the fall in domestic production there may not be fully compensated for by the rise in imported varieties. If this occurs, the lagging country can lose![3] When both countries draw from the same distribution, as in Melitz (2003), both gain from a fall in trade cost. Thus, only when the countries draw from the distributions that are different enough, can the backward country lose.

Note that compared to the previous literature, the technological potential effect is a completely new channel, through which trade can affect welfare in trading countries. Traditional trade models (whether Ricardian or a variant of Heckscher-Ohlin) offer the basic insight that gains from trade arise when a country faces prices different from its autarky prices. Thus, aside from distributional issues, these models suggest that, ceteris paribus, one would prefer to trade with a country that is different rather than a country which is similar, and with a large country rather than a small one. Moreover, these models suggest that improvements in a trading partners productivity will benefit a country. For example, in the standard Ricardian model with a continuum of goods, productivity improvements by a trading partner raise the welfare of all agents as they weakly raise the real income of domestic labor, the only factor, in terms of each and every good. See Dornbush, Samuelson and Fischer (1977).[4] Also, a fall in trading costs tends to raise welfare as the price of imports falls which raises the real income of labor.

[3] Note that all these results still hold in the Melitz and Ottaviano (2003) setting, in which they incorporate endogenous markups using the linear demand system with horizontal product differentiation. An appendix with detailed proofs is available upon request.

[4] The introduction of nonhomothetic preferences (see Matsuyama (2000)) does not change this result.

In a richer version of the Ricardian model, Krugman (1986) argues that technological catch up by the followers may hurt the leaders, while technological progress by the leaders helps all countries. The results follow from a combination of terms of trade and real income effects. Progress in the follower country results in greater competition with the leaders exports. This has adverse terms of trade effects for the leader, which creates the possibility of welfare losses for it. However, technological improvements by the leader raise welfare in both countries. Though the leader suffers adverse terms of trade effects, the productivity improvements more than compensate for them, while the follower country gains since the price of the technologically advanced goods it imports falls. These adverse terms of trade effects are one way for exogenous changes such as productivity improvements or falling trade costs to reduce welfare. However, this is not the channel by which the results are obtained here.

Monopolistic competition models with economies of scale where countries have access to the same technology (for example, Helpman and Krugman (1985)) offer a further insight into the effects of trade and technological change. Trade increases market size, which results in a greater variety of products as well as lower prices for the products offered as firms are better able to exploit economies of scale in large markets. In this manner, trade can improve not just aggregate welfare, but the welfare of all agents.[5] However, even in these models, the size of countries plays a crucial role in the determination of gains from trade: the larger the trading partner, the greater the increase in market size due to trade and the greater the gains from trade. In this model, productivity improvements in a trading partner raise welfare as they raise effective market size![6]

Most recently, Melitz and Ottaviano (2003) highlight the role of market potential in trade. They consider a single factor (labor) monopolistic competition model with firm level heterogeneity. Countries differ in their size and in their trade costs but all firms, whether domestic or foreign,

[5] In the simple HOS model, trade always results in trade-offs: some agents gain while others lose. In monopolistic competition models, gains from trade due to variety effects accrue to all consumers. In fact, if countries are close enough in their relative factor availability, these gains swamp any losses from factor price changes. This explains why free trade with a similar country may be welcomed while free trade with a country that is very different in terms of its endowments is harder to sell.

[6] A formal proof that productivity improvements in one country do not hurt its trading partner in the monopolistic competition model with homogeneous firms is available upon request.

draw from the same Pareto productivity distribution. In other words, they have access to the same technological possibilities. Their work has implications for the effect of changing country size, unilateral, bilateral, and preferential liberalization. They show that the larger country gains more from trade than the smaller one.[7] The larger country has more "market potential" than the smaller one and as a result, is a better export base in the trading equilibrium. Thus, more firms produce in the larger country, competition is stronger, and prices are lower than in the smaller country which is why the larger country gains more from trade. In their model, an increase in the size of a country due to an increase in its labor force raises per capita welfare in the growing country leaving that in its partner unchanged.

Their results on the effects of liberalization are more striking. In standard models, unilateral liberalization is welfare improving in the absence of externalities, second best or profit shifting effects. In contrast, they show that unilateral liberalization hurts the liberalizing country while benefiting others through the market potential effect. Such liberalization makes a country a worse export base so that its market potential is reduced: firms prefer to locate behind high trade barriers and export to countries with low trade barriers. The liberalizing country suffers a reduction in productivity of domestic firms and a reduction in domestic variety which is not fully compensated for by increased import variety. In addition, they show that preferential liberalization, like a customs union, raises welfare of the union members at the expense of non union ones. The market potential of the union rises, making it a better export base, with consequent beneficial effects on productivity and variety.

This paper focuses on the effect of falling trade costs and technological progress on the *absolute* welfare of asymmetric countries. It provides general results when the distributions countries draw from are ordered according to HRSD without having to make functional form assumptions. It also provides a complete characterization for the Pareto distribution, presenting clean results on absolute welfare changes.[8] In addition, the calibration of the model is used to show the magnitude

[7] This result is reminiscent of the standard variety effects in monopolistic competition.

[8] Falvey, Greenaway and Yu (2005) also use a Melitz (2003) setting to look at the effects of differences in productivity distributions across countries. However, they consider only the case of the Pareto distribution and a difference in its support and have no results regarding the effects on *absolute* welfare of falling trade costs or productivity differences

of the effects described in the paper. For example, a 1% difference in the means of the productivity distributions leads to a 9% difference in welfare levels in two countries.

What lies behind differences in the distributions that firms draw from and what are the policy implications of the results? One way to interpret them is just as difference in the technology available to countries. However, there is a richer interpretation that is more useful. In developing countries, part of the reason why productivity is low is that infrastructure is inadequate. After all, if the power fails on a regular basis, either one has to invest in expensive backup generating equipment (which raises costs) or suffer from lower labor productivity. In such settings, it may also be inappropriate to use cutting edge technology if it is more sensitive to variations in voltage that are the norm in developing countries. As a result, the appropriate technology may differ depending on the infrastructure. Such an interpretation suggests that there may be a significant additional benefit from the government investing in infrastructure: namely, an increase in technological potential!

The paper is organized as follows. Section 2 presents the benchmark model with heterogenous firms. Section 3 describes the equilibrium in a closed economy and Section 4 studies the properties of this equilibrium. Section 5 lays out the properties of the equilibrium in the open economy and proves the main result about productivity improvement. Section 6 discusses the Pareto distribution case and presents the results of a calibration of a model. Section 7 contains some concluding remarks.

2 The Model

The model is based on that of Melitz (2003), who extends Krugman's (1980) trade model by introducing firm level productivity differences. However, all countries in his model are symmetric in terms of the technologies available.[9] This paper allows for the difference in the countries' access to technology so that countries are no longer symmetric. Analytical results, without having to make specific distributional assumptions, are derived. Factor price equalization is achieved by introducing a homogenous good in both countries with constant return to scale production technology and zero

of any form.

[9] Ghironi and Melitz (2003) and Helpman, Melitz, and Yeaple (2003) also deal with symmetric countries. Bernard, Redding and Schott (2004) develop a heterogeneous agent HOS model and so allow for asymmetries in factor endowments. However, outside the FPE region they have to resort to simulations.

costs of transportation. An economy consists of two sectors and has one production factor, labor. A homogenous good (the numeraire) is produced in the first sector. Firms in the second sector produce a continuum of differentiated goods indexed by z.

2.1 Preferences

There are L consumers in the economy. Each supplies one unit of labor and has the a utility function given by $U = (N)^{1-\beta} (C)^{\beta}$, where $1 > \beta > 0$. N is a homogenous good and $C = \left(\int_{z\in\Omega} q(z)^{\rho} dz\right)^{1/\rho}$ can be thought of as the number of services obtained from consuming $q(z)$ units of each variety z when there is a mass Ω of available varieties of the differentiated good. The elasticity of substitution between any two differentiated goods is $\sigma = \frac{1}{1-\rho} > 1$. Preference are Cobb Douglas over N and C so that the shares of a consumer's income spent on N and C are, respectively, $1-\beta$ and β. Denote the price of variety z by $p(z)$. It is easy to verify that the cost of a unit of C defines the perfect price index

$$P = \left[\int_{z\in\Omega} p(z)^{1-\sigma} dz\right]^{\frac{1}{1-\sigma}}. \tag{1}$$

As originally shown by Dixit and Stiglitz (1977), the demand for variety z is given by

$$q(z) = C\left[\frac{p(z)}{P}\right]^{-\sigma}. \tag{2}$$

Using (2) shows that expenditure on variety z is

$$p(z)q(z) = PC\left[\frac{p(z)}{P}\right]^{1-\sigma}, \tag{3}$$

where $PC = \int_{z\in\Omega} p(z)q(z)dz$ is the aggregate expenditure on differentiated goods. Note that the share of expenditure on a particular variety depends only on the price of that variety relative to the price index.

2.2 Production and Firm Behavior

The homogeneous good is produced under constant returns to scale: one unit of labor makes a unit of this good. Hence, we can normalize the wage rate and the price of the homogenous good in a closed economy to unity. Moreover, as long as this good can be traded freely and there is incomplete specialization as we assume throughout, prices and nominal wages in both countries are also unity.[10] The expenditure on and (in a closed economy) the revenue earned is denoted by R^N. The labor used in the two sectors is denoted by L^N and L^C.

The differentiated good sector has a continuum of prospective entrants that are the same ex-ante. To enter, firms pay an entry cost of $f_e > 0$, which is thereafter sunk. Then they draw their productivity from a common distribution $g(\varphi)$ with positive support over $(0, \infty)$ and a continuous cumulative distribution $G(\varphi)$. At each point of time, there is a mass, M_e, of firms that make such a draw. Once a firm knows its productivity, it can choose to produce or exit. If its productivity draw is below a cutoff level, φ^*, it is best off exiting at once.[11] Any firm that stays in the market has a constant per period profit level. A firm exits (due to some unspecified catastrophic shock) with a constant probability δ in each period.[12] There is no discounting[13] and only stationary equilibria are considered. Note that because exit is random, the productivity distribution for successful entrants, exiting incumbents, and hence, for active firms is the same.

