A Model of Trade with Ricardian Comparative Advantage and Intra-sectoral Firm Heterogeneity*

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Abstract

In this paper, we incorporate Ricardian comparative advantage into a multi-sector version of Melitz's (2003) model to explain the pattern of international specialization and trade. The model is able to capture the existence of inter-industry trade and intra-industry trade in a single unified framework. Trade liberalization can lead to a "reverse-Melitz outcome" in the two-way trade sectors in which the country has the strongest comparative disadvantage, if the country is sufficiently large or its tariff reduction is sufficiently asymmetric compared with its trading partners. In this case, the productivity cutoff for survival is lowered while the exporting cutoff increases in the face of trade liberalization, leading to reductions in real wage in terms of these goods. This is because the inter-sectoral resource allocation (IRA) effect together with the unilateral liberalization (UL) effect dominate the Melitz selection effect in these sectors. Analyses of data of Chinese manufacturing sectors confirm our hypotheses. Our model can be extended to capture the effect that, in the comparative advantage sector, it is possible that firms that sell domestically have higher average productivity than firms that do not, as documented by Lu (2010) and others.

Keywords: inter-industry trade, intra-industry trade, heterogeneous firms, trade liberalization

JEL Classification codes: F12, F14

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1 Introduction

How do firms' entry, exit, output and exporting decisions respond to trade integration and trade liberalization? Do they respond differently across sectors? How is trade pattern determined by the interaction between pattern of comparative advantage across sectors and monopolistic competition between firms within the same sector? How are trade pattern and welfare affected by globalization? We try to answer these questions by developing a model of trade with comparative advantage across sectors and intra-sectoral firm heterogeneity.

There are by and large two types of international trade: inter-industry trade and intra-industry trade. It is widely recognized that the former is driven by comparative advantage and the latter by economies of scale. The most widely used models for capturing comparative advantage are of the Ricardian type (e.g. Dornbusch, Fisher and Samuelson (DFS) 1977, Eaton and Kortum 2002) and the Heckscher-Ohlin type. The most notable models used to capture intra-industry trade are probably attributed to Krugman (1979, 1980). More recently, Melitz (2003) extends Krugman's (1980) model to analyze intra-industry trade when there is firm heterogeneity, thus capturing the selection of firms according to productivity and profit-shifting to firms of higher productivity when a country opens up to trade and trade liberalization. It stimulates much further work in this direction, notably Chaney (2008), Melitz and Ottaviano (2008), and Arkolakis (2010), to name just a few.

In this paper, we incorporate Ricardian comparative advantage into a multi-sector version of Melitz's (2003) model. By doing so, we have a model that explains how comparative advantage, economies of scale and firm selection interact to sort sectors into ones in which only one of the countries produces (where there is inter-industry trade) and ones in which both countries produce (where there is intra-industry trade). A number of testable hypotheses are generated. First, sectors in which one of the countries has strong comparative advantage would be characterized by inter-industry trade, while sectors in which neither country has strong comparative advantage would be characterized by intra-industry trade. Second, for any given country, the fraction of firms that export is higher for a sector with stronger comparative advantage. Third, we are able to understand better the causes of the welfare effect of trade liberalization. We find that we can decompose the total effect of trade liberalization into those caused by inter-sectoral resource allocation (which we call IRA effect), selection of firms effect according to productivity (which we call Melitz selection effect) and unilateral reduction of importing cost (which we call unilateral liberalization effect).

Although, like Melitz (2003), trade integration (switching from autarky to trade) is always welfare-improving, the welfare effect of trade liberalization (reduction of trade barriers) depends on the relative size of the two countries, the degree of asymmetry in trade liberalization between the two countries and the pattern of comparative advantage.

First, in the case of symmetric trade liberalization, we find that the interaction of the IRA effect and the Melitz selection effect can give rise to an outcome that is opposite to what is predicted by Melitz. For lack of a better term, we call this reverse-Melitz outcome. This is not a criticism of Melitz's work, but rather a complement of his pathbreaking contribution by pointing out richer possibilities when his model is extended to multi-sector setting. Melitz predicts that symmetric trade liberalization leads to an increase in the productivity cutoff for survival but a decrease in the exporting productivity cutoff, and this gives rise to an increase in the average productivity of the firms that serve the domestic market, leading to an increase in domestic real wage in terms of goods in the sector. Our model predicts, however, that in certain sectors of a country, symmetric trade liberalization can lead to a decrease in the productivity cutoff for survival but an increase in the exporting productivity cutoff, and this gives rise to a decrease in the average productivity of the firms that serve the domestic market, leading to domestic real wage reductions in terms of goods in these sectors. This is because the IRA effect dominates the Melitz selection effect in the sectors where the country has the strongest comparative disadvantage and yet still produces. The reason why the country can profitably produce in the sectors in which it has comparative disadvantage is the home market effect in the larger country, as explained by Krugman (1980). For this reason, the reverse-Melitz outcome cannot exist in the smaller country in a two-country setting.

Second, in the case of asymmetric trade liberalization, another reason for the existence of reverse-Melitz outcome is that the country understakes sufficiently drastic asymmetric trade liberalization compared with its trading partners. This is because unilateral reduction of iceberg importing cost in Home always leads to the reverse-Melitz outcome in all sectors in Home, while unilateral reduction of iceberg importing cost of Foreign always leads to the Melitz outcome in all sectors in Home. Therefore, if the former effect dominates the latter, we have the reverse-Melitz outcome for Home.

Therefore, upon trade liberalization, our theory predicts that there exists a reverse-Melitz outcome in the comparative disadvantage sectors and a Melitz outcome in the comparative advantage sectors, if the country is sufficiently large or its trade liberaliation is sufficiently asymmetric compared with its trading partners. In other words, in the face of trade liberalization, the fraction of exporters and the share of export revenue in total revenue both increase in the comparative advantage sectors but they both decrease in the sectors in which the country has the least comparative advantage yet still produces. The theory is confirmed by testing the hypotheses using Chinese firm-level data. China's liberalization upon its accession to WTO in 2001 fits the above conditions very well: It was large, and its trade liberaliztion was very asymmetric.

Recently, there has been some discussion of another "reverse-Melitz outcome", which is completely different from ours. Lu (2010) incorporates comparative advantage into the one-sector Melitz (2003) model and demonstrates that, in the *comparative advantage sectors*, firms that sell domestically can have higher average productivity than firms that do not. She supports her theory by the finding that in sectors where China had comparative advantage (i.e. labor-intensive sectors), Chinese firms that mainly exported were on average less productive than those that served the domestic market. Does her theoretical and empirical findings contradict our theory or empirical finding here? The answer is no. First, as far as theory is concerned, our model can be easily modified to yield the same theoretical prediction as Lu by making a slight change in the assumption about market-entry costs, namely, assuming that a firm needs to incur a market entry cost if it enters a market, be it domestic or foreign. Second, even with this modification, all the propositions in our paper remain the same. Most importantly, the model continues to yield our reverse-Melitz outcome. In addition, the modified model throws light on how the peculiar feature of the Chinese exporting sector (namely the existence of a large fraction of firms engaging in processing trade) can possibly explain Lu's emprical findings.

The introduction of comparative advantage in a multi-sector Melitz model captures a number of effects that a one-sector Melitz model without comparative advantage cannot. Moreover, these interesting effects indeed occur in the real world, as revealed by the empirical evidence of this paper and Lu's (2010).

In the recent theoretical literature modeling open economy with heterogeneous firms, papers by Okubo (2009) and Bernard, Redding and Schott (2007) are the closest to ours. Like us, Okubo (2009) also introduces multiple sectors into the Melitz model, thus making it a hybrid of the multiple-sector Ricardian model and the Melitz model. In the two-sector case he analyzes the general equilibrium effects, allowing the endogenous determination of the relative wage. But the focus of his paper is quite different from ours, though there are some similarities. He mainly focuses on changes in population and the effects on the number of varieties. We mainly focus on how the strength of comparative advantage of a sector affects firm selection under trade liberalization. We analyze and obtain closed form solution of the international pattern of specialization and trade as a function of trade barriers, relative country size and Ricardian comparative advantage. We decompose the total effect of trade liberalization into the IRA effect, the unilateral liberalization effect and Melitz selection effect, and explain the condition under which the Melitz selection effect is dominated by the other two effects. Most importantly, we identify the conditions under which there exists a reverse-Melitz outcome (accompanied by the lowering of real wage) from trade liberalization in certain sectors or even the entire economy. We carry out empirical tests of the hypotheses while he does not conduct any empirical tests.

Bernard, Redding and Schott (2007) incorporate firm heterogeneity into a two-sector, two-country Heckscher-Ohlin model, and analyze how falling trade costs lead to the reallocation of resources, both within and across industries. Inter-sectoral resource reallocation changes the ex-ante comparative advantage and provides a new source of welfare gains from trade as well as causes redistribution of income across factors. In their paper, trade liberalization raises the productivity cutoff for survival and lowers the exporting productivity cutoff in both industries, with the effect being disproportionately larger in the comparative advantage sectors. Therefore, there is no reverse-Melitz outcome in their paper.[1]

One could have captured inter-industry trade and intra-industry trade in a unified model without assuming firm heterogeneity.[2] As is found elsewhere in the literature, the aggregate results remain about the same whether or not firm heterogeneity is assumed. Probably the largest benefit from incorporating firm heterogeneity is that we are able to use firm level data to confront some of the hypotheses. For example, some propositions contain predictions about the variation in the percentage of firms that export across sectors. Such propositions cannot be derived from a model with homogeneous firms.

[1]Other papers analyzing the effects of trade liberalization based on Melitz-type models include Baldwin and Forslid (2006) and Pfluger and Russek (2010).

[2]For example, Helpman and Krugman (1985) integrate the inter-industry trade and intra-industry trade model with homogeneous firms.

The paper is organized as follows. Section 2 presents the model with heterogeneous firms in the closed economy and examines the properties of the equilibrium. In section 3, we carry out an analysis of the equilibrium in the open economy. We analyze the pattern of specialization and trade and identify the existence of inter-industry trade as well as intra-industry trade. In section 4, we show the impact of opening up to trade on the productivity cutoffs and welfare in each sector. In section 5, we analyze the effects of both symmetric and asymmetric trade liberalization, and demonstrate the existence of a reverse-Melitz outcome in the most comparative disadvantage two-way trade sectors when the country is sufficiently large or trade liberalization is sufficiently asymmetric. In section 6, we extend our model by modifying our assumption to allow for the possibility that some firms only export but do not serve the domestic market. After modification, all previous propositions remain unchanged, but the model now yields predictions consistent with theoretical and empirical findings by Lu (2010). In section 7, empirical tests of the main propositions in section 5 are carried out. Section 8 concludes.