The productivity distribution of successful entrants in the economy is proportional to the initial productivity distribution with the factor of proportionality being the mass of firms that are alive in the stationary equilibrium denoted by M. In a stationary equilibrium, in every period the mass of new successful entrants should exactly replace the firms who face the bad shock and exit. As a result, this gives the aggregate stability condition: $p_{in} M_e = \delta M$, where $p_{in} = 1 - G(\varphi^*)$ is the probability of successful entry. In this manner, M_e and φ^* determine M and φ^* is endogenously determined.

The labor needed to produce q units of a variety is $l(\varphi) = f + q/\varphi$. $f > 0$ is a fixed overhead cost in terms of labor and $\frac{1}{\varphi}$ is the unit labor requirement of a firm with productivity $\varphi > 0$. All firms have the same fixed costs, but differ in their productivity levels. Due to symmetry, the constant elasticity of substitution form assumed, and the fact that there are a continuum of firms,

[10] Even if unit labor requirements differ, factor price equalization in efficiency units is achieved.
[11] The existence and uniqueness of φ^* will be shown in Section 3.
[12] It would be more plausible to make the probability of exit depend on the firm's productivity. For example, Hopenhayan (1992) models exit caused by series of bad shocks affecting the firm's productivity.
[13] Again, this assumption is made for simplicity.

each firm faces a downward sloping demand function with a constant demand elasticity of σ. And as expected in the CED case, it chooses its price so that its marginal revenue, $p(1-\frac{1}{\sigma})$, equals it marginal costs, $\frac{1}{\varphi}$. From this, it follows that price is

$$p(\varphi) = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\varphi}\right) = \frac{1}{\rho\varphi}. \tag{4}$$

Hence, profits are

$$\pi(\varphi) = r(\varphi) - \frac{p(\varphi)\, q}{p(\varphi)\,\varphi} - f = \frac{r(\varphi)}{\sigma} - f. \tag{5}$$

Variable profits are, thus, a constant share of revenue and this share is greater the less the substitutability between varieties. Also, note that

$$\frac{q(\varphi_1)}{q(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma}; \qquad \frac{r(\varphi_1)}{r(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1}, \tag{6}$$

so that a more productive firm has larger output and revenues, charges a lower price, and earns higher profits compared to a firm with the low productivity level.

Only a firm with $\pi(\varphi) \geq 0$ will find it profitable to produce once it has entered. A firm's value function is given by $\max\left\{0, \sum_{t=0}^{\infty}(1-\delta)^t \pi(\varphi)\right\} = \max\left\{0, \frac{1}{\delta}\pi(\varphi)\right\}$. Since $\pi(0) = -f$ is negative, and $\pi(\varphi)$ is increasing in φ, we can determine the lowest productivity level at which a firm will produce (the cutoff level φ^*) by $\pi(\varphi^*) = 0$. Any entering firm drawing a productivity level $\varphi < \varphi^*$ will exit immediately. Therefore, the distribution of productivity in equilibrium, $\mu(\varphi)$, is:

$$\mu(\varphi) = \begin{cases} \frac{g(\varphi)}{1-G(\varphi^*)}, & \text{if } \varphi \geq \varphi^*, \textit{ and} \\ 0 & \text{otherwise.} \end{cases} \tag{7}$$

Since each firm produces a unique variety z and draws a productivity φ, with a mass M of firms, the price index is given by

$$P = \left[\int_{\varphi^*}^{\infty}\left[\int_0^M p(z,\varphi)^{1-\sigma} dz\right]\mu(\varphi)\, d\varphi\right]^{\frac{1}{1-\sigma}}.$$

As firms are symmetric ex-ante, p does not depend on z so that $\int_0^M p(z,\varphi)^{1-\sigma} dz = Mp(\varphi)^{1-\sigma}$. Hence,

$$P = M^{\frac{1}{1-\sigma}}\left[\int_{\varphi^*}^{\infty} p(\varphi)^{1-\sigma}\mu(\varphi)\, d\varphi\right]^{\frac{1}{1-\sigma}}.$$

Recall that $p(\varphi) = \frac{1}{\rho\varphi}$ and define $\tilde{\varphi}$[14] as:

$$\tilde{\varphi}(\varphi^*) \equiv \left[\int_0^\infty \varphi^{\sigma-1}\mu(\varphi)\,d\varphi\right]^{\frac{1}{\sigma-1}} = \left[\frac{1}{1-G(\varphi^*)}\int_{\varphi^*}^\infty \varphi^{\sigma-1}g(\varphi)\,d\varphi\right]^{\frac{1}{\sigma-1}}, \tag{8}$$

so that

$$P = M^{\frac{1}{1-\sigma}}p(\tilde{\varphi}). \tag{9}$$

As in Melitz (2003), all aggregate variables can be written in terms of a representative firm, $\tilde{\varphi}$, and M.

$$Q = M^{1/\rho}q(\tilde{\varphi}), \quad R^C = PQ = Mr(\tilde{\varphi}) \equiv M\bar{r}, \quad \Pi^C = M\pi(\tilde{\varphi}) \equiv M\bar{\pi}. \tag{10}$$

where $Q = C = \left(\int_{z\in\Omega} q(z)^\rho\,dz\right)^{1/\rho}$, $R^C = \displaystyle\int_0^\infty r(\varphi)M\mu(\varphi)\,d\varphi$ and $\Pi^C = \displaystyle\int_0^\infty \pi(\varphi)M\mu(\varphi)\,d\varphi$ represent, respectively, aggregate revenue and profits in the differentiated good sector, $\bar{r}$ and $\bar{\pi}$ represent the average revenue and profit as well as the revenue and profit of the firm with productivity $\tilde{\varphi}$. Note that this allows a heterogeneous firm setting to be transformed to a homogenous firm one, where all firms have productivity $\tilde{\varphi}$.

3 Equilibrium in a Closed Economy

To derive the productivity cutoff level φ^* in the equilibrium, we use the free entry (FE) condition:

$$(1-G(\varphi^*))\frac{\bar{\pi}}{\delta} = f_e. \tag{11}$$

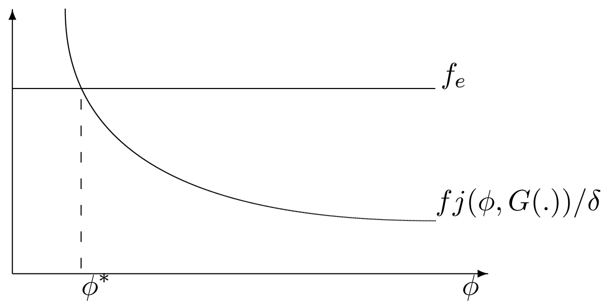
As shown in Melitz (2003), the average profit level $\bar{\pi}$ can be written as a function of φ^*: $\bar{\pi} = fk(\varphi^*)$, where $k(\varphi^*) = [\tilde{\varphi}(\varphi^*)/\varphi^*]^{\sigma-1} - 1$. Using this formula in (11) and denoting $(1-G(\varphi^*))k(\varphi^*)$ by $j(\varphi^*, G(\cdot))$, we obtain a final equation for φ^*:

$$\frac{f}{\delta}j(\varphi^*, G(\cdot)) = f_e, \tag{12}$$

where $\frac{f}{\delta}j(\varphi^*, G(\cdot))$ is the present discounted value of the expected profits upon entering when drawing from $G(\cdot)$. As shown in Melitz (2003), $\frac{f}{\delta}j(\varphi^*, G(\cdot))$ is decreasing in φ^* and intersects the f_e line only once. This ensures the existence and uniqueness of φ^*. The solution of (12) does not

[14] The assumption of a finite $\tilde{\varphi}$ requires the $(\sigma-1)^{th}$ un-centered moment of $g(\varphi)$ be finite.

Figure 1: The Closed Economy Equilibrium



depend on the labor stock in the economy. Moreover, a graphical representation of (12) in Figure 1 provides a simple way to analyze the changes in φ^* due to changes in the parameters of the model.

Since there are zero profits ex-ante and only one factor, labor, the value added in a sector, or a revenue in this case, equals the value of payments to factors.[15] As a result, the aggregate revenues in both sectors are exogenously fixed by the country size L: $L^N = (1-\beta) L$ and $L^C = \beta L$.

In any period, the mass of firms, which produce differentiated goods, is given by $M = R^C/\bar{r} = \beta L / (\sigma (\bar{\pi} + f))$. Note that the larger the country size L, the more firms enter the market. As a result, the price index falls and welfare per worker[16] rises due to an increase in product variety.

4 Analysis of the Equilibrium

Now we turn to the effect of a better productivity distribution: in this section we will compare two closed economies, home and foreign, with different productivity distributions.

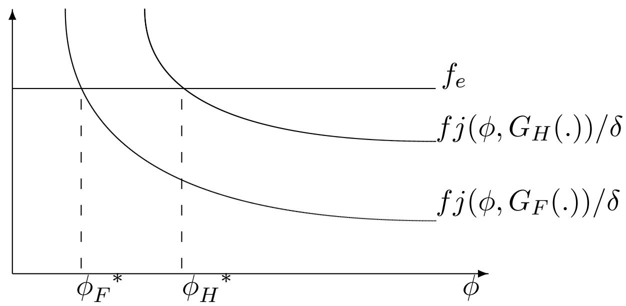
Definition 1 *The productivity distribution $G_H(\varphi)$ dominates the productivity distribution $G_F(\varphi)$ in terms of the hazard rate order, $G_H(\cdot) \succ_{hr} G_F(\cdot)$, if for any given productivity level φ,*

$$g_h(\varphi) / (1 - G_H(\varphi)) < g_F(\varphi) / (1 - G_F(\varphi)).$$

[15] Note that labor payments include those to cover sunk entry costs.

[16] It is determined by the indirect utility function: $W = \left(\frac{(1-\beta)w}{1}\right)^{1-\beta} \left(\frac{\beta w}{P}\right)^{\beta} = \frac{(1-\beta)^{1-\beta}\beta^{\beta}}{P^{\beta}}$.

Figure 2: Two Closed Economies, Home and Foreign



Hazard rate stochastic dominance (HRSD) allows a ranking of the expectations of an increasing function above some cutoff level, i.e., if $y(x)$ is increasing in x and $G_H(\cdot) \succ_{hr} G_F(\cdot)$, then for any given level φ, $E_H[y(x) \mid x > \varphi] > E_F[y(x) \mid x > \varphi]$.[17] In terms of the model, this means that for any given level φ, entrants in the home country with the productivity distribution $G_H(\cdot)$ have a better chance of obtaining a productivity draw above this level than do entrants in the foreign country with the productivity distribution $G_F(\cdot)$. Given this difference, we obtain

Lemma 1 *For any given level φ, $j(\varphi, G_H(\cdot)) > j(\varphi, G_F(\cdot))$*

Proof. *See Appendix.* ■

Using Lemma 1 in Figure 2, we conclude that $\varphi_H^* > \varphi_F^*$. Intuitively, since home firms have a better chance of obtaining a productivity above any cutoff level, only more productive firms can survive. As a result, the home country has a lower price index and a higher welfare per worker than the foreign country.

5 The Open Economy

Trade has two basic effects in an economy: on the one hand, it provides an opportunity to sell in the new market; on the other hand, it brings new competitors from abroad. We consider trade with costs: when firms become exporters, they face new costs, such as transport costs, tariffs, etc. As in Melitz (2003), both countries are assumed to be of the same size, and in each country, after the

[17] Note that the usual (first-order) stochastic dominance allows us to compare only the unconditional expectations, i.e., if $G_H(\cdot) \succ_{st} G_F(\cdot)$, then $E_H[y(x)] > E_F[y(x)]$. For more detail see Shaked and Shanthikumar (1994).

firm's productivity is revealed, a firm who wishes to export must pay a per-period fixed cost, $f_x > 0$. Per-unit trade costs are modeled in the standard iceberg formulation: $\tau > 1$ units shipped result in 1 unit arriving.[18] Regardless of export status, a firm still incurs the same overhead production cost of f per period.

In order to ensure factor price equalization across countries and to focus the analysis on firm selection effects, assume that the homogenous good is produced using the same technology in both countries after trade[19], and that its export does not incur transport costs.[20] The next two sections consider trade with no specialization. Section 5.1 presents the equilibrium in the case of symmetric countries and studies the effect of falling trade costs on welfare of trading countries. Section 5.2 proves the main result about productivity improvement.

5.1 Equilibrium in the Open Economy

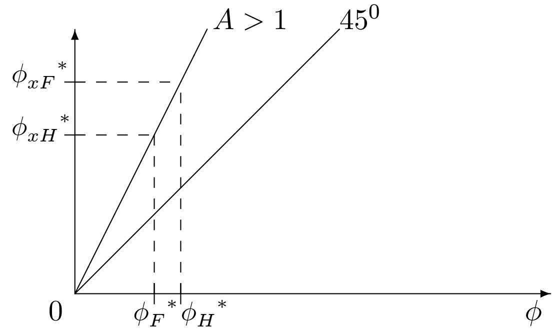
In each country under trade, the aggregate revenue earned by domestic firms in the differentiated good sector, R_i^C, can differ from the aggregate expenditure on the differentiated goods, E_i^C, $i = H, F$. ($R_i^C = \gamma_i L$, where γ_i is the fraction of labor employed in the differentiated good sector in country i, and $E_i^C = \beta L$.[21])

Since consumers in each country spend a share β of their incomes on the differentiated goods, and as the world expenditure on the differentiated goods equals the revenues earned in this sector, $\gamma_H + \gamma_F = 2\beta$. The export price is $p_x(\varphi) = \tau p(\varphi)$. Using (3), the revenues earned by a firm in country i from domestic sales can be written as $r_i(\varphi) = E_i^C (P_i \rho \varphi)^{\sigma - 1}$, where P_i denotes the price index in the differentiated good sector. The revenue of a firm in country i is $r_i(\varphi)$, if the firm does not export, and $r_i(\varphi) + r_j(\tau^{-1}\varphi)$, $i \neq j$, if the firm exports. The actual bundle of goods available can differ across countries as not every firm in each country decides to export.

We assume that $G_H \succ_{hr} G_F$ and consider stationary equilibria only. Then, in country i, the

[18] To simplify the analysis, the nominal exchange rate is normalized to one.
[19] This requires $2\beta < 1$.
[20] $\tau = 1$ for the homogenous good.
[21] As in the autarky, the aggregate revenue R_i^C in the differentiated good sector equals the total payment to the labor, i.e., $R_i^C = L_i^C = \gamma_i L$. The total revenue is $R_i = R_i^N + R_i^C = L$, $i = H, F$.

Figure 3: The Open Economy Productivity Cutoff Levels



profits earned by a firm from sales in the domestic and foreign markets are, respectively,

$$\pi_{di}\left(\varphi\right)=\frac{r_i\left(\varphi\right)}{\sigma}-f \qquad \text{and} \qquad \pi_{xi}\left(\varphi\right)=\frac{r_j\left(\tau^{-1}\varphi\right)}{\sigma}-f_x, \quad i=H,F. \tag{13}$$

Total profits can be written as $\pi_i\left(\varphi\right)=\max\left\{0,\pi_{di}\left(\varphi\right)\right\}+\max\left\{0,\pi_{xi}\left(\varphi\right)\right\}$. As in autarky, the productivity cutoff levels must satisfy $\pi_{di}\left(\varphi_i^*\right)=0$ and $\pi_{xi}\left(\varphi_{xi}^*\right)=0$.

Lemma 2 *The productivity cutoff levels in both countries are linked: $\varphi_{xH}^*=A\varphi_F^*$ and $\varphi_{xF}^*=A\varphi_H^*$, where $A=\tau\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}}$.*

Proof. *See Appendix.* ■

Assumption 1 *To ensure that in both countries only firms producing in the domestic market can export, assume that $f_x/f>X$, where X depends on the difference in the productivity distributions.* [22]

Note that Assumption 1 implies $\varphi_{xi}^*>\varphi_i^*$, thus, from Lemma 2, A should be more than 1. The results of Lemma 2 are depicted in Figure 3. The productivity cutoff level for exporting firms depends on the price index and the mass of domestic firms in the country they export to, which, in turn, depend on the productivity cutoff level for domestic firms in this country.

The ex-ante probabilities of successful entry and being an exporter conditional on successful entry are, respectively, $p_{in,i}=1-G\left(\varphi_i^*\right)$ and $p_{xi}=\left[1-G_i\left(\varphi_{xi}^*\right)\right]/\left[1-G_i\left(\varphi_i^*\right)\right]$. The productivity

[22] *As will be proved in Lemma 3, a country with better productivity distribution (home) is more productive and has a lower price index in the equilibrium. Thus, from (13), $\pi_{xH}\left(\varphi\right)$ may become steeper than $\pi_{dH}\left(\varphi\right)$ as $\pi_{d,H}=\frac{1}{\sigma}E_H^C\left(P_H\rho\varphi\right)^{\sigma-1}-f$ and $\pi_{x,H}=\frac{1}{\sigma}E_F^C\left(P_F\frac{\rho\varphi}{\tau}\right)^{\sigma-1}-f_x$. If $\pi_{xH}\left(\varphi\right)$ is too steep, then for any f and f_e, we will get $\varphi_{xH}^*<\varphi_H^*$, which can be prevented if f_x/f is large enough.*

distribution for incumbent firms in country i is $\mu_i(\varphi) = g_i(\varphi)/[1 - G_i(\varphi_i^*)]$ $\forall\varphi \geq \varphi_i^*$ and zero otherwise. Let M_i denote the mass of firms in country i that are alive in the equilibrium. Then the mass of exporting firms and the total mass of varieties available in country i are $M_{xi} = p_{xi}M_i$ and $M_{ti} = M_i + M_{xj}$, respectively.

Using (8), define a representative domestic firm by $\tilde{\varphi}_i \equiv \tilde{\varphi}(\varphi_i^*, G_i(\cdot))$ and a representative exporting firm by $\tilde{\varphi}_{xi} \equiv \tilde{\varphi}(\varphi_{xi}^*, G_i(\cdot))$. The average revenue and profit in country i are

$$\bar{r}_i = r_i(\tilde{\varphi}_i) + p_{xi}r_j\left(\tau^{-1}\tilde{\varphi}_{xi}\right) \qquad \text{and} \qquad \bar{\pi}_i = \pi_{di}(\tilde{\varphi}_i) + p_{xi}\pi_{xi}(\tilde{\varphi}_{xi}). \tag{14}$$

For each country we can write all aggregate variables in terms of $\tilde{\varphi}_{ti}$[23], where:

$$\tilde{\varphi}_{ti} \equiv \left\{\frac{1}{M_{ti}}\left[M_i\tilde{\varphi}_i^{\sigma-1} + M_{xj}\left(\tau^{-1}\tilde{\varphi}_{xj}\right)^{\sigma-1}\right]\right\}^{\frac{1}{\sigma-1}}, \ i = H, F, \ i \neq j. \tag{15}$$

$$\text{Then,} \quad P_i = M_{ti}^{\frac{1}{1-\sigma}}p(\tilde{\varphi}_{ti}) \quad \text{and} \quad E_i^C = M_{ti}r_i(\tilde{\varphi}_{ti}), \quad i = H, F. \tag{16}$$

As in autarky , the FE condition for country i is

$$(1 - G_i(\varphi_i^*))\frac{\bar{\pi}_i}{\delta} = f_e \tag{17}$$

Using the same technique as before, it can be shown that

$$\pi_{di}(\varphi_i^*) = 0 \iff \pi_{di}(\tilde{\varphi}_i) = fk_i(\varphi_i^*), \tag{18}$$

$$\pi_{xi}(\varphi_{xi}^*) = 0 \iff \pi_{xi}(\tilde{\varphi}_{xi}) = f_xk_i(\varphi_{xi}^*), \tag{19}$$