2 A Closed-economy Model

In this section, we shall describe the features of a closed economy, but where necessary we also touch upon some features of a two-country model when the closed economy opens up to trade. The closed economy is composed of multiple sectors: a homogenous-good sector, and a continuum of sectors of differentiated goods. There is only one factor input called labor. The homogeneous good is produced using a constant returns to scale technology. It is freely traded with zero trade costs when the country is opened up to trade. Firms are free to choose the sectors into which they enter. We assume that in order to produce a differentiated good, a firm has to pay a sunk cost of entry. After entry, a firm decides whether or not to produce according to whether the expected present discounted value of its economic profit is non-negative after its firm-specific productivity has realized. The economic profit is determined by the following factors. There is a fixed cost of production per period, and a constant marginal cost of production. The fixed cost of production is the same for all firms but the marginal cost of production of a firm is partly determined by a random draw from a distribution. Upon payment of the entry cost f_e, the firm earns the opportunity to make a random draw from a distribution of firm productivity. The draw will determine the firm-specific component of the firm's productivity (i.e. reciprocal of the unit labor requirement for production). The above characterizations of the model are basically drawn from Melitz (2003). Unlike Melitz, there is another factor that affects the variable cost of production of a firm, which is an exogenously determined sector-specific technological level. In general, this technological level differs across sectors in a country as well as differs across countries within the same sector. The set of sector-specific technological levels across sectors in both countries determine the pattern of comparative advantage across sectors of each country.

There are L consumers, each supplying one unit of labor. Preferences are defined by a nested Cobb-Douglas function:

$$\ln U = \alpha \ln C_h + \int_0^1 b_k \ln C_k dk \tag{1}$$

$$C_k = \left[\int_0^{\theta_k} c_k(j)^\rho dj\right]^{\frac{1}{\rho}} \text{ with } \int_0^1 b_k dk = 1-\alpha \text{ and } 0<\rho<1, \tag{2}$$

where α denotes the share of expenditure on the homogenous good, b_k is the share of expenditure on differentiated good $k \in [0,1]$; θ_k is the endogenously determined mass of varieties in differentiated-good sector k. The homogeneous good is produced with constant unit labor requirement $1/A_h$. The price of the homogeneous good is w/A_h, where w is the wage, as it is produced and sold under perfect competition. For the differentiated-goods sectors, the exact price index for each sector is denoted by P_k, where

$$P_k = \left[\int_0^{\theta_k} p_k(j)^{1-\sigma} dj\right]^{\frac{1}{1-\sigma}}, \text{ where } \infty > \sigma = \frac{1}{1-\rho} > 1$$

where $p_k(j)$ denotes the price of variety j in sector k, and σ denotes the elasticity of substitution between varieties. Cost minimization by firms implies that the gross revenue of firm j in sector k is given by

$$r_k(j) = b_k E \left[\frac{p_k(j)}{P_k}\right]^{1-\sigma} \tag{3}$$

where $E = wL$ denotes the total expenditure on all goods.

The labor productivity of a firm in the differentiated-good sector k is the product of two terms: one is a firm-specific, random variable φ_k following a Pareto distribution $P(1,\gamma) = 1 - \left(\frac{1}{\varphi_k}\right)^\gamma$ where $\varphi_k \in [1,\infty]$ and γ ($> \sigma - 1$) is the shape parameter of the distribution;[3] the other is A_k, which is exogenous and sector-specific. The labor productivity of a firm is thus equal to $A_k\varphi_k$. Production labor employed by firm j in sector k is a linear function of output $y_k(j)$:

$$l_k(j) = f + \frac{y_k(j)}{A_k\varphi_k(j)},$$

where f is the fixed cost of production per period, and $A_k\varphi_k(j)$ is the productivity of firm j in sector k. Therefore, under monopolistic competition in sector k the profit-maximizing price is given by

$$p_k(j) = \frac{w}{\rho A_k \varphi_k(j)} \tag{4}$$

Note that we could allow γ and σ to be different across sectors and still obtain all the propositions of this paper, but the derivation would be very tedious and no additional insights are obtained.

(3) and (4) imply that the flow of profit of firm j in sector k is given by

$$\pi_k(j) = \frac{r_k(j)}{\sigma} - fw = \frac{b_k wL\left[P_k w^{-1}\rho A_k\varphi_k(j)\right]^{\sigma-1}}{\sigma} - fw$$

[3] The assumption $\gamma > \sigma - 1$ ensures that, in equilibrium, the size distribution of firms has a finite mean.

If a firm draws too low a productivity, it will exit immediately, as its expected economic profit is negative. Denote the cutoff productivity for a firm to survive in sector k by $\overline{\varphi}_k$. We shall call this the productivity cutoff for survival. Then, the aggregate (exact) price index in sector k can be rewritten as

$$P_k = \left\{ \theta_k \int_{\overline{\varphi}_k}^{\infty} [p_k(\varphi)]^{1-\sigma} \frac{g(\varphi)}{1-G(\overline{\varphi}_k)} d\varphi \right\}^{\frac{1}{1-\sigma}} = \theta_k^{\frac{1}{1-\sigma}} p_k(\widetilde{\varphi}_k),$$

where $p_k(\varphi) \equiv \frac{w}{\rho A_k \varphi}$, $G(\varphi)$ is the c.d.f. of the distribution of the firm-specific component of productivity φ in the sector and $g(\varphi)$ is its p.d.f. The function $G(\varphi)$ is the same for all sectors. Moreover,

$$p_k(\widetilde{\varphi}_k) = \frac{w}{\rho A_k \widetilde{\varphi}_k}$$

where $\widetilde{\varphi}_k$ can be interpreted as the "average" productivity in sector k. It can be easily shown that

$$\begin{aligned} \widetilde{\varphi}_k &= \left[\int_{\overline{\varphi}_k}^{\infty} \varphi^{\sigma-1} \frac{g(\varphi)}{1-G(\overline{\varphi}_k)} d\varphi \right]^{\frac{1}{\sigma-1}} \\ &= \left(\frac{\gamma}{\gamma-\sigma+1} \right)^{\frac{1}{\sigma-1}} \overline{\varphi}_k \end{aligned} \tag{5}$$

The zero cutoff profit (ZCP) condition determines the productivity $\overline{\varphi}_k$ of the marginal firm that makes zero expected economic profits:

$$\sigma f w = r_k(\overline{\varphi}_k) = \frac{b_k w L}{\theta_k} \left(\frac{\overline{\varphi}_k}{\widetilde{\varphi}_k} \right)^{\sigma-1} = \frac{b_k w L}{\theta_k} \left(\frac{\gamma-\sigma+1}{\gamma} \right) \qquad \text{(ZCP)} \tag{6}$$

As more firms enter, the cutoff productivity increases. This in turn lowers the probability of surviving after entry. So, when the cutoff productivity becomes sufficiently high, there will be no more entry. More precisely, the free entry (FE) condition, which relates the cutoff productivity to the entry cost f_e, is given by

$$f_e w = p_{in} \widetilde{\pi}_k = [1 - G(\overline{\varphi}_k)]\, \widetilde{\pi}_k \qquad \text{(FE)} \tag{7}$$

where $p_{in} \equiv 1 - G(\overline{\varphi}_k)$ is the ex-ante probability of successful entry; $\widetilde{\pi}_k \equiv \pi_k(\widetilde{\varphi}_k)$ is the net average profit of a surviving firm, which is equal to $fw \left[\left(\frac{\widetilde{\varphi}_k}{\overline{\varphi}_k} \right)^{\sigma-1} - 1 \right] = fw \left(\frac{\sigma-1}{\gamma-\sigma+1} \right)$ according to the ZCP condition (6) and equation (5).[4]

Solving for the above system of 2 equations, (6) and (7), for 2 unknowns, we can get

$$(\overline{\varphi}_k)^{\gamma} = \left(\frac{\sigma-1}{\gamma-\sigma+1} \right) \frac{f}{f_e} \equiv D_1; \qquad \theta_k = \left(\frac{\gamma-\sigma+1}{\gamma} \right) \frac{b_k}{\sigma f} L \equiv D_2(k) \cdot L$$

Therefore, the fraction of firms that can successfully enter, $1 - G(\overline{\varphi}_k)$, is the same across sectors. However, the actual cutoff productivity, $A_k \overline{\varphi}_k$, still differs across sectors. From now on, we assume $\left(\frac{\sigma-1}{\gamma-\sigma+1} \right) \frac{f}{f_e} \geq 1$, in order to avoid corner solution.

[4] $\widetilde{\pi}_k \equiv \pi_k(\widetilde{\varphi}_k) = \frac{r_k(\widetilde{\varphi}_k)}{\sigma} - fw = \frac{1}{\sigma} \left(\frac{\widetilde{\varphi}_k}{\overline{\varphi}_k} \right)^{\sigma-1} r_k(\overline{\varphi}_k) - fw = fw \left[\left(\frac{\widetilde{\varphi}_k}{\overline{\varphi}_k} \right)^{\sigma-1} - 1 \right] = fw \left(\frac{\sigma-1}{\gamma-\sigma+1} \right)$. The third equality arises from the fact that $\left(\frac{\widetilde{\varphi}_k}{\overline{\varphi}_k} \right)^{\sigma-1} = \frac{r_k(\widetilde{\varphi}_k)}{r_k(\overline{\varphi}_k)}$. The fourth equality stems from the fact that $\sigma f w = r_k(\overline{\varphi}_k)$, which is the ZCP condition (6). The fifth equality comes from (5).

Lemma 1 *In the closed economy, the fraction of firms that can successfully enter is independent of A_k. The number of firms in each sector is also independent of A_k.*

Note that Lemma 1 holds even if σ and γ differ across sectors.

The intuition for $\overline{\varphi}_k$ to be independent of A_k is that an increase in A_k causes a firm's optimal price to decrease, and as a result, the aggregate price for this sector decreases as well. Consequently, each firm's optimal price relative to the sectoral aggregate price is unchanged so that the expected profit of each firm does not change. As a result, the fraction of firms that can successfully enter is independent of A_k. Note that though the increase in A_k does not affect the number of firms in the sector, it improves consumers' welfare due to the increased output of each firm.

3 An Open-economy Model

In this section, we consider a global economy with two countries: Home and Foreign. We attach an asterisk to all the variables pertaining to Foreign. We index sectors such that as the index increases Home's comparative advantage strengthens. In other words, the sector-specific relative productivity $a(k) \equiv a_k \equiv \frac{A_k}{A_k^*}$ increases in $k \in [0, 1]$. Therefore, $a'(k) > 0$.

On the demand side, we assume that consumers in both countries have identical tastes:

$$\ln U = \alpha \ln C_h + \int_0^1 b_k \ln C_k dk \qquad \text{with } \int_0^1 b_k dk = 1 - \alpha$$
$$\text{and } C_k = \left(\int_0^{\theta_k} c_k(i)^\rho di + \int_0^{\theta_k^*} c_k^*(j)^\rho dj \right)^{\frac{1}{\rho}}$$

On the production side, the labor productivity in the homogeneous good sector are respectively A_h and A_h^* in Home and Foreign. In the rest of the paper, we assume that the homogeneous good sector is sufficiently large so that the homogeneous good is produced in both countries.[5] We also assume that there is no trade cost associated with the homogeneous good. Therefore free trade of homogeneous goods implies that the wage ratio is determined by relative labor productivity in the sector, i.e. $\omega \equiv \frac{w}{w^*} = \frac{A_h}{A_h^*}$, where w^* denotes Foreign's wage. Without loss of generality, we assume that $\frac{A_h}{A_h^*} = 1$ and normalize by setting $w^* = 1$. Therefore, in equilibrium $w = w^* = 1$. The specification on technology in the differentiated-good sectors is the same as in the closed economy. The assumptions of a freely traded outside good that is produced by all countries, and Pareto distribution of firm productivity in each differentiated-good sector, greatly simplify the analysis.[6]

[5] The sufficient condition is $\alpha > \max\left\{\frac{L}{L+L^*}, \frac{L^*}{L+L^*}\right\}$. However, this is just a sufficient, not necessary, condition. In general, we do not need such a strong assumption on α, as each country usually both imports and exports differentiated goods. If trade in differentiated goods is close to balanced, α can be much smaller.

[6] In adopting these assumptions, we follow Chaney (2008), who was probably the first to make these assumptions to simplify the analysis.

The subscript "dk" pertains to a domestic firm serving the domestic market in sector k, the subscript "xk" pertains to a domestic firm serving the foreign market in sector k, and the subscript "k" pertains to sector k regardless of who serves the market. For the differentiated-good sectors, each firm's profit-maximizing price in the domestic market is given, as before, by $p_{dk}(j) = \frac{1}{\rho A_k \varphi_k(j)}$. But Home's exporting firms will set higher prices in Foreign's market due to the existence of an iceberg trade cost, such that τ (> 1) units of goods have to be shipped from the source in order for one unit to arrive at the destination. Therefore, the optimal export price of a Home-produced good sold in Foreign is given by $p_{xk}(j) = \frac{\tau}{\rho A_k \varphi_k(j)}$. Similarly, Foreign's firms' pricing rules are given by $p^*_{dk}(j) = \frac{1}{\rho A^*_k \varphi^*_k(j)}$ and $p^*_{xk}(j) = \frac{\tau}{\rho A^*_k \varphi^*_k(j)}$. Following Melitz (2003), we initially assume that trade costs are symmetrical so that iceberg importing cost of Home is the same as that of Foreign. In addition to the iceberg trade cost, the exporting firm has to bear a fixed cost of exporting, f_x, which is the same for all firms.

3.1 Firm entry and exit

According to the firms' pricing rules, the gross revenue and net profit of firm j in differentiated sector k from domestic sales for Home's firms are, respectively:

$$r_{dk}(j) = b_k L \left[\frac{p_{dk}(j)}{P_k}\right]^{1-\sigma},$$
$$\pi_{dk}(j) = \frac{r_{dk}(j)}{\sigma} - f.$$

The expressions for the corresponding variables for Foreign's firms, $r^*_{dk}(j)$ and $\pi^*_{dk}(j)$, are defined analogously. The variables P_k and P^*_k are the aggregate price index in sector k of goods sold in Home and Foreign, respectively. Their expressions are given in equation (8) below. Following the same logic, the gross exporting revenue and net profit of firm j in sector k for Home's firms are, respectively:

$$r_{xk}(j) = b_k L^* \left[\frac{p_{xk}(j)}{P^*_k}\right]^{1-\sigma},$$
$$\pi_{xk}(j) = \frac{r_{xk}(j)}{\sigma} - f_x.$$

The expressions for the corresponding variables for Foreign's firms, $r^*_{xk}(j)$ and $\pi^*_{xk}(j)$, are defined analogously. Let $\overline{\varphi}_{dk}$ and $\overline{\varphi}_{xk}$ denote productivity cutoffs in sector k for domestic sales and exporting respectively for Home's firms; $\overline{\varphi}^*_{dk}$ and $\overline{\varphi}^*_{xk}$ denote the corresponding variables for Foreign. Consequently, the mass of exporting firms from Home is equal to:

$$\theta_{xk} = \frac{1 - G(\overline{\varphi}_{xk})}{1 - G(\overline{\varphi}_{dk})}\theta_{dk} = \left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}_{xk}}\right)^{\gamma}\theta_{dk}$$

where θ_{dk} denotes the mass of operating firms in Home. The corresponding expression relating the variables θ^*_{xk} and θ^*_{dk} for Foreign are defined analogously. Then, in differentiated-good sector k, the mass of varieties available to consumers in Home is equal to

$$\theta_k = \theta_{dk} + \theta^*_{xk}$$

and θ_k^* is defined analogously. The aggregate price indexes are given by:

$$P_k = (\theta_k)^{\frac{1}{1-\sigma}} \, p_{dk}(\widetilde{\varphi}_k), \qquad P_k^* = (\theta_k^*)^{\frac{1}{1-\sigma}} \, p_{dk}^*(\widetilde{\varphi}_k^*) \tag{8}$$

where $\widetilde{\varphi}_k$ and $\widetilde{\varphi}_k^*$ denote the aggregate productivity in differentiated sector k for goods sold in Home and Foreign, respectively. They are given respectively by:

$$(\widetilde{\varphi}_k)^{\sigma-1} = \frac{1}{\theta_k}\left[\theta_{dk}\left(\widetilde{\varphi}_{dk}\right)^{\sigma-1} + \theta_{xk}^*\left(\tau^{-1}\frac{1}{a_k}\widetilde{\varphi}_{xk}^*\right)^{\sigma-1}\right], \tag{9}$$

$$(\widetilde{\varphi}_k^*)^{\sigma-1} = \frac{1}{\theta_k^*}\left[\theta_{dk}^*\left(\widetilde{\varphi}_{dk}^*\right)^{\sigma-1} + \theta_{xk}\left(\tau^{-1}a_k\widetilde{\varphi}_{xk}\right)^{\sigma-1}\right] \tag{10}$$

where $\widetilde{\varphi}_{dk}$ ($\widetilde{\varphi}_{dk}^*$) and $\widetilde{\varphi}_{xk}$ ($\widetilde{\varphi}_{xk}^*$) denote respectively the aggregate productivity level of all of Home's (Foreign's) operating firms and Home's (Foreign's) exporting firms.[7] The relationships between $\widetilde{\varphi}_{dk}$ and $\overline{\varphi}_{dk}$, between $\widetilde{\varphi}_{dk}^*$ and $\overline{\varphi}_{dk}^*$, between $\widetilde{\varphi}_{xk}$ and $\overline{\varphi}_{xk}$, and between $\widetilde{\varphi}_{xk}^*$ and $\overline{\varphi}_{xk}^*$, are exactly the same as in the closed economy, namely equation (5). That is, $\widetilde{\varphi}_{sk} = \left(\frac{\gamma}{\gamma-\sigma+1}\right)^{\frac{1}{\sigma-1}} \overline{\varphi}_{sk}$ and $\widetilde{\varphi}_{sk}^* = \left(\frac{\gamma}{\gamma-\sigma+1}\right)^{\frac{1}{\sigma-1}} \overline{\varphi}_{sk}^*$ for $s = x, d$. From the above equations, it is obvious that these aggregate productivity measures as well as aggregate price indexes are functions of $(\overline{\varphi}_{dk}, \overline{\varphi}_{dk}^*, \overline{\varphi}_{xk}, \overline{\varphi}_{xk}^*, \theta_{dk}, \theta_{dk}^*)$. As will be shown below, as long as $\frac{f_x}{f}$ is sufficiently large, an entering firm will produce only if it can generate positive expected profit by selling domestically, and export only if it can generate positive expected profit by selling abroad.[8] Then we have the following four zero cutoff profit conditions

$$r_{dk}(\overline{\varphi}_{dk}) = b_k L \left(P_k \rho A_k \overline{\varphi}_{dk}\right)^{\sigma-1} = \sigma f \tag{11}$$

$$r_{dk}^*(\overline{\varphi}_{dk}^*) = b_k L^* \left(P_k^* \rho A_k^* \overline{\varphi}_{dk}^*\right)^{\sigma-1} = \sigma f \tag{12}$$

$$r_{xk}(\overline{\varphi}_{xk}) = b_k L^* \left(\frac{P_k^*}{\tau}\rho A_k \overline{\varphi}_{xk}\right)^{\sigma-1} = \sigma f_x \tag{13}$$

$$r_{xk}^*(\overline{\varphi}_{xk}^*) = b_k L \left(\frac{P_k}{\tau}\rho A_k^* \overline{\varphi}_{xk}^*\right)^{\sigma-1} = \sigma f_x \tag{14}$$

Define $\widetilde{\pi}_k$ and $\widetilde{\pi}_k^*$ as the average profit flow of a surviving firm in sector k in Home and Foreign

[7] The derivation of the above two equations are available from the corresponding author's homepage at http://ihome.ust.hk/~elai/ or upon request.

[8] The condition is $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$. If this condition is not satisfied, then there exist some sectors in which all firms export (besides serving the domestic market).

respectively. It can be easily shown that[9]

$$\widetilde{\pi}_k = \pi_{dk}(\widetilde{\varphi}_{dk}) + \left[\frac{1 - G(\overline{\varphi}_{xk})}{1 - G\left(\overline{\varphi}_{dk}\right)}\right] \pi_{xk}(\widetilde{\varphi}_{xk}) = \frac{\sigma - 1}{\gamma - \sigma + 1}\left[f + \left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}_{xk}}\right)^{\gamma} f_x\right]$$

$$\widetilde{\pi}_k^* = \pi_{dk}^*(\widetilde{\varphi}_{dk}^*) + \left[\frac{1 - G(\overline{\varphi}_{xk}^*)}{1 - G\left(\overline{\varphi}_{dk}^*\right)}\right] \pi_{xk}^*(\widetilde{\varphi}_{xk}^*) = \frac{\sigma - 1}{\gamma - \sigma + 1}\left[f + \left(\frac{\overline{\varphi}_{dk}^*}{\overline{\varphi}_{xk}^*}\right)^{\gamma} f_x\right].$$

These are analogous to the equation shown in footnote 4 for the closed economy. The potential entrant will enter if her expected post-entry profit is above the cost of entry. Hence, the free entry (FE) conditions for Home and Foreign are, respectively

$$f_e = \left[1 - G\left(\overline{\varphi}_{dk}\right)\right] \widetilde{\pi}_k = \left(\frac{\sigma - 1}{\gamma - \sigma + 1}\right)\left[f \cdot \left(\overline{\varphi}_{dk}\right)^{-\gamma} + f_x \cdot \left(\overline{\varphi}_{xk}\right)^{-\gamma}\right] \tag{15}$$

$$f_e = \left[1 - G\left(\overline{\varphi}_{dk}^*\right)\right] \widetilde{\pi}_k^* = \left(\frac{\sigma - 1}{\gamma - \sigma + 1}\right)\left[f \cdot \left(\overline{\varphi}_{dk}^*\right)^{-\gamma} + f_x \cdot \left(\overline{\varphi}_{xk}^*\right)^{-\gamma}\right] \tag{16}$$

3.2 General equilibrium

Assuming that both countries produce in sector k, given the wage ratio $A_h/A_h^* = 1$, we can solve for $(\overline{\varphi}_{dk}, \overline{\varphi}_{dk}^*, \overline{\varphi}_{xk}, \overline{\varphi}_{xk}^*, \theta_{dk}, \theta_{dk}^*)$ from the four zero cutoff profit conditions and two free entry conditions (11) to (16) since the aggregate prices are functions of these six variables (for details, please refer to Appendix A). The solutions are given below.