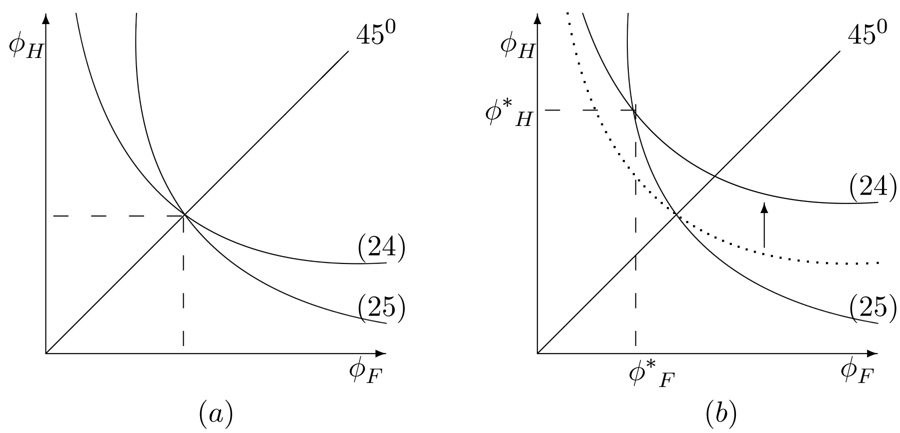
where $k_i(\varphi) = [\tilde{\varphi}_i(\varphi)/\varphi]^{\sigma-1} - 1$. Thus, $\bar{\pi}_i$ in an open economy is:

$$\bar{\pi}_i = fk_i(\varphi_i^*) + p_{xi}f_xk_i(\varphi_{xi}^*). \tag{20}$$

For the time being, denote $j(\varphi, G_i(\cdot))$ by $j_i(\varphi)$, $i = H, F$. Substituting (20) into (17) leads to a

[23] $\tilde{\varphi}_{ti}$ is a productivity level of the representative firm in country i. Note that in contrast to Melitz (2003), $\bar{r}_i \neq r_i(\tilde{\varphi}_{ti})$ and $\bar{\pi}_i \neq \pi_i(\tilde{\varphi}_{ti})$ because of asymmetric countries.

Figure 4: Proof of Lemma 3



system of equations with two unknown variables (see Appendix):

$$\frac{f}{\delta}j_H(\varphi_H^*) + \frac{f_x}{\delta}j_H(A\varphi_F^*) = f_e, \tag{21}$$

$$\frac{f}{\delta}j_F(\varphi_F^*) + \frac{f_x}{\delta}j_F(A\varphi_H^*) = f_e, \tag{22}$$

where $j_i(\cdot)$ is a decreasing function. The left-hand side of (21) ((22)) is the present discounted values of the expected profits earned by a firm in the home (foreign) country considering entry into the market.

Assumption 2 *The difference in the productivity distributions is not large enough for trade to result in specialization. In other words, in the equilibrium, each country produces both the homogenous and differentiated goods.*[24]

A necessary condition for Assumption 2 is $f_e < \frac{f}{\delta}j_F\left(\frac{1}{A}j_H^{-1}\left(\frac{\delta f_e}{f_x+f}\right)\right) + \frac{f_x}{\delta}j_F\left(Aj_H^{-1}\left(\frac{\delta f_e}{f_x+f}\right)\right)$. (See Appendix for the proof.)

Lemma 3 *If Assumption 1 and Assumption 2 hold, there exists a unique solution* $(\varphi_H^*, \varphi_F^*)$ *of (21) and (22). Moreover,* $\varphi_F^* < \varphi_H^* < \varphi_{xH}^* < \varphi_{xF}^*$.

[24] *The home country with better productivity distribution is more productive and has a lower price index in the equilibrium. If the difference between counties is large, then P_H can become low enough so that the ex-ante profits from entering of firms in the foreign country do not cover the entry costs, thus, no firm there will choose to enter.*

Proof. *The sketch of a proof is following.*[25] *First, for any productivity levels* φ_H *and* φ_F*, express* φ_H *as a function of* φ_F*, using (21) and (22):*

$$(21) \implies \varphi_H = j_H^{-1}\left(\frac{\delta f_e}{f} - \frac{f_x}{f} j_H(A\varphi_F)\right), \tag{23}$$

$$(22) \implies \varphi_H = \frac{1}{A} j_F^{-1}\left(\frac{\delta f_e}{f_x} - \frac{f}{f_x} j_F(\varphi_F)\right). \tag{24}$$

Then, plot both functions in the same figure and find the equilibrium pair $(\varphi_H^*, \varphi_F^*)$ *as an intersection of two curves. Note that both curves are decreasing in* φ_F *and for any pair of distributions* $G_H(\cdot)$ *and* $G_F(\cdot)$*, the curve corresponding to equation (23) is flatter than the curve corresponding to equation (24) at any intersection point. This ensures the uniqueness of the intersection. (If there is another intersection, at this point, the curve corresponding to equation (23) should be steeper than the curve corresponding to equation (24), which violates the property proved above.)*

Finally, if countries have the same productivity distribution, i.e., if they are symmetric, the intersection of two curves lies on the 45^0 *line as shown in Figure 4(a) and in the equilibrium* $\varphi_H^* = \varphi_F^*$*. Then, if the productivity distribution in a country improves (worsens) in terms of HRSD, the curve corresponding to the equation for this country shifts up (down). In particular, if the home country has a better distribution in terms HRSD* ($G_H(\cdot) \succ_{hr} G_F(\cdot)$)*, the curve corresponding to equation (23) shifts up as shown in Figure 4(b) and in the equilibrium* $\varphi_F^* < \varphi_H^*$*. From Lemma 2,* $\varphi_{xi}^* = A\varphi_j^*$*,* $i \neq j$*, which leads to* $\varphi_F^* < \varphi_H^* < \varphi_{xH}^* < \varphi_{xF}^*$*.* ■

The resulting productivity cutoff levels are depicted in Figure 3. Ex-ante, home firms receive productivity draws from a better distribution. As a result, the home productivity cutoff level for surviving firms, φ_H^*, is higher than φ_F^*. However, while making an export decision, home firms face less severe competition abroad compared to that faced by foreign firms in the home country. Thus, $\varphi_{xH}^* < \varphi_{xF}^*$.

Given φ_H^* and φ_F^*, the trade balance equation allows to derive γ_H and γ_F, the shares of labor in the differentiated good sectors in both countries, as the functions of φ_H^* and φ_F^*. (See Appendix for details.)

[25] *See Appendix for the complete proof.*

Lemma 4 *If Assumption 1 and Assumption 2 hold, then the home country imports the homogenous good and exports the differentiated goods. The foreign country also exports the differentiated goods, but unlike the home country, it exports the homogenous good as well.*

Proof. *See Appendix.* ■

Having φ_H^* and φ_F^*, $\bar{\pi}_i$ and $M_i = \frac{R_i^C}{\bar{r}_i} = \frac{\gamma_i L}{\sigma(\bar{\pi}_i + f + p_{xi} f_x)}$ can be obtained. In turn, this determines the price index and the mass of variety available in each country. Note that from (16), the price index in country i depends on the average productivity there, $\tilde{\varphi}_{ti}$, and the mass of variety available, M_{ti}. In turn, M_{ti} depends on $\tilde{\varphi}_{ti}$ and the productivity cutoff level φ_i^*. This allows to write P_i as a function of φ_i^* (see equation (39) in Appendix) and the welfare per worker as:

$$W_i = \frac{(1-\beta)^{1-\beta}\,\beta^{\beta}}{P_i^{\beta}} = (1-\beta)^{1-\beta}\,\beta^{\beta}\left(\frac{\beta L}{\sigma f}\right)^{\beta/(\sigma-1)}(\rho\varphi_i^*)^{\beta}\,. \tag{25}$$

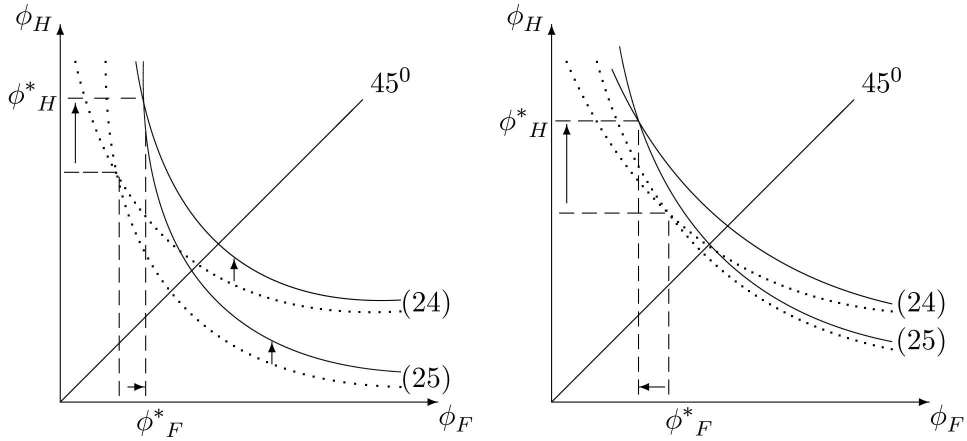
Thus, comparative advantage in the differentiated good sector (a better distribution in terms of HRSD) leads to a greater technological potential and a higher welfare per worker at home than abroad.[26]

Note that a fall in the per-unit trade cost τ due to globalization shifts both curves corresponding to equations (23) and (24) up. As a result, φ_H^* (and, consequently, φ_{xF}^*) increases.[27] However, as shown in Figure 5, φ_F^* (and, consequently, φ_{xH}^*) may increase or decrease. In other words, there is a possibility of welfare loss in the less developed country. Intuitively, when identical countries draw from the same distribution, as in Melitz (2003), a fall in trade costs raises both countries welfare. A fall in transport costs creates more export opportunities, which intensifies competition, and this raises the cutoff level, and hence, welfare. However, this result is crucially dependent on symmetry all around. As everything is continuous, when countries draw from similar distributions, Melitz (2003) result must go through. However, when countries draw from very different distributions, the backward one may lose. All firms lose a part of their domestic market, but exporting firms more than make up for this loss. However, when home firms are more advanced, the home market is a

[26] Note that both countries gain from trade compared to autarky.