$$\left(\overline{\varphi}_{dk}\right)^{\gamma} = D_1\left[\frac{B - B^{-1}}{B - \left(a_k\right)^{\gamma}}\right] \tag{17}$$

$$\left(\overline{\varphi}_{dk}^*\right)^{\gamma} = D_1\left[\frac{B - B^{-1}}{B - \left(a_k\right)^{-\gamma}}\right] \tag{18}$$

$$\overline{\varphi}_{xk} = \left(\frac{B f_x}{f}\right)^{\frac{1}{\gamma}} \frac{\overline{\varphi}_{dk}^*}{a_k} \tag{19}$$

$$\overline{\varphi}_{xk}^* = \left(\frac{B f_x}{f}\right)^{\frac{1}{\gamma}} a_k \overline{\varphi}_{dk} \tag{20}$$

$$\theta_{dk} = D_2\left(k\right)\left[\frac{BL - \frac{B - (a_k)^{\gamma}}{B (a_k)^{\gamma} - 1} L^*}{B - B^{-1}}\right] \tag{21}$$

$$\theta_{dk}^* = D_2\left(k\right)\left[\frac{BL^* - \frac{B (a_k)^{\gamma} - 1}{B - (a_k)^{\gamma}} L}{B - B^{-1}}\right] \tag{22}$$

[9] $\widetilde{\pi}_{dk} \equiv \pi_{dk}(\widetilde{\varphi}_{dk}) = \frac{r_{dk}(\widetilde{\varphi}_{dk})}{\sigma} - f = \frac{1}{\sigma}\left(\frac{\widetilde{\varphi}_{dk}}{\overline{\varphi}_{dk}}\right)^{\sigma-1} r_{dk}(\overline{\varphi}_{dk}) - f = f\left[\left(\frac{\widetilde{\varphi}_{dk}}{\overline{\varphi}_{dk}}\right)^{\sigma-1} - 1\right] = f \cdot \frac{\sigma-1}{\gamma-\sigma+1}$. The third equality arises from the fact that $\left(\frac{\widetilde{\varphi}_{dk}}{\overline{\varphi}_{dk}}\right)^{\sigma-1} = \frac{r_{dk}(\widetilde{\varphi}_{dk})}{r_{dk}(\overline{\varphi}_{dk})}$. The fourth equality comes from the fact that $\sigma f = r_{dk}(\overline{\varphi}_{dk})$, which is the ZCP condition above. The fifth equality comes from equation (5). Furthermore, $\widetilde{\pi}_{xk} = f_x\left(\frac{\sigma-1}{\gamma-\sigma+1}\right)$ can be derived from similar steps as above by replacing the subscript "d" by "x" and the variable f by f_x. Finally, note that $1 - G(\varphi) = \varphi^{-\gamma}$.

where $B \equiv \tau^{\gamma}\left(\frac{f_x}{f}\right)^{\frac{\gamma}{\sigma-1}-1}$. The variable B can be interpreted as a summary measure of trade barriers; a_k can be interpreted as competitiveness of Home in differentiated goods sector k. Recall that $a_k'(k) > 0$ is assumed.

In a one-sector model, Melitz (2003) imposes the condition $\tau^{\sigma-1} f_x > f$ so as to ensure that some firms produce exclusively for their domestic market in both countries. In this paper, we adopt a more stringent condition, $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$, so as to ensure that, in each country, some firms sell exclusively to their domestic market in all sectors.[10] This condition implies that $B > 1$.[11]

According to equations (21) and (22) Home's firms will exit sector k when $\theta_{dk} \le 0$, and Foreign's firms will exit the sector if $\theta^*_{dk} \le 0$. This implies that $B^{-1}\frac{B-(a_k)^{\gamma}}{B(a_k)^{\gamma}-1} < \frac{L}{L^*} < B\frac{B-(a_k)^{\gamma}}{B(a_k)^{\gamma}-1}$ is needed for both countries to produce positive outputs in sector k, otherwise there will be complete dominance by one country in the sector and one-way trade. Rearranging these inequalities, we can sort the sectors into three types according to Home's strength of comparative advantage. Home will not produce in sector k *iff* $k \le k_1$, where k_1 satisfies

$$(a_{k_1})^{\gamma} = \frac{B\left(\frac{L}{L^*}+1\right)}{B^2\frac{L}{L^*}+1}; \tag{23}$$

and Foreign will not produce in sector k *iff* $k \ge k_2$, where k_2 satisfies[12]

$$(a_{k_2})^{\gamma} = \frac{B^2\frac{L^*}{L}+1}{B\left(\frac{L^*}{L}+1\right)}. \tag{24}$$

Therefore, the solutions to (17)-(22) are valid if and only if $k \in (k_1, k_2)$. It is clear that $k \in (k_1, k_2)$ implies that $(a_k)^{\gamma} \in \left(\frac{1}{B}, B\right)$ for any possible GDP ratio L/L^*, which ensures that the productivity cutoffs will never reach the corner for the sectors in which both countries produce.

When $k \notin (k_1, k_2)$, the number of firms in one of the countries solved from the system (17)-(22) is negative. In that case, there is no interior solution to some of the equations in the system. This reflects the fact that no firms from that country enters in sector k, which means that the other country completely dominates that sector. Therefore, a different set of equations need to be solved for this case. Without loss of generality, we consider the **Home-dominated sectors**. As there is no competition from Foreign's firms when Home's firms sell in Foreign, the aggregate price indexes become

[10] The proof is straightforward. From Table 1, we see that $\overline{\varphi}_{dk} < \overline{\varphi}_{xk} \Leftrightarrow \frac{f_x}{f} > \frac{1}{B}\cdot\frac{B(a_k)^{\gamma}-1}{B-(a_k)^{\gamma}}$. Similarly, $\overline{\varphi}^*_{dk} < \overline{\varphi}^*_{xk} \Leftrightarrow \frac{f_x}{f} > \frac{1}{B}\cdot\frac{B-(a_k)^{\gamma}}{B(a_k)^{\gamma}-1}$. Equations (21) and (22) imply that $\frac{1}{B}\cdot\frac{B(a_k)^{\gamma}-1}{B-(a_k)^{\gamma}} \le \frac{L^*}{L}$ and $\frac{1}{B}\cdot\frac{B-(a_k)^{\gamma}}{B(a_k)^{\gamma}-1} \le \frac{L}{L^*}$ for $k \in [k_1, k_2]$, where $\theta_{dk} \ge 0$ and $\theta^*_{dk} \ge 0$. Hence $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ is a sufficient condition for $\overline{\varphi}_{dk} < \overline{\varphi}_{xk}$ and $\overline{\varphi}^*_{dk} < \overline{\varphi}^*_{xk}$ for all two-way trade sectors.

In addition, Table 1 shows that $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ is also a sufficient condition for $\overline{\varphi}_{dk} < \overline{\varphi}_{xk}$ and $\overline{\varphi}^*_{dk} < \overline{\varphi}^*_{xk}$ (whenever the country produces) for all one-way trade sectors.

[11] As $\tau > 1$, $\frac{f_x}{f} \ge 1$, and $\gamma > \sigma - 1$, it is obvious that $B \equiv \tau^{\gamma}\left(\frac{f_x}{f}\right)^{\frac{\gamma}{\sigma-1}-1} > 1$ under our condition.

[12] Because $\frac{B^2\frac{L^*}{L}+1}{B\left(\frac{L^*}{L}+1\right)} > \frac{B\left(\frac{L}{L^*}+1\right)}{B^2\frac{L}{L^*}+1}$ holds as long as $B > 1$, we always have $k_1 < k_2$.

$$P_k = (\theta_{dk})^{\frac{1}{1-\sigma}} \frac{1}{\rho A_k \widetilde{\varphi}_{dk}}$$
$$P_k^* = (\theta_{xk})^{\frac{1}{1-\sigma}} \frac{\tau}{\rho A_k \widetilde{\varphi}_{xk}}$$

Accordingly, the two zero cutoff profit conditions for Home (11) and (13) continue to hold.

As the free entry condition (15) for Home's firms continues to hold, solving the diminished system of three equations (11), (13), (15) for three unknowns, we have

$$\theta_{dk} = \frac{b_k L}{\sigma f}\left(\frac{\gamma - \sigma + 1}{\gamma}\right) = D_2(k) L$$
$$\theta_{xk} = \frac{b_k L^*}{\sigma f_x}\left(\frac{\gamma - \sigma + 1}{\gamma}\right) = D_2(k) \frac{f}{f_x} L^*$$
$$(\overline{\varphi}_{dk})^\gamma = \frac{L + L^*}{L} D_1.$$

Furthermore, we can easily obtain $(\overline{\varphi}_{xk})^\gamma = \left(\frac{L+L^*}{L^*}\right)\frac{f_x}{f} D_1$ by noting that $\theta_{xk} = \frac{1-G(\overline{\varphi}_{xk})}{1-G(\overline{\varphi}_{dk})}\theta_{dk}$. An analogous set of solutions for the Foreign-dominated sectors can be obtained.[13], [14]

Proposition 1 *In sectors $k \in [k_2, 1]$, where Home has the strongest comparative advantage, only Home produces, and there is one-way trade. An analogous situation applies to Foreign in sectors $k \in [0, k_1]$. In sectors $k \in (k_1, k_2)$, where neither country has strong comparative advantage, both countries produce, and there is two-way trade.*

We show the three zones of international specialization in Figure 1. The upward sloping curve (including the dotted portions) corresponds to equation (21), while the downward sloping curve (including the dotted portions) corresponds to equation (22). The horizontal portion of θ_{dk} in the diagram corresponds to the equation for θ_{dk} above when Home dominates sector k completely. The horizontal portion of θ_{dk}^* corresponds to the analogous equation for Foreign.

[13] They are: $\theta_{dk}^* = \frac{b_k L^*}{\sigma f}\left(\frac{\gamma-\sigma+1}{\gamma}\right) = D_2(k) L^*$; $\theta_{xk}^* = \frac{b_k L}{\sigma f_x}\left(\frac{\gamma-\sigma+1}{\gamma}\right) = D_2(k)\frac{f}{f_x} L$; and $(\overline{\varphi}_{dk}^*)^\gamma = \frac{L+L^*}{L^*} D_1$.

[14] The uniqueness of the above equilibrium is proved in an appendix posted on the corresponding author's homepage at http://ihome.ust.hk/~elai/ or upon request.

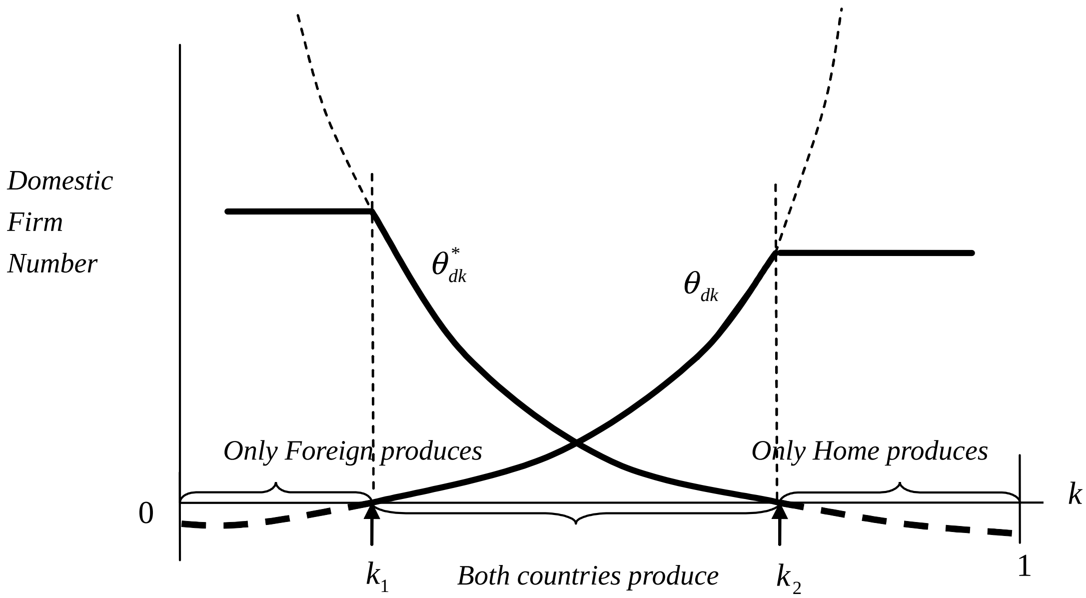


Figure 1. Three Zones of International Specialization (assumptions: (i) expenditure shares are equal across sectors; (ii) $L < L^*$).

4 Opening up to Trade

In this section, we analyze how opening trade between the two countries impacts the economy of each country, e.g. the productivity cutoffs, the mass of producing and exporting firms, as well as welfare. Before proceeding with the analysis, it is helpful to list the solutions to the relevant variables corresponding to the three types of sectors in Table 1.

Sector type	Foreign-dominated	Two-way trade	Home-dominated
	$k < k_1$	$k_1 < k < k_2$	$k > k_2$
$(\overline{\varphi}_{dk})^\gamma$	$\varnothing$	$D_1 \frac{B-B^{-1}}{B-(a_k)^\gamma}$	$D_1 \frac{L+L^*}{L}$
$(\overline{\varphi}_{xk})^\gamma$	$\varnothing$	$D_1 \frac{B-B^{-1}}{B-(a_k)^{-\gamma}} \left(\frac{1}{a_k}\right)^\gamma \left(\frac{Bf_x}{f}\right)$	$D_1 \frac{f_x}{f} \left(\frac{L+L^*}{L^*}\right)$
$(\overline{\varphi}^*_{dk})^\gamma$	$D_1 \frac{L+L^*}{L^*}$	$D_1 \frac{B-B^{-1}}{B-(a_k)^{-\gamma}}$	$\varnothing$
$(\overline{\varphi}^*_{xk})^\gamma$	$D_1 \frac{f_x}{f} \frac{L+L^*}{L}$	$D_1 \frac{B-B^{-1}}{B-(a_k)^\gamma} (a_k)^\gamma \left(\frac{Bf_x}{f}\right)$	$\varnothing$
θ_{dk}	0	$D_2(k) \frac{BL - \frac{B-(a_k)^\gamma}{B(a_k)^\gamma - 1} L^*}{B-B^{-1}}$	$D_2(k) L$
θ_{xk}	0	$\left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}_{xk}}\right)^\gamma \theta_{dk}$	$D_2(k) \frac{f}{f_x} L^*$
θ^*_{dk}	$D_2(k) L^*$	$D_2(k) \frac{BL^* - \frac{B(a_k)^\gamma - 1}{B-(a_k)^\gamma} L}{B-B^{-1}}$	0
θ^*_{xk}	$D_2(k) \frac{f}{f_x} L$	$\left(\frac{\overline{\varphi}^*_{dk}}{\overline{\varphi}^*_{xk}}\right)^\gamma \theta^*_{dk}$	0
P_k	$[D_2(k) L]^{\frac{1}{1-\sigma}} a_k B^{\frac{1}{\gamma}} \left(\frac{L}{L+L^*}\right)^{\frac{1}{\gamma}} \frac{1}{\rho A_k \widetilde{\varphi}_{ck}}$	$[D_2(k) L]^{\frac{1}{1-\sigma}} \frac{1}{\rho A_k \widetilde{\varphi}_{dk}}$	$[D_2(k) L]^{\frac{1}{1-\sigma}} \frac{1}{\rho A_k \widetilde{\varphi}_{dk}}$
P^*_k	$[D_2(k) L^*]^{\frac{1}{1-\sigma}} \frac{1}{\rho A^*_k \widetilde{\varphi}^*_{dk}}$	$[D_2(k) L^*]^{\frac{1}{1-\sigma}} \frac{1}{\rho A^*_k \widetilde{\varphi}^*_{dk}}$	$\frac{[D_2(k)L^*]^{\frac{1}{1-\sigma}}}{\rho A^*_k \widetilde{\varphi}^*_{ck}} \frac{B^{\frac{1}{\gamma}}}{a_k} \left(\frac{L^*}{L+L^*}\right)^{\frac{1}{\gamma}}$

Table 1: Solution of the System

$$D_1 = \left(\frac{\sigma - 1}{\gamma - \sigma + 1}\right) \frac{f}{f_e} \;;\quad D_2(k) = \left(\frac{\gamma - \sigma + 1}{\gamma}\right) \frac{b_k}{\sigma f} \;;\quad (a_{k_1})^\gamma = \frac{B\left(\frac{L}{L^*} + 1\right)}{B^2 \frac{L}{L^*} + 1};\quad (a_{k_2})^\gamma = \frac{B^2 \frac{L^*}{L} + 1}{B\left(\frac{L^*}{L} + 1\right)}$$

4.1 Impacts on productivity cutoffs

In this subsection, we analyze how trade affects the productivity cutoffs from two aspects: within sector and across sectors. First, we look at how trade integration changes the cutoffs within a certain sector. In this regard, we find that the impacts of trade integration on productivity cutoffs are the same as in Melitz (2003) in all sectors. Then we compare the cutoffs across sectors upon trade integration. We add a subscript c to all the parameters pertaining to autarky (c=closed economy). It has been shown in Section 2 that the autarky productivity cutoff for survival in Home and Foreign is given by $(\overline{\varphi}_{ck})^\gamma = (\overline{\varphi}^*_{ck})^\gamma = \left(\frac{\sigma-1}{\gamma-\sigma+1}\right) \frac{f}{f_e} = D_1$. **If both countries produce**, then the equilibrium cutoffs for survival are given by (17) and (18). As $(a_k)^\gamma \in \left(\frac{1}{B}, B\right)$, we have $\overline{\varphi}_{dk} > \overline{\varphi}_{ck}$ and $\overline{\varphi}^*_{dk} > \overline{\varphi}^*_{ck}$.

Recall that **if only one country produces**, the equilibrium productivity cutoffs for survival are given by:

$$(\overline{\varphi}_{dk})^\gamma = \frac{L + L^*}{L} D_1 > (\overline{\varphi}_{ck})^\gamma \quad \text{if only Home produces}$$
$$(\overline{\varphi}^*_{dk})^\gamma = \frac{L + L^*}{L^*} D_1 > (\overline{\varphi}^*_{ck})^\gamma \quad \text{if only Foreign produces}$$

Hence, the least productive firms in all sectors will exit the market after trade integration. As a result, resources will be reallocated to the most productive firms. Furthermore, $\overline{\varphi}_{dk} > \overline{\varphi}_{ck}$ implies that $\widetilde{\varphi}_{dk} > \widetilde{\varphi}_{ck}$, and $\overline{\varphi}^*_{dk} > \overline{\varphi}^*_{ck}$ implies that $\widetilde{\varphi}^*_{dk} > \widetilde{\varphi}^*_{ck}$. Therefore, the average productivity in any sector k

is higher under trade integration than in autarky. Thus we generalize Melitz's result to a setting where there exist endogenous intra-industry trade and inter-industry trade in a unified model.

In the closed economy, the cutoffs for survival are identical across sectors. However, this is not true any more in the open economy. In the sectors where both countries produce, the equilibrium cutoff for survival is an increasing function of the sectoral comparative advantage. More precisely, as a_k increases, $\overline{\varphi}_{dk}$ rises but $\overline{\varphi}^*_{dk}$ falls, and, following the free entry conditions (15) and (16), $\overline{\varphi}_{xk}$ falls but $\overline{\varphi}^*_{xk}$ rises. Thus, we have

Proposition 2 *In sectors where both countries produce, for a given country, a sector with stronger comparative advantage has a higher fraction of domestic firms that export and higher fraction of revenue derived from exporting.*

Moreover, $\overline{\varphi}^*_{xk} > \overline{\varphi}_{xk} > \overline{\varphi}_{dk} > \overline{\varphi}^*_{dk}$ iff Home is more competitive in sector k ($a_k > 1$), while $\overline{\varphi}_{xk} > \overline{\varphi}^*_{xk} > \overline{\varphi}^*_{dk} > \overline{\varphi}_{dk}$ iff $a_k < 1$. This result and Proposition 2 are summarized by Figure 2 below.

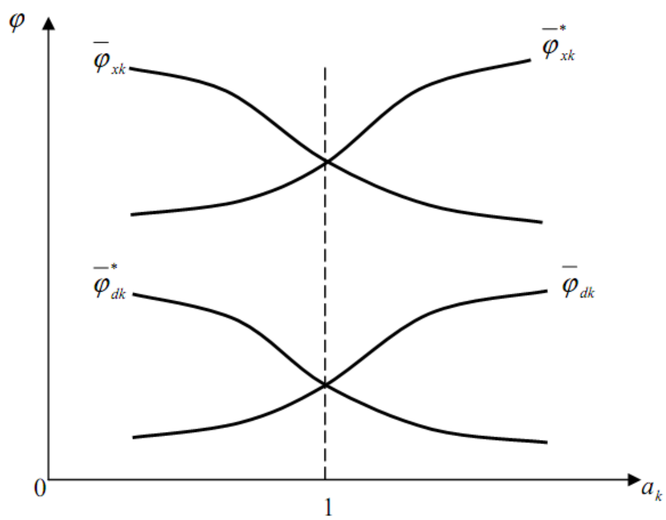


Figure 2. How productivity cutoffs vary across sectors

4.2 Impacts on welfare

The impact of opening up to trade on welfare is the same as predicted by the original one-sector Melitz (2003) model. The analysis is similar and so we relegate the proof to the appendix. In the appendix, it is shown that welfare increases after trade integration in both countries. The following proposition and Figure 3 summarize the analysis.

Proposition 3 *Welfare increase in both countries after they open up to trade with each other.*

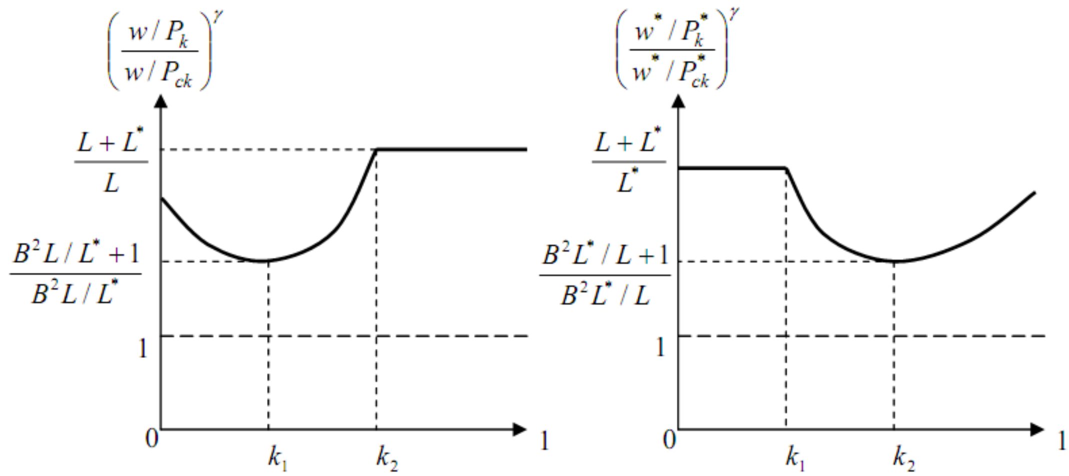


Figure 3. Welfare Impact of Trade Integration ($w = w^* = 1$ by assumption and normalization)

In the next section, we perform comparative statics concerning the effects of trade liberalization.