[27] An increase in φ_H^* can be shown mathematically using equation (38) from Appendix. ($\psi(\varphi_H^*)$ decreases as A falls.)

Figure 5: A Fall in Trade Cost.



(a) Both Home and Foreign Countries Gain.

(b) Home Country Gains, Foreign Country Loses.

tougher one for foreign firms than vice versa. Hence, home firms expand at the expense of foreign ones. As not all firms export, the productivity cutoff level (and hence, welfare) at home rises while that abroad falls. Proposition 1 presents the first result of a paper:

Proposition 1 *In the absence of specialization, falling trade costs raise welfare in the advanced country. The laggard country may gain or lose: it must gain if it is not too different from its trade partner and may lose if it is very backward.*

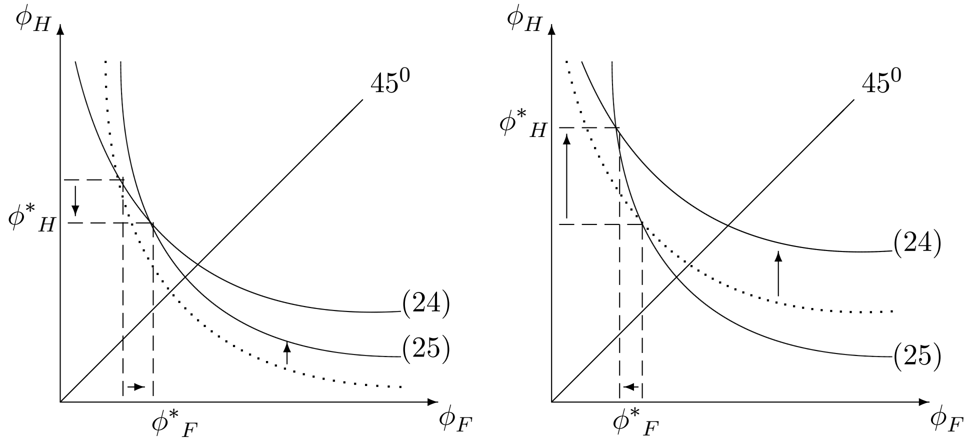
Proposition 1 offers an explanation of why globalization may adversely affect developing countries whose technology is likely to be dominated by that of the developed world.

5.2 Productivity Improvement and Trade

How does technological progress in a country affect its trading partner? What is the effect of productivity improvement in a trading partner on welfare in each country? To answer this question, the same technique as in the proof of Lemma 4 can be used: productivity improvement in terms of HRSD in the foreign country shifts the curve corresponding to equation (24) up as shown in Figure 6(a), which proves Lemma 5:

Lemma 5 *In the absence of specialization, the productivity improvement in terms of HRSD in the*

Figure 6: Proof of Lemma 5



(a) Productivity Improvement in the Foreign Country

(b) Productivity Improvement in the Home Country

foreign country raises φ_F^* *and* $\varphi_{xH}^* = A\varphi_F^*$, *and reduces* φ_H^* *and* $\varphi_{xF}^* = A\varphi_H^*$.[28]

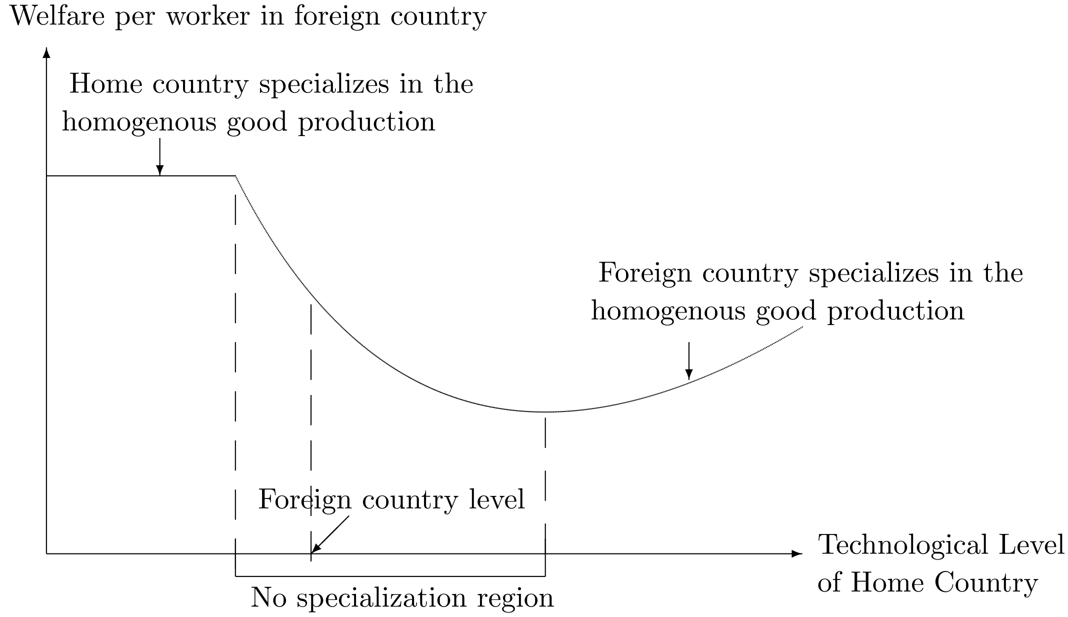
The interpretation of this result is that when the foreign country faces the productivity improvement, firms there have a better chance of receiving a high productivity draw. Thus, some foreign firms with low productivities, which survive before, exit and φ_F^* rises. As for the home country, a more competitive foreign market decreases the present discounted value of the expected profits of firms at home. Hence, fewer firms enter the market and the productivity cutoff level φ_H^* falls.

In the absence of specialization, trade occurs according to Lemma 4. Productivity improvements in the foreign country lead to a fall in the volume of trade. The home country produces and exports fewer differentiated goods. (See Appendix.) Productivity improvements in the foreign country raise the technological potential there while reducing it at home. Using the same technique, it can be shown that technology improvement in the home country reduces welfare abroad while raising it at home. (See Figure 6(b).)

The intuition for these results is actually quite simple. Monopolistic competition in the differentiated good sector results in firms charging prices above their marginal costs. As a result, the

[28] *Productivity improvements may result in Assumption 1 and/or Assumption 2 being violated. Note that this case is excluded from the analysis as we assume both Assumption 1 and Assumption 2 hold true after the productivity improvement.*

Figure 7: Welfare per Worker in Foreign Country



relative price ratio of a differentiated good relative to the numeraire exceeds the ratio of marginal costs. Thus, too little of the differentiated good is produced and consumed in equilibrium. Anything that makes this distortion worse reduces welfare. An improvement in the partner's productivity distribution does exactly this: domestic production of the differentiated good falls, and so does consumption as the fall in consumption of domestic varieties is not fully compensated for by increases in consumption of foreign varieties. Proposition 2 summarizes the main result.

Proposition 2 *In the absence of specialization, productivity improvement in one country raises the productivity cutoff level there while reducing it in the other country. As a result, consumers in the country, which makes the progress and raises its technological potential, gain, while consumers in the other country lose.*

Figure 7 depicts the relationship between welfare per worker in the foreign country and the technological level of the home country.[29] It shows that in the absence of specialization, productivity improvement in the home country decreases welfare per worker in the foreign country.

[29] There is no parameter in the model that describes the technological level of a country, since the productivity distributions are not specified. Thus, each point on the horizontal axes is an abstract representation of the technological level of the home country: the home country is the more advanced the further to the right the point.

Note that at some point, productivity improvement in the leading home country makes the gap between the two countries large enough so that the foreign country specializes in the homogenous good, while the home country produces and exports the differentiated goods[30], and the productivity cutoff levels for domestic producers and exporters there, φ_H^* and φ_{xH}^*, determine the price indices, volume of trade, and welfare in both countries. A difference between trade with no specialization and the case in this section is that now welfare at home does not depend on the productivity distribution in the foreign country and the foreign country gains from productivity improvement at home. This increase in welfare in the foreign country is shown in the right part of Figure 7. The horizontal part in Figure 7 corresponds to the case of the home country specialization in the homogenous good, in which the welfare in the foreign country depends only on its own productivity distribution.

6 The Pareto Distribution Case

In the case of the Pareto productivity distribution, the assumption of HRSD can be relaxed to the usual (first order) stochastic dominance (USD) instead.[31] To show this, assume that the Pareto productivity distribution is given by $G_i(\varphi) = 1 - \left(\frac{\varphi_{\min,i}}{\varphi}\right)^{k_i}$, where $\varphi > \varphi_{\min,i}$, $k_i > \sigma - 1$, $i = H, F$. The hazard rate for the Pareto distribution is $\frac{g_i(\varphi)}{1-G_i(\varphi)} = \frac{k_i}{\varphi}$. Therefore, if $k_H < k_F$ (or $k_H > k_F$), i.e., the productivity distribution in the home country dominates that in the foreign country in terms of HRSD, $G_H(\cdot) \succ_{hr} G_F(\cdot)$ (or $G_H(\cdot) \prec_{hr} G_F(\cdot)$), then lemmas 3 and 4 and propositions 1 and 2 can be used to describe the equilibrium in the economy and the effects of productivity improvements and a fall in trade cost on welfare in both countries.

We need to consider the case when $k_H = k_F = k$, but $\varphi_{\min,H} > \varphi_{\min,F}$, i.e., the productivity distribution in the home country dominates that in the foreign country in terms of USD, however, the productivity distributions in both countries are equivalent in terms of HRSD.[32] Using the same

[30] In terms of the model, this means that $\gamma_H = 2\beta$ and $\gamma_F = 0$.
[31] Note that HRSD implies USD, however, the opposite is not always true.
[32] Falvey, Greenaway and Yu (2005) consider this case, however, they have no results regarding the effects on absolute welfare.

techniques as before, it can be shown straightforwardly that the results of this paper still hold.[33] Thus, in the case of the Pareto productivity distribution, the assumption of HRSD can be replaced by the assumption of USD without any change in the results.