5 Trade liberalization

In Melitz (2003), both Home and Foreign gain from opening to trade and from trade liberalization. Here, we show that trade liberalization can lead to real wage reduction in some sectors, and even for the whole country. We shall analyze symmetric and asymmetric trade liberalization separately.

5.1 Symmetric Trade Liberalization

So far, we have been assuming that bilateral trade barrriers are symmetrical. In other words, if τ_1 is the iceberg trade cost of exporting from Home to Foreign, and τ_2 is the iceberg trade cost of exporting from Foreign to Home, then $\tau_1 = \tau_2 = \tau$. In this case, symmetric trade liberalization is interpreted as a reduction of τ, which lowers $B \equiv \tau^\gamma \left(\frac{f_x}{f}\right)^{\frac{\gamma-\sigma+1}{\sigma-1}}$. Without loss of generality, we only focus on the case when $L/L^* \geq 1$. With a slight abuse of language, "the real wage in the sector" shall mean "the real wage in terms of the aggregate good in the sector".

As (36) in the appendix and (17) show, in the sectors where both countries produce, the real wages in Home and Foreign in terms of good k, $1/P_k$ and $1/P_k^*$, just depend on the production cutoff $\overline{\varphi}_{dk}$ and $\overline{\varphi}_{dk}^*$ respectively. Thus, $\frac{d(\overline{\varphi}_{dk})^\gamma}{dB} > 0 \Leftrightarrow \frac{d(1/P_k)}{dB} > 0$ and $\frac{d\left(\overline{\varphi}_{dk}^*\right)^\gamma}{dB} > 0 \Leftrightarrow \frac{d\left(1/P_k^*\right)}{dB} > 0$. We calculate

$$\frac{d\left(\overline{\varphi}_{dk}\right)^{\gamma}}{dB}=\frac{2B^{-1}-\left(1+B^{-2}\right)\left(a_k\right)^{\gamma}}{\left[B-\left(a_k\right)^{\gamma}\right]^2} \tag{25}$$

$$\frac{d\left(\overline{\varphi}_{dk}^{*}\right)^{\gamma}}{dB}=\frac{2B^{-1}-\left(1+B^{-2}\right)\left(a_k\right)^{-\gamma}}{\left[B-\left(a_k\right)^{-\gamma}\right]^2} \tag{26}$$

which shows that $\overline{\varphi}_{dk}$ increases with B (and $\overline{\varphi}_{xk}$ decreases with B according to (15)) if and only if $(a_k)^{\gamma}<\frac{2B}{1+B^2}$. Moreover, $\overline{\varphi}_{dk}^{*}$ increases with B (and $\overline{\varphi}_{xk}^{*}$ decreases with B according to (16)) if and only if $(a_k)^{\gamma}>\frac{1+B^2}{2B}$. Recalling that $(a_{k_1})^{\gamma}=\frac{B\left(\frac{L}{L^*}+1\right)}{B^2\frac{L}{L^*}+1}$ and $(a_{k_2})^{\gamma}=\frac{B^2\frac{L^*}{L}+1}{B\left(\frac{L^*}{L}+1\right)}$, and comparing them with the above thresholds, we can obtain the following conclusions. (i) When $L=L^*$, k_1 and k_2 exactly coincide with these thresholds, meaning that in the two-way trade sectors, $\overline{\varphi}_{dk}$ (as well as real wage in sector k) always decreases with B, and $\overline{\varphi}_{xk}$ always increases with B. In other word, Melitz's predictions hold in this case. (ii) As L/L^* increases above one, k_1 decreases, and there exist some two-way trade sectors $k\in\left[k_1,\frac{2B}{1+B^2}\right]$, in which $\overline{\varphi}_{dk}$ increases with B and $\overline{\varphi}_{xk}$ decreases with B. That is, symmetric trade liberalization leads to a decrease in the productivity cutoff for survival but an increase in the exporting cutoff. Moreover, the real wage in these sectors also fall. These are all opposite to the predictions of the original Melitz model. Thus, we call this the "reverse-Melitz outcome". (iii) As L/L^* increases above one, k_2 decreases, and so there does not exist any sector in which $\overline{\varphi}_{dk}^{*}$ increases with B or $\overline{\varphi}_{xk}^{*}$ decreases with B. Thus, the reverse-Melitz outcome does not exist in any sector in the smaller country.

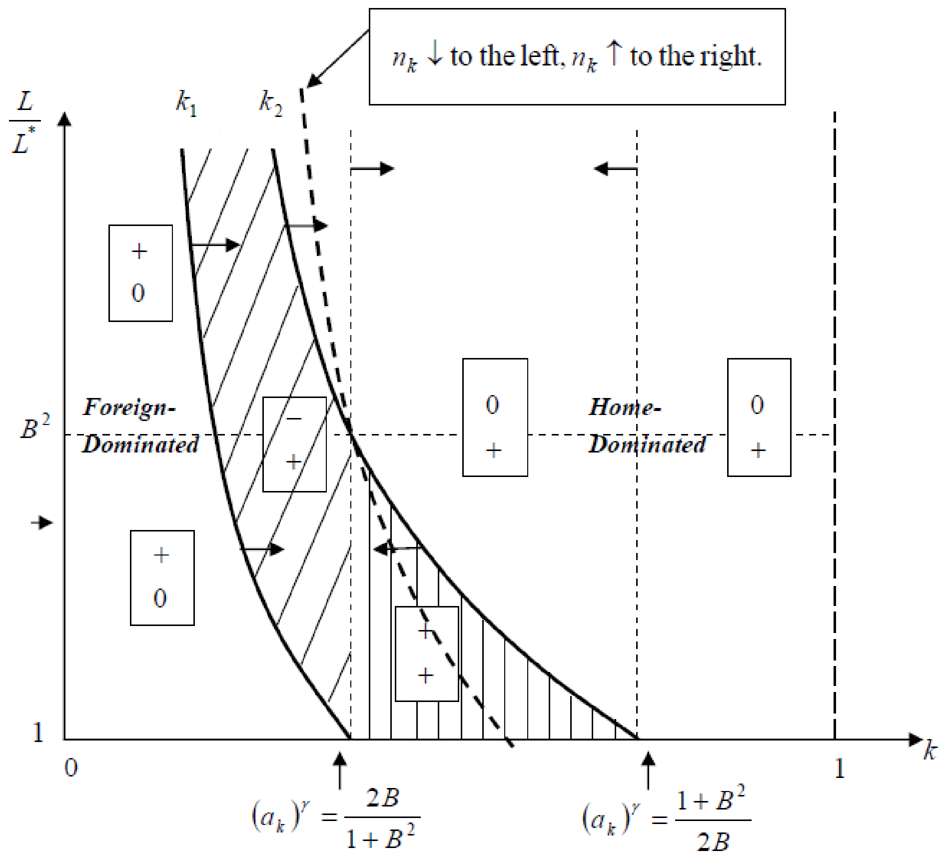
For a more detailed mathematical analysis of the impacts of symmetric trade liberalization, refer to equations (36) to (38) and to Appendix C.

Figure 4 summarizes the effects graphically. The diagram shows the welfare effects of symmetric trade liberalization. The k_1 and k_2 curves show the pattern of international specialization for any given L/L^*. (Recall that $L/L^*\geq 1$ is assumed.) The zone to the left of the k_1 curve corresponds to sectors completely dominated by Foreign. The zone to the right of the k_2 curve corresponds to the sectors completely dominated by Home. The downward sloping k_1 curve indicates that as the relative size of Home becomes larger, it can profitably produce in more sectors. This shows the home market effect as explained by Krugman (1980) — the firms located in the larger country has the advantage of saving the trade costs of serving the larger market, which more than compensates for its cost disadvantage relative to the firms located in the smaller country in the same sector. On the other hand, the downward sloping k_2 curve shows that Foreign, the smaller country, can profitably produce in fewer sectors as the relative size of Home increases. This reminds us of the result in Markusen and Venables (2000), in which they find that the larger country can export a good in which it has comparative disadvantage because of home market effect. As will be shown later, this explains why the "reverse-Melitz outcome" can only occur in the larger country under symmetric trade liberalization or symmetric trade cost reduction.

The figure also shows, for any given value of L/L^*, the signs of the real-wage effect of symmetric trade liberalization on Home and Foreign in different sectors. The upper sign inside a rectangle indicates the sign of Home's change in real wage in terms of good k due to an infinitesimal decrease in τ, and the lower sign indicates the sign of Foreign's change in real wage in terms of good k. For example, for $1<L/L^*<B^2$ (indicated by the arrow on the vertical axis in Figure 4), when there is an infinitesimal

reduction of B (via reduction in τ), Home's real wage (i) increases in terms of goods in the Foreign-dominated sectors (the zone to the left of the k_1 curve), (ii) decreases in the two-way trade sectors to the right of the k_1 curve but to the left of the vertical line $(a_k)^\gamma = \frac{2B}{1+B^2}$ (this corresponds to the slanted-hatched zone), (iii) increases in the two-way trade sectors to the right of the vertical line $(a_k)^\gamma = \frac{2B}{1+B^2}$ but to the left of the k_2 curve (this corresponds to the vertically-hatched zone), and (iv) does not increase or decrease in the Home-dominated sectors (the zone to the right of the k_2 curve).

Note that Figure 4 indicates that there is a "reverse-Melitz outcome" for Home (the larger country) in the slanted-hatched zone, in the sense that $\overline{\varphi}_{dk}$ decreases and $\overline{\varphi}_{xk}$ increases in response to symmetric trade liberalization. However, the Melitz selection effect dominates in Home in the vertically-hatched zone, in the sense that $\overline{\varphi}_{dk}$ increases and $\overline{\varphi}_{xk}$ decreases in response to symmetric trade liberalization. These results reflect the algebraic derivation above and in Appendix B. Note that there is no reverse-Melitz outcome for the smaller country under symmetric trade liberalization. However, this result is going to change under asymmetric trade liberalization, as we shall show in the next section.



Legend: $\bar{\varphi}_{dk} \downarrow$, $\bar{\varphi}_{xk} \uparrow$ and $\bar{\varphi}^*_{dk} \uparrow$, $\bar{\varphi}^*_{xk} \downarrow$ and $n_k \downarrow$, $n^*_k \uparrow$

Melitz outcome for Foreign (real wage in the sector rises).
Reverse-Melitz outcome for Home (real wage in the sector falls).

$\bar{\varphi}_{dk} \uparrow$, $\bar{\varphi}_{xk} \downarrow$ and $\bar{\varphi}^*_{dk} \uparrow$, $\bar{\varphi}^*_{xk} \downarrow$

Melitz outcome for both countries (real wage in the sector rises).

Figure 4. Welfare Effects of Symmetric Trade Liberalization (infinitesimal reduction of B through a reduction of τ). In each region, the upper sign inside the rectangle indicates the welfare change of Home and the lower sign indicates the welfare change of Foreign. The short horizontal arrows indicate the movement of lines as B falls.

As B decreases, the curves for k_1 and k_2, as well as the vertical lines corresponding to $(a_k)^\gamma = \frac{2B}{B^2+1}$ and $(a_k)^\gamma = \frac{B^2+1}{2B}$, will all shift, with the directions of shifts shown by the small horizontal arrows in Figure 4. For any given L/L^*, as τ (and therefore B) decreases from a large number, k_1 increases, k_2 first decreases then increases, $(a_k)^\gamma = \frac{2B}{B^2+1}$ increases while $(a_k)^\gamma = \frac{B^2+1}{2B}$ decreases.

Depending on the range of $[a_0, a_1]$ and the value of L/L^*, it is possible that the k_1 or k_2 curve (or both) may situate outside the range $k \in [0,1]$ for some or all values of L/L^*. For example, if $a_{k_1} < a_0$ for a given value of L/L^*, then no Foreign-dominated sector exist for that value of L/L^*. This is because as L/L^* gets sufficiently large, the home-market effect in Home gets so strong that Home can compete even in the sector in which it has the weakest comparative advantage, namely sector $k = 0$.

The above discussion and Figure 4 can be summarized by the following lemma and proposition:

Lemma 2 *When the two country are of the same size, symmetric trade liberalization improves the real wages in all two-way trade sectors in both countries.*

Proposition 4 *Consider the sectors in which both countries produce. Suppose Home is larger than Foreign. In the sectors where Home has the strongest comparative disadvantage but still produces, there is a reverse-Melitz outcome in the sense that $\overline{\varphi}_{dk}$ decreases while $\overline{\varphi}_{xk}$ increases in the face of symmetric trade liberalization, leading to reduction in Home's real wage in these sectors.*

Proposition 4 deserves more discussion, as it highlights one of the most important results of this paper. If Home is the larger country, the sectors in which its real wage deceases upon symmetric trade liberalization are defined by $\left\{ k \mid \; (a_{k_1})^{\gamma} < (a_k)^{\gamma} < (a_{k_2})^{\gamma} \text{ and } (a_k)^{\gamma} < \frac{2B}{1+B^2} \right\}$. The first condition indicates that the sector is a two-way trade sector. The second condition indicates that the sector is among those in which the larger country has the weakest comparative advantage. The two conditions combined says that, in the sectors where the larger country has the weakest comparative advantage yet still produces, Home's real wage decreases with symmetric trade liberalization. In other words, there is a **reverse-Melitz outcome** in these sectors, i.e. $\overline{\varphi}_{dk}$ decreases while $\overline{\varphi}_{xk}$ increases in the face of symmetric trade liberalization, leading to a decrease in the average productivity of firms serving the Home market, thus lowering real wage in that sector. We can explain the existence of the reverse-Melitz outcome by decomposing the total effect of symmetric trade liberalization into two effects: the Melitz selection effect and the inter-sectoral resource allocation (IRA) effect. We shall analyze from the perspective of Home and Home's firms.

- Note that the number of potential entrants in sector k in Home is given by

$$n_k = \frac{\theta_{dk}}{1 - G\left(\overline{\varphi}_{dk}\right)} = \theta_{dk}\left(\overline{\varphi}_{dk}\right)^{\gamma} = D_1 D_2\left(k\right)\left[\frac{BL}{B - (a_k)^{\gamma}} - \frac{L^*}{B\left(a_k\right)^{\gamma} - 1}\right] \tag{27}$$

  and recall

$$\theta_{dk} = D_2\left(k\right)\left[\frac{BL - \frac{B-(a_k)^{\gamma}}{B(a_k)^{\gamma}-1}L^*}{B - B^{-1}}\right] \tag{21}$$

$$\left(\overline{\varphi}_{dk}\right)^{\gamma} = D_1\left[\frac{B - B^{-1}}{B - (a_k)^{\gamma}}\right] \tag{17}$$

$$\frac{d\left(\overline{\varphi}_{dk}\right)^{\gamma}}{dB} = \frac{2B^{-1} - \left(1 + B^{-2}\right)\left(a_k\right)^{\gamma}}{\left[B - (a_k)^{\gamma}\right]^2} \tag{25}$$

$$\frac{1}{P_k} = \left[\frac{B - B^{-1}}{B - (a_k)^{\gamma}}\right]^{\frac{1}{\gamma}} \frac{1}{P_{ck}} \qquad \text{(36) from the appendix}$$

- When $L = L^*$, and $a_k = 1$, $\forall k$, our model collapses to the Melitz model with a homogenous-good sector. (27) implies that $n_k = D_1 D_2 (k) L$. With symmetric trade liberalization, the numbers of potential entrants n_k and n_k^* will remain unchanged. Note that (17) implies that $(\overline{\varphi}_{dk})^\gamma = D_1 \left(\frac{B+1}{B}\right)$. Therefore, $\frac{d(\overline{\varphi}_{dk})^\gamma}{dB} < 0$. That is, real wages in all sectors rise with symmetric trade liberalization. As a result, the export revenue of a typical exporting firm will increase as trade cost falls. **This creates pressure for both $\overline{\varphi}_{xk}$ and $\overline{\varphi}_{xk}^*$ to decrease.** Meanwhile, this will force the least productive firms in each country to exit, as there are more firms exporting to the domestic market. **This creates pressure for both $\overline{\varphi}_{dk}$ and $\overline{\varphi}_{dk}^*$ to increase.** The increase in average productivity in all sectors lead to increase in real wage in all sectors. **This is the Melitz selection effect**, which is the only effect here. Thus, we have the **Melitz outcome**.

- Next, we allow a_k to deviate from 1 for some k, but keep $L = L^*$. This creates comparative advantage for Home in some sectors and comparative disadvantage for Home in other sectors. Note that (25) holds only if sector k satisfies the constraint for two-way trade, given by $(a_{k_1})^\gamma < (a_k)^\gamma < (a_{k_2})^\gamma$. Observe that (i) (23) implies that $(a_{k_1})^\gamma < (a_k)^\gamma$ is equivalent to $2B^{-1} - \left(1 + B^{-2}\right)(a_k)^\gamma < 0$; therefore, (25) implies that $\frac{d(\overline{\varphi}_{dk})^\gamma}{dB} < 0$ for all two-way trade sectors. In other words, symmetric trade liberalization always increases the real wage in a two-way trade sector. That is, the Melitz selection effect dominates in all two-way trade sectors as long as $L = L^*$. (ii) (25) implies that $\left|\frac{d(\overline{\varphi}_{dk})^\gamma}{dB}\right|$ increases with a_k. That is, the dominance of the Melitz effect in a sector decreases as the comparative advantage of Home diminishes. (iii) (23) implies that at $k = k_1$, $2B^{-1} - \left(1 + B^{-2}\right)(a_k)^\gamma = 0$, which in turn implies that $\frac{d(\overline{\varphi}_{dk})^\gamma}{dB} = 0$. That is, the Melitz selection effect is completely offset in sector k_1, the sector in which Home has the least comparative advantage yet still produces. What happens to make $\left|\frac{d(\overline{\varphi}_{dk})^\gamma}{dB}\right|$ increase with a_k? The effect comes from re-allocation of resources (labor) between sectors as B decreases, which we call **inter-sectoral resource allocation (IRA) effect**. Symmetric trade liberalization leads to resources in Home (as well in Foreign) being re-allocated away from the differentiated-good sectors in which it has comparative disadvantage to ones in which it has comparative advantage (and possibly the homogeneous good sector). Therefore, n_k decreases and n_k^* increases in the sectors in which Home has comparative disadvantage. As n_k^* increases, Foreign's market becomes more competitive (as there are more firms in Foreign) and so $r_{xk}(\varphi)$ decreases for all φ. **This creates pressure for an increase in $\overline{\varphi}_{xk}$** (i.e. only the more productive Home firms can profitably export now). As n_k decreases, θ_{dk} also decreases. This leads to the expansion of the sizes of the surviving Home firms. Thus, $r_{dk}(\varphi)$ increases for all φ. **This creates pressure for a decrease in $\overline{\varphi}_{dk}$** as some less productive firms which were expected to be unprofitable before can be expected to be profitable now. The IRA effect causes the variables n_k, n_k^*, $r_{xk}(\varphi)$, $\overline{\varphi}_{xk}$, θ_{dk}, $r_{dk}(\varphi)$, $\overline{\varphi}_{dk}$ to move in opposite directions in the sectors in which Home has comparative advantage. In other words, the IRA effect reinforces the Melitz selection effect in the sectors in which Home has comparative advantage but counteracts the Melitz effect in the sectors in which it has comparative disadvantage.[15] Observations (ii) and (iii) above indicate that the IRA effect is stronger when Home has weaker comparative advantage in the sector. However, as long as $L = L^*$, the IRA

[15] The definition of a comparative advantage sector is bound to be subjective. Here, we define a sector to be a comparative advantage (disadvantage) sector if n_k increases (decreases) as τ decreases.

effect never dominates the Melitz selection effect, as each country cannot profitably produce goods in which it does not have sufficiently strong comparative advantage. Without any home market effect, the range of goods produced by Home is limited by its comparative advantage. Therefore, there is still no reverse-Melitz outcome in any sector.

- Next, we allow $L/\ L^*$ to increase above one, in addition to $a_k \neq 1$ for some k. Now, because of increasing returns to scale and the home market effect as explained in Krugman (1980), it is possible for the IRA effect to dominate the Melitz selection effect in Home, as Home is now able to profitably produce goods that it was not able to when $L = L^*$. In other words, because of its large size, Home is now able to profitably produce goods in which it has comparative disadvantage. In these sectors, $\frac{d(\overline{\varphi}_{dk})^\gamma}{dB} < 0$ — the IRA effect dominates the Melitz selection effect, and we have the **reverse-Melitz outcome**. However, Foreign, the smaller country, can never have reverse-Melitz outcome in any sector, because it is not able to profitably produce any good that it was not able to when $L = L^*$.

As the IRA effects in the comparative advantage sectors are positive, there are gains in real wage in terms of these sectors' goods upon symmetric trade liberalization. Can these gains offset the losses in the comparative disadvantage sectors mentioned above? The answer is, it depends on Home's relative size. If Home's relative size is large, and the Foreign-dominated sector is small, then the gains cannot offset the losses. For example, when $B = 2$, $L/L^* = 5$, $\gamma = 2$ (and therefore $a_{k_1} = 0.756$ and $a_{k_2} = 0.866$); and suppose $a_0 = 0.8$ (and therefore $k_1 < 0$, which means that there does not exist any sector in which Foreign completely dominates). Then, Home will unambiguously lose from symmetric trade liberalization, as it loses in the sectors where $k \in [0, k_2]$, and does not gain or lose in the sectors where $k \in [k_2, 1]$ and in the homogeneous good sector.