6.1 Calibration

The goal of this section is to estimate the magnitude of the effects described in the model. To calibrate the parameters, consider the case when both countries have the same productivity distribution. We interpret periods as years and set the size of the exogenous firm exit shock $\delta = 0.1$, which reflects destruction of one in ten jobs a year. As in Ghironi and Melitz (2004), we set $\sigma = 3.8$,a number that comes from Bernard, Eaton, Jensen and Kortum (BEJK, 2003), who show it fits to the US plant and macro trade data. To set the shape parameter k of the Pareto productivity distribution, we use the standard deviation of log US plant domestic sales, 0.84, reported by BEJK for the simulated data.[34] In the model this is equal to $(\sigma - 1)/k$.[35] Thus, given $\sigma = 3.8$, $k = 3.3$. We set $\tau = 1.3$ in line with Obstfeld and Rogoff (2001). To derive the ratio of the fixed costs of exporting to the fixed costs of production for the domestic market, f_x/f, the proportion of exporting plants, 21%, reported in BEJK, is used. In the model this proportion is equal to $p_x = (1 - G(\varphi_x^*)) / (1 - G(\varphi^*)) = \left(\tau (f_x/f)^{1/(\sigma-1)}\right)^{-k}$, thus, $f_x/f = 1.8$.

Note that the equilibrium condition in the case of symmetric countries with the Pareto productivity distribution can be written as

$$\frac{\sigma - 1}{k - (\sigma - 1)} \left(\frac{\varphi_{\min}}{\varphi^*}\right)^k \left[1 + \frac{f_x}{f}\left(\tau\left(\frac{f_x}{f}\right)^{1/(\sigma-1)}\right)^{-k}\right] = \delta \frac{f_e}{f}. \tag{26}$$

Thus, without loss of generality, $\varphi_{\min}$ can be normalized to 1. To get the ratio of entry costs to the fixed costs of production for the domestic market, f_e/f, the proportion of the US firms

[33] An appendix with detailed proofs is available upon request.

[34] We use the standard deviation of log domestic sales reported for the simulated data (0.84) instead of that reported for the actual data (1.67), since the latter is inflated for several reasons: it is computed across all the sectors, and not within a sector; it includes sources of heterogeneity outside the scope of the model; and lastly, it is inflated relative to the dispersion of product level sales as more productive plants are much more likely to produce multiple products.

[35] Note that this formula differs from that derived by Ghironi and Melitz (2004) of $1/(k - \sigma + 1)$. This is due to an algebraic error in their paper, which does not affect their theoretical results as confirmed in personal communication with the authors.

that entered the market and failed within the first two years, which equals to approximately 17%, according to Bartelsman, Haltiwanger and Scarpetta (2004), is used.[36] In our model this number equals to $G(\varphi^*)$. Using the value of φ^* from this relationship in (26) leads to $f_e/f = 64$. Finally, we set $\beta = 0.5$.[37]

We want to compare the case when countries are symmetric ($k_H = k_F = 3.3$) with two cases when the home country has better productivity distribution than the foreign one, i.e., when k_H is 1% smaller than k_F and when k_H is 2% smaller than k_F.[38] This comparison depends on the value of trade costs, τ. Consider τ between 1.16 and 1.62. Figure 8 depicts the level of welfare at home and abroad.[39]As shown in Figure 8, falling trade costs, while beneficial for both countries, widen the difference in welfare of two countries: when the difference in the means of the productivity distributions is 1%[40], a fall in trade costs from 62% to 16% raises the welfare in the home and foreign countries by, respectively, 7.4% and 2% so that the difference in the welfare levels rises from 3.4% to 9%. Moreover, when $\tau = 1.16$, the welfare in the home country is 6.2% higher and the welfare in the foreign country is 2.6% lower compared to the case of symmetric countries.

Figure 9 depicts the change in welfare relative to that in autarky for each country. As shown in 9, both countries gain from trade. However, the technologically advanced country always gains more than the laggard one. Also, the larger is the technological gap between countries, the larger are the gains from falling trade costs for the advanced country. As to the backward country, falling trade costs bring lower gains to it and may even hurt it if this country is backward enough.

[36]We take this value as the best approximation of the failure rate, since according to Bartelsman, Haltiwanger and Scarpetta (2004), in the US, the time when the firm is registered differs from that when its employment is recorded, giving rise to the possibility that firms are recorded as having zero employees in the first year and positive employment in the second year, so that entrant firms include zero-employees firms.

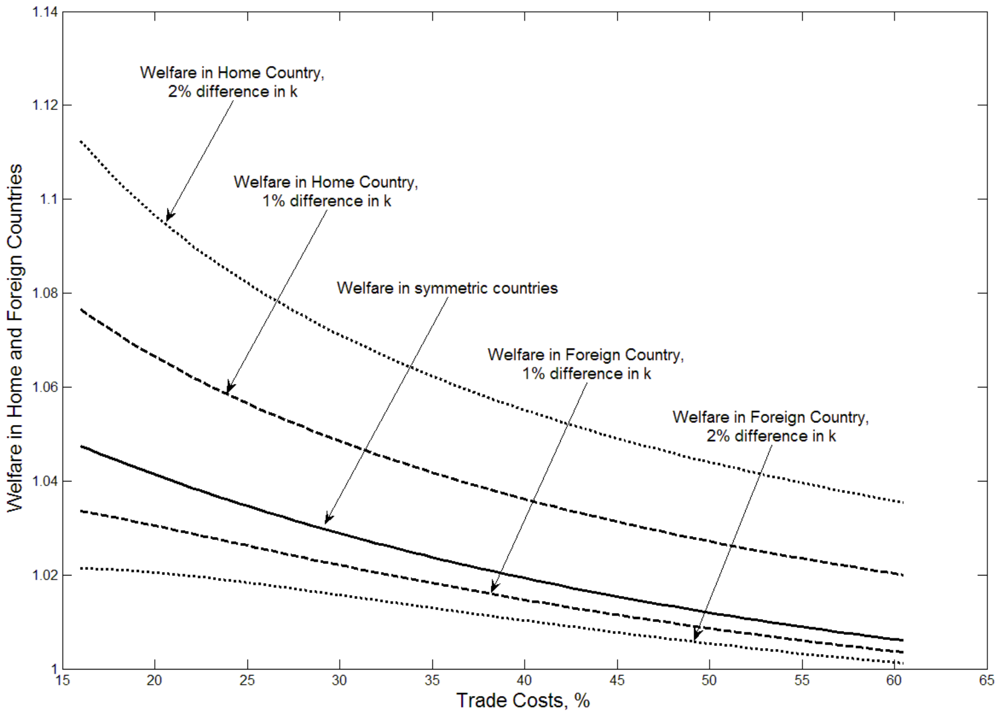
[37]Note that changes in β do not affect the values of productivity cutoffs in the equilibrium. The only way β affects the results of calibration is through welfare, which is proportional to $(\varphi^*)^\beta$. Thus, higher β will magnify any change in welfare, while lower β will make the change in welfare smaller.

[38]Note that 1% and 2% differences in the shape parameters result in approximately 0.5% and 1% differences in the distribution means, respectively.

[39]Both countries are of the same size L, which is chosen so that welfare in country i defined in (25) becomes $W_i = (\varphi_i^*)^\beta$. Note that larger L will lead to higher welfare in both countries, while lower L will make the welfare in each country smaller.

[40]Recall that this difference results from a 2% difference in k.

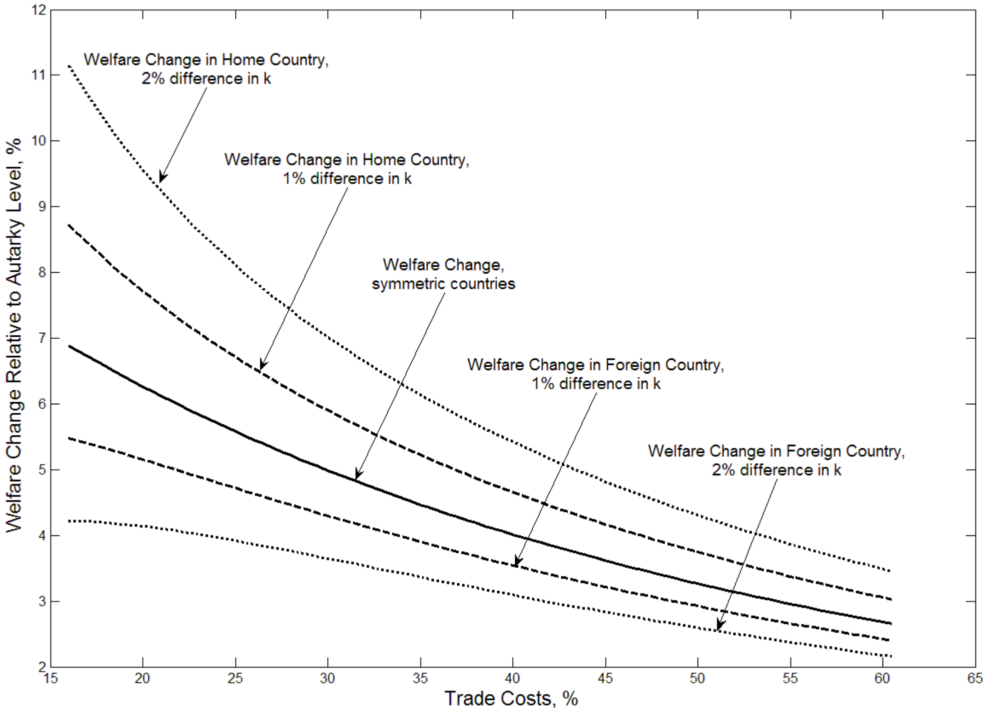
Figure 8: Welfare in Home and Foreign Countries



7 Conclusion

This paper uses a simple stochastic, general equilibrium model of international trade between two asymmetric countries, one of which has a comparative advantage over another in terms of the productivity distribution. The results are derived without resorting to simulations or imposing strong restrictions on the model. It is shown that in the absence of specialization, falling trade costs may hurt the laggard country while helping the advanced one. Moreover, productivity improvement in one country increases its technological potential, and hence, welfare but hurts its trading partner. In contrast, if a country is the only producer of the differentiated goods (the other one specializes in the homogenous good), then its welfare does not depend on the productivity distribution in the differentiated good sector abroad and the laggard country gains from productivity improvement in the advanced country.

Figure 9: Welfare Relative to Autarky Level in Home and Foreign Countries



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8 Appendix

Proof of Lemma 1. Using (8), we can write $j(\varphi^*, G_i(\cdot))$ as

$$\begin{aligned} j_i(\varphi^*) &\equiv j(\varphi^*, G_i(\cdot)) = \frac{1}{(\varphi^*)^{\sigma-1}} \int_{\varphi^*}^{\infty} \varphi^{\sigma-1} g_i(\varphi)\, d\varphi - [1 - G_i(\varphi^*)] & (27) \\ &= [1 - G_i(\varphi^*)] \left(E_i \left[\left(\frac{\varphi}{\varphi^*} \right)^{\sigma-1} \mid \varphi > \varphi^* \right] - 1 \right), \quad i = H, F. & (28) \end{aligned}$$

Thus, for any given level φ^*,

$$\begin{aligned} j_H(\varphi^*) - j_F(\varphi^*) &= [1 - G_H(\varphi^*)] \left(E_H \left[\left(\frac{\varphi}{\varphi^*} \right)^{\sigma-1} \mid \varphi > \varphi^* \right] - 1 \right) - \\ & \quad [1 - G_F(\varphi^*)] \left(E_F \left[\left(\frac{\varphi}{\varphi^*} \right)^{\sigma-1} \mid \varphi > \varphi^* \right] - 1 \right). \end{aligned}$$

If $G_H(\cdot) \succ_{hr} G_F(\cdot)$, then, for any given level φ^*, $1 - G_H(\varphi^*) > 1 - G_F(\varphi^*)$. Moreover, since $\left(\frac{\varphi}{\varphi^*}\right)^{\sigma-1}$ is increasing in φ, $E_H\left[\left(\frac{\varphi}{\varphi^*}\right)^{\sigma-1} \mid \varphi > \varphi^*\right] > E_F\left[\left(\frac{\varphi}{\varphi^*}\right)^{\sigma-1} \mid \varphi > \varphi^*\right]$. Note that $E_i\left[\left(\frac{\varphi}{\varphi^*}\right)^{\sigma-1} \mid \varphi > \varphi^*\right] > 1$, $i = H, F$. Therefore, $j_H - j_F > 0$. ■

Proof of Lemma 2. Recall that $r_i(\varphi) = \beta L (P_i \rho \varphi)^{\sigma-1}$, $r_{xi}(\varphi) = \tau^{1-\sigma} r_j(\varphi)$, $i \neq j$, $r_i(\varphi_i^*) = \sigma f$, and $r_{xi}(\varphi_{xi}^*) = \sigma f_x$. Define $A \equiv \tau \left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}}$. Then,

$$\begin{aligned} \frac{r_H(\varphi_H^*)}{r_F(\varphi_F^*)} &= 1, \Longrightarrow \frac{\varphi_H^*}{\varphi_F^*} = \frac{P_F}{P_H}; \quad \frac{r_{xH}(\varphi_{xH}^*)}{r_{xF}(\varphi_{xF}^*)} = 1, \Longrightarrow \frac{\varphi_{xH}^*}{\varphi_{xF}^*} = \frac{P_H}{P_F}, & (29) \\ \frac{r_{xi}(\varphi_{xi}^*)}{r_i(\varphi_i^*)} &= \frac{f_x}{f}, \Longrightarrow \frac{\varphi_{xH}^*}{\varphi_H^*} = A \frac{P_H}{P_F}; \quad \text{and} \quad \frac{\varphi_{xF}^*}{\varphi_F^*} = A \frac{P_F}{P_H}. & (30) \end{aligned}$$

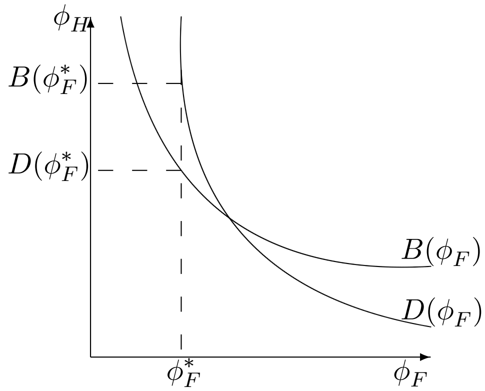
$$\text{Thus,} \quad \varphi_{xH}^* = A \varphi_F^*, \quad \varphi_{xF}^* = A \varphi_H^*. \tag{31}$$

■

The equilibrium conditions in the case of open trade. As in autarky, substituting (20) in (17) for each country leads to the system:

$$\begin{aligned} \frac{f}{\delta}(1 - G_H(\varphi_H^*)) k_H(\varphi_H^*) + \frac{f_x}{\delta}(1 - G_H(\varphi_{xH}^*)) k_H(\varphi_{xH}^*) &= f_e, & (32) \\ \frac{f}{\delta}(1 - G_F(\varphi_F^*)) k_F(\varphi_F^*) + \frac{f_x}{\delta}(1 - G_F(\varphi_{xF}^*)) k_F(\varphi_{xF}^*) &= f_e. & (33) \end{aligned}$$

Figure 10: Example



Using the definition of $j_i(\varphi)$ and Lemma 2, (21) and (22) are obtained from the system above. ■

Proof of Lemma 3. First, note that the function $j(\varphi, G_i(\cdot))$, $i = H, F$, is a decreasing function of φ.[41] Thus, both curves corresponding to equations (23) and (24) are decreasing in φ_F.

From (21), the slope of the curve corresponding to equation (23) is

$$-\frac{f_x}{f} A \frac{j_1(A\varphi_F, G_H(\cdot))}{j_1(\varphi_H, G_H(\cdot))}, \text{ where } \varphi_H \equiv B(\varphi_F) \text{ is defined by (23).}$$

From (22), the slope of the curve corresponding to equation (24) is

$$-\frac{f}{f_x} \frac{1}{A} \frac{j_1(\varphi_F, G_F(\cdot))}{j_1(A\varphi_H, G_F(\cdot))}, \text{ where } \varphi_H \equiv D(\varphi_F) \text{ is defined by (24).}$$

Note that $\varphi_H \equiv B(\varphi_F)$ and $\varphi_H \equiv D(\varphi_F)$ could differ for the same φ_F as, for example, shown in Figure 10.

The comparison of the slopes leads to :

$$\left| -\frac{f_x}{f} A \frac{j_1(A\varphi_F, G_H(\cdot))}{j_1(B(\varphi_F), G_H(\cdot))} \right| \gtrless \left| -\frac{f}{f_x} \frac{1}{A} \frac{j_1(\varphi_F, G_F(\cdot))}{j_1(AD(\varphi_F), G_F(\cdot))} \right|$$

or

$$\left(\frac{f_x}{f} \right)^2 \gtrless \frac{|j_1(B(\varphi_F), G_H(\cdot))|}{A\,|j_1(A\varphi_F, G_H(\cdot))|} \cdot \frac{|j_1(\varphi_F, G_F(\cdot))|}{A\,|j_1(AD(\varphi_F), G_F(\cdot))|}. \quad (34)$$

[41] $j_1(\varphi, G_i(\cdot)) = -\frac{1}{\varphi}(\sigma - 1)[1 - G(\varphi)][k(\varphi) + 1] < 0$. (See Melitz (2003).)

Using the formula for $j_1(\varphi, G_i(\cdot)) = -\frac{1}{\varphi}(\sigma-1)\varphi^{1-\sigma}\int_{\varphi}^{\infty} x^{\sigma-1}g_i(x)\,dx$ and Assumption 1, we obtain

$$\frac{|j_1(B(\varphi_F), G_H(\cdot))|}{A|j_1(A\varphi_F, G_H(\cdot))|} = \frac{B(\varphi_F)^{-\sigma}\int_{B(\varphi_F)}^{\infty} x^{\sigma-1}g_H(x)\,dx}{A^{1-\sigma}(\varphi_F)^{-\sigma}\int_{A\varphi_F}^{\infty} x^{\sigma-1}g_H(x)\,dx} \equiv A^{\sigma-1}\frac{B(\varphi_F)^{-\sigma}}{(\varphi_F)^{-\sigma}}Q_H, \tag{35}$$

$$\frac{|j_1(\varphi_F, G_F(\cdot))|}{A|j_1(AD(\varphi_F), G_F(\cdot))|} = \frac{A^{\sigma-1}(\varphi_F)^{-\sigma}\int_{\varphi_F}^{\infty} x^{\sigma-1}g_F(x)\,dx}{D(\varphi_F)^{-\sigma}\int_{AD(\varphi_F)}^{\infty} x^{\sigma-1}g_F(x)\,dx} \equiv A^{\sigma-1}\frac{(\varphi_F)^{-\sigma}}{D(\varphi_F)^{-\sigma}}Q_F, \tag{36}$$

where $Q_H > 1$, $Q_F > 1$. Thus, we can rewrite (34) as

$$\left(\frac{f_x}{f}A^{1-\sigma}\right)^2 \gtrless Q_H Q_F \frac{D(\varphi_F)^{\sigma}}{B(\varphi_F)^{\sigma}} \tag{37}$$

By definition, $A = \tau\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}}$. Thus, $\left(\frac{f_x}{f}A^{1-\sigma}\right)^2 = \left(\tau^{1-\sigma}\right)^2 < 1$. Note that at any intersection of two curves, i.e., when $B(\varphi_F) = D(\varphi_F)$, the right-hand side of inequality (37) equals to $Q_H Q_F > 1$. Thus, at this point, the curve corresponding to equation (23) is flatter than the curve corresponding to equation (24). This property implies the uniqueness of the intersection point, since both curves are decreasing in φ_F. (If there is another intersection, at this point, the curve corresponding to equation (23) should be steeper than the curve corresponding to equation (24), which violates the property proved above.) Note that this result does not depend on the relationship between the productivity distributions in two countries.

Second, if countries have the same productivity distribution, i.e., if they are symmetric, the intersection of two curves lies on the 45^0 line as shown in Figure 4(a) and in the equilibrium $\varphi_H^* = \varphi_F^*$. Then, if the home country faces the productivity improvement, i.e., $G_{H,A}(\cdot) \succ_{hr} G_{H,B}(\cdot)$, then from Lemma 1, $j(\varphi, G_{H,A}(\cdot)) > j(\varphi, G_{H,B}(\cdot))$ for any φ. Using this result and recalling that $j(\varphi, G_{H,n}(\cdot))$, $n = A, B$, is decreasing in φ, it can be shown that the curve corresponding to equation (23) shifts up and in the equilibrium, $\varphi_F^* < \varphi_H^* < \varphi_{xH}^* < \varphi_{xF}^*$.[42] (See Figure 4(b).) The similar result can be proved in the case when the foreign country faces the productivity

[42] Note that at the new intersection, the new curve is also flatter than that corresponding to equation (24).

improvement, i.e., $G_{F,A}(\cdot) \succ_{hr} G_{F,B}(\cdot)$.

Finally, we discuss the restrictions imposed on parameters to ensure the existence of the equilibrium. We start with Assumption 2, which means that in the equilibrium with no specialization, both countries produce the differentiated goods, thus, both (21) and (22) should hold. Therefore, from (21), we derive $\varphi_F^* \equiv s(\varphi_H^*) = \frac{1}{A} j_H^{-1}\left(\frac{\delta f_e - f j_H(\varphi_H^*)}{f_x}\right)$ and substitute it in (22) to obtain an equation just for φ_H^* :

$$\psi(\varphi_H^*) \equiv \frac{f}{\delta} j_F(s(\varphi_H^*)) + \frac{f_x}{\delta} j_F(A\varphi_H^*) = f_e. \tag{38}$$

Note that $\psi'(\varphi_H^*) > 0$. (We can use the same technique as we used to compare the slopes of curves corresponding to (23) and (24) to prove it.) From Assumption 1, $\varphi_H^* < \varphi_{xH}^* = A\varphi_F^*$. Moreover, from (23), $\varphi_H^* < j_H^{-1}\left(\frac{\delta f_e}{f_x + f}\right)$. Therefore, we can derive the necessary condition for Assumption 2: the solution of (38) exists only if $f_e < \psi\left(j_H^{-1}\left(\frac{\delta f_e}{f_x+f}\right)\right)$ or $f_e < \frac{f}{\delta} j_F\left(\frac{1}{A} j_H^{-1}\left(\frac{\delta f_e}{f_x+f}\right)\right) + \frac{f_x}{\delta} j_F\left(A j_H^{-1}\left(\frac{\delta f_e}{f_x+f}\right)\right)$.

Assumption 1 implies that for any i and j, $i \neq j$, $\frac{\varphi_i^*}{\varphi_j^*} < A$. We proved that in the equilibrium, $\varphi_H^* > \varphi_F^*$. Thus, Assumption 1 requires $\frac{\varphi_H^*}{\varphi_F^*} < A$. ($\frac{\varphi_F^*}{\varphi_H^*} < A$ follows from it.) From (38), $\varphi_H^* = \psi^{-1}(f_e)$. Recalling that $\varphi_F^* = s(\varphi_H^*)$, we derive the necessary condition for Assumption 1: $\frac{\psi^{-1}(f_e)}{s(\psi^{-1}(f_e))} < A$. ■

The price index in country i. By definition, $M_{ti} = \beta L / r_i(\tilde{\varphi}_{ti})$, where $r_i(\tilde{\varphi}_{ti}) = r_i(\varphi_i^*)\left(\frac{\tilde{\varphi}_{ti}}{\varphi_i^*}\right)^{\sigma-1} = \sigma f\left(\frac{\tilde{\varphi}_{ti}}{\varphi_i^*}\right)^{\sigma-1}$. As a result, formula (16) can be written as

$$P_i = \left(\frac{\beta L}{\sigma f}\right)^{\frac{1}{1-\sigma}} \frac{1}{\rho \varphi_i^*}. \tag{39}$$

■

Proof of Lemma 4. We need to show that $\gamma_H > \beta > \gamma_F$. Given φ_H^* and φ_F^*, the trade balance equation can be written as

$$p_{xH} M_H r_F\left(\tau^{-1}\tilde{\varphi}_{xH}\right) + (1-\gamma_H) L - (1-\beta) L = p_{xF} M_F r_H\left(\tau^{-1}\tilde{\varphi}_{xF}\right). \tag{40}$$

By using $M_i = \frac{R_i^C}{\bar{r}_i} = \gamma_i L / \bar{r}_i$, $i = H, F$, in the trade balance equation (40) and denoting $\frac{r_i(\tilde{\varphi}_i)}{p_{xi} r_j(\tau^{-1}\tilde{\varphi}_{xi})}$

by b_i, the following expression for γ_H is obtained:

$$\gamma_H = \beta \frac{(b_F - 1)(b_H + 1)}{b_H b_F - 1} = \beta \left(1 + \frac{b_F - b_H}{b_H b_F - 1}\right). \tag{41}$$

By construction, $\gamma_F = 2\beta - \gamma_H$. To prove that $\gamma_H > \beta$ (home country exports the differentiated goods), we need to show that $b_H b_F > 1$ and $b_F > b_H$. Given that $r_i(\varphi) = E_i^C (P_i \rho \varphi)^{\sigma-1}$, formula (39) leads to:

$$b_i = \tau^{\sigma-1} \frac{1}{p_{xi}} \left(\frac{\tilde{\varphi}_i}{\varphi_i^*} * \frac{\varphi_j^*}{\tilde{\varphi}_{xi}}\right)^{\sigma-1} = \tau^{\sigma-1} \frac{(\varphi_i^*)^{1-\sigma} \int_{\varphi_i^*}^{\infty} x^{\sigma-1} g_i(x)\, dx}{\left(\varphi_j^*\right)^{1-\sigma} \int_{A\varphi_j^*}^{\infty} x^{\sigma-1} g_i(x)\, dx}.$$

Thus, $b_F b_H > \tau^{2\sigma-2} > 1$. To prove that $b_F > b_H$, rewrite b_i as $b_i = \tau^{\sigma-1} A^{1-\sigma} \frac{a_i(\varphi_i^*)}{a_i(A\varphi_j^*)} = \frac{f}{f_x} \frac{a_i(\varphi_i^*)}{a_i(A\varphi_j^*)}$, $i \neq j$, where $a_i(\varphi) \equiv \varphi^{1-\sigma} \int_{\varphi}^{\infty} x^{\sigma-1} g_i(x)\, dx$ is decreasing in φ.[43] From Lemma 2, $b_F = \frac{f}{f_x} \frac{a_F(\varphi_F^*)}{a_F(A\varphi_H^*)} > \frac{f}{f_x} \frac{a_F(\varphi_H^*)}{a_F(A\varphi_F^*)}$. We want to show that $\frac{f}{f_x} \frac{a_F(\varphi_H^*)}{a_F(A\varphi_F^*)} > b_H = \frac{f}{f_x} \frac{a_H(\varphi_H^*)}{a_H(A\varphi_F^*)}$. To do this, it is enough to compare the elasticities of the decreasing functions $a_F(\cdot)$ and $a_H(\cdot)$, or, respectively, ε_F and ε_H, and prove that $\varepsilon_F > \varepsilon_H$.

$$a_i'(\varphi) = \frac{1-\sigma}{\varphi} a_i(\varphi) - g_i(\varphi) \Longrightarrow \varepsilon_i(\varphi) = -\frac{a_i'(\varphi)}{a_i(\varphi)} \varphi = (\sigma - 1) + \varphi \frac{g_i(\varphi)}{a_i(\varphi)}.$$

$$\frac{g_i(\varphi)}{a_i(\varphi)} = \frac{g_i(\varphi)}{1 - G_i(\varphi)} \left(\frac{\varphi^{1-\sigma}}{1 - G_i(\varphi)} \int_{\varphi}^{\infty} x^{\sigma-1} g_i(x)\, dx\right)^{-1}.$$

HRSD implies that $\frac{1}{1-G_H(\varphi)} \int_{\varphi}^{\infty} x^{\sigma-1} g_H(x)\, dx > \frac{1}{1-G_F(\varphi)} \int_{\varphi}^{\infty} x^{\sigma-1} g_F(x)\, dx$ and $\frac{g_F(\varphi)}{1-G_F(\varphi)} > \frac{g_H(\varphi)}{1-G_H(\varphi)}$. Thus, $g_F(\varphi)/a_F(\varphi) > g_H(\varphi)/a_H(\varphi)$, $\varepsilon_F > \varepsilon_H$, $b_F > b_H$, and $\gamma_H > \beta$. Thus, $\gamma_F < \beta$. This proves Lemma 4. ■

Productivity improvements and the volume of trade. The homogenous and differentiated good exports from the foreign country are, respectively, $[\gamma_H - \beta] L = \beta L \frac{b_F - b_H}{b_H b_F - 1}$ and $(2\beta - \gamma_H) L \frac{1}{1+b_F} = \beta L \frac{b_H - 1}{b_H b_F - 1}$. The export of differentiated goods from the home country and the volume of trade are $\gamma_H L \frac{1}{1+b_H} = \beta L \frac{b_F - 1}{b_H b_F - 1}$. By construction, $b_H(\cdot)$ is decreasing in φ_H^*, whereas b_F is increasing in φ_H^*.

[43] $a_i'(\varphi) = (1-\sigma)\varphi^{-\sigma} \int_{\varphi}^{\infty} x^{\sigma-1} g_i(x)\, dx - g_i(\varphi) < 0.$

The trade comparison is straightforward, taking the derivatives of γ_H and export functions with respect to φ_H^* and recalling that $b_F > b_H > 1$, $b_H b_F > 1$, and φ_H^* falls when the foreign country faces the productivity improvement. Thus, productivity improvement in the foreign country leads to the fall in the volume of trade ■