Based on the above analysis, we end this section with the following two propositions:

Proposition 5 *Consider the sectors in which both countries produce. Suppose Home is larger than Foreign. In the face of symmetric trade liberalization, the fraction of exporters increases in Home's comparative advantage sectors but decreases in the sectors in which Home has the strongest comparative disadvantage.*

Proposition 6 *Consider the sectors in which both countries produce. Suppose Home is larger than Foreign. In the face of symmetric trade liberalization, the fraction of revenue derived from exporting increases in Home's comparative advantage sectors but decreases in the sectors in which Home has the strongest comparative disadvantage.*

5.2 Asymmetric Trade Liberalization

We have shown that reverse-Melitz outcome occurs only in the larger country under symmetic trade liberalization. However, we shall show below that it occurs even in the smaller country under asymmetric trade liberalization, if the percentage reduction of importing cost of the smaller country is sufficiently greater than that of the larger country. In the extreme case, unilateral trade liberalization of Home lowers its real wage in all sectors regardless of its relative size. This result is important as we shall use it to test the reverse-Melitz outcome in China, which underwent asymmetric trade liberalization upon its accession to the WTO.

Let τ_1 denote the trade cost of exporting from Home to Foreign, and τ_2 denote the trade cost of exporting from Foreign to Home. In general $\tau_1 \neq \tau_2$ and therefore $B_1 \neq B_2$. The detailed analysis is relegated to the Appendix. In the appendix, we prove that (i) **Home's real wage falls in all sectors as Home unilaterally reduces its tariffs against Foreign's exports** (we call this **unilateral liberalization (UL) effect**); and (ii) Home's real wage rises in all sectors as Foreign unilaterally reduces its tariffs against Home's exports. The UL effect works similarly as the IRA effect in Home's comparative disadvantage sectors: n_k and θ_{dk} both fall, while n_k^* rises. As n_k^* increases, it forces up $\overline{\varphi}_{xk}$ as Foreign's market becomes more competitive. As θ_{dk} decreases, the revenues of all domestic firms increase, forcing down $\overline{\varphi}_{dk}$.

The following equations extracted from the appendix will be useful in the ensuing analysis.

$$(a_{k_1})^\gamma = \frac{B_1\left(\frac{L}{L^*}+1\right)}{B_1 B_2 \frac{L}{L^*}+1} \tag{39}$$

$$(a_{k_2})^\gamma = \frac{B_1 B_2 \frac{L^*}{L}+1}{B_2\left(\frac{L^*}{L}+1\right)} \tag{40}$$

$$\frac{d\left(\overline{\varphi}_{dk}\right)^\gamma}{dB_2} = D_1 \frac{B_2^{-2}}{B_1-(a_k)^\gamma} \tag{41}$$

$$\frac{d\left(\overline{\varphi}_{dk}\right)^\gamma}{dB_1} = D_1 \frac{B_2^{-1}-(a_k)^\gamma}{\left[B_1-(a_k)^\gamma\right]^2} \tag{42}$$

Suppose $\tau_1$and τ_2 both decrease so that B_1 and B_2 both fall.

Assumptions: (a) Define $\lambda \equiv dB_1/dB_2$ where $\lambda > 0$; and

(b) $|dB_1/B_1| < |dB_2/B_2|$ (which is equivalent to $|d\tau_1/\tau_1| < |d\tau_2/\tau_2|$, i.e. the percentage reduction in iceberg importing cost is lower in Foreign than in Home).

Note that (a) and (b) imply that $B_1 > \lambda B_2$. If reduction in B_1 and B_2 results in a fall in $\overline{\varphi}_{dk}$, then we have a reverse-Melitze outcome. Therefore, reverse-Melitz outcome exists in a sector iff

$$
\begin{aligned}
& \frac{d\left(\overline{\varphi}_{dk}\right)^{\gamma}}{dB_2}+\lambda\frac{d\left(\overline{\varphi}_{dk}\right)^{\gamma}}{dB_1}>0 \\
\iff \quad & B_1+\lambda B_2-\left(1+\lambda B_2^2\right)\left(a_k\right)^{\gamma}>0 \\
\iff \quad & \left(a_k\right)^{\gamma}<\frac{B_1+\lambda B_2}{1+\lambda B_2^2}
\end{aligned}
$$

Thus, we have

Lemma 3 *Reverse-Melitz outcome exists in a sector iff* $\left(a_k\right)^{\gamma}<\frac{B_1+\lambda B_2}{1+\lambda B_2^2}$.

Now, consider the case $L=L^*$. Equations (41) and (42) imply that there is reverse-Melitz outcome when $k=k_1$ (the two-way trade sector in which Home has the weakest compararive advantage) iff

$$
\begin{aligned}
& \frac{d\left(\overline{\varphi}_{dk}\right)^{\gamma}}{dB_2}+\lambda\frac{d\left(\overline{\varphi}_{dk}\right)^{\gamma}}{dB_1}>0 \text{ at } k=k_1 \\
\iff \quad & B_1+\lambda B_2-\left(1+\lambda B_2^2\right)\left(a_{k_1}\right)^{\gamma}>0 \qquad (28)\\
\iff \quad & \left(B_1-\lambda B_2\right)\left(B_1B_2-1\right)>0,
\end{aligned}
$$

which is true according to our assumption $B_1>\lambda B_2$ and the fact that B_1, $B_2>1$.

From Lemma 3 and the above result, we can conclude that there is reverse-Melitz outcome for the sectors satisfying

$$
\frac{2B_1}{B_1B_2+1}=\left(a_{k_1}\right)^{\gamma}<\left(a_k\right)^{\gamma}<\frac{B_1+\lambda B_2}{1+\lambda B_2^2}.
$$

Therefore we have

Conclusion 1: *There is reverse-Melitz outcome in Home even if $L=L^*$, as long as $|d\tau_1/\tau_1|<|d\tau_2/\tau_2|$.*

The intuition for Conclusion 1 is as follows. We assume $L=L^*$ and allow a_k to deviate from 1 for some k. This creates comparative advantage for Home in some sectors and comparative disadvantage for Home in other sectors. Note that (41) and (42) hold only if sector k satisfies the constraint for two-way trade, given by $\left(a_{k_1}\right)^{\gamma}<\left(a_k\right)^{\gamma}<\left(a_{k_2}\right)^{\gamma}$. Observe that (i) (39) implies that $\left(a_{k_1}\right)^{\gamma}<\left(a_k\right)^{\gamma}$ is equivalent to $2B_1-\left(1+B_1B_2\right)\left(a_k\right)^{\gamma}<0$; therefore, (41) and (42) imply that $\frac{d(\overline{\varphi}_{dk})^{\gamma}}{dB_2}+\lambda\frac{d(\overline{\varphi}_{dk})^{\gamma}}{dB_1}>0$ at $k=k_1$ iff $\left(B_1-\lambda B_2\right)\left(B_1B_2-1\right)>0$, which is true as long as $|d\tau_1/\tau_1|<|d\tau_2/\tau_2|$. In other words, asymmetric trade liberalization (with $|d\tau_1/\tau_1|<|d\tau_2/\tau_2|$) lowers the real wage for the two-way trade sectors in which Home has the weakest comparative advantage, i.e. sectors k satisfying $\frac{2B_1}{B_1B_2+1}=\left(a_{k_1}\right)^{\gamma}<\left(a_k\right)^{\gamma}<\frac{B_1+\lambda B_2}{1+\lambda B_2^2}$. That is, the reverse-Melitz outcome exists even when $L=L^*$, contrary to the case with symmetric trade liberalization. (ii) (41) and (42) imply that $\frac{d(\overline{\varphi}_{dk})^{\gamma}}{dB_2}+\lambda\frac{d(\overline{\varphi}_{dk})^{\gamma}}{dB_1}$

is negative when a_k gets sufficiently large.[16] That is, there will not be reverse-Melitz outcome in the sectors in which Home has sufficiently strong comparative advantage.

Suppose we allow $L \neq L^*$. For reverse-Melitz outcome to exist, we invoke (39) and (28), by solving for $\frac{L}{L^*}$ from $(a_{k_1})^\gamma = \frac{B_1+\lambda B_2}{1+\lambda B_2^2}$, and find that the reverse-Melitz outcome can occur in the most comparative disadvantage two-way trade sectors in Home (i.e. k_1) as long as

$$\frac{L}{L^*} > \frac{\lambda B_2}{B_1} = \frac{|d\tau_1/\tau_1|}{|d\tau_2/\tau_2|}$$

The right hand side is less than one. Therefore, we have

Conclusion 2: *It is possible for reverse-Melitz outcome to occur in Home under asymmetric trade liberalization even if Home is smaller than Foreign. More specifically, as long as* $|d\tau_1/\tau_1| < |d\tau_2/\tau_2|$, *reverse-Melitz outcome exists in sector* k_1 *iff* $L/L^* > |d\tau_1/\tau_1| \, / \, |d\tau_2/\tau_2|$.

We summarize the above conclusions in Propositions 7, 8 and 9 below, which are parallel to Propositions 4, 5 and 6 respectively.

Proposition 7 *Consider the sectors in which both countries produce. If the percentage decrease in Home's iceberg import cost is more than that of Foreign's, then* $\overline{\varphi}_{dk}$ *decreases while* $\overline{\varphi}_{xk}$ *increases in the sectors in which Home has the strongest comparative disadvantage, leading to reduction in Home's real wage in these sectors, as long as Home is not too small compared with Foreign.*

Proposition 8 *Consider the sectors in which both countries produce. If the percentage decrease in Home's iceberg import cost is more than that of Foreign's, then the fraction of exporters increases in Home's comparative advantage sectors but decreases in the sectors in which Home has the strongest comparative disadvantage, as long as Home is not too small compared with Foreign.*

Proposition 9 *Consider the sectors in which both countries produce. If the percentage decrease in Home's iceberg import cost is more than that of Foreign's, then the fraction of revenue derived from exporting increases in Home's comparative advantage sectors but decreases in the sectors in which Home has the strongest comparative disadvantage, as long as Home is not too small compared with Foreign.*

Discussion. Symmetric trade liberalization is a special case of asymmetric liberalization (with $|d\tau_1/\tau_1| = |d\tau_2/\tau_2|$). (In fact, the same results as in the symmetric case analyzed in the last subsection obtain even when $\tau_1 \neq \tau_2$.) We can think of asymmetric liberalization (with Home liberalizing more than Foreign, i.e. $|d\tau_1/\tau_1| < |d\tau_2/\tau_2|$) as the combination of symmetric liberalization and unilateral

[16] As (28) shows, the reverse-Melitz outcome requires that $B_1 + \lambda B_2 - \left(1 + \lambda B_2^2\right)(a_{k_1})^\gamma$ be positive. However, the expression gets smaller as a_{k_1} increases.

liberalization by Home. Symmetric liberalization has been thoroughly analyzed in the last subsection. It leads to the reverse-Melitz outcome in Home's most comparative disadvantage two-way trade sectors if Home is larger than Foreign. Unilateral liberalization by Home leads to reduction of real wage in all sectors in Home, contributing to an additional reason for the existence of the reverse-Melitz outcome. We call this unilateral liberalization effect (UL effect). The UL effect explains why reverse-Melitz outcome occurs under asymmetric liberalization even when Home is smaller than Foreign. Note that reduction of real wage occurs even in a one-sector model (with say $a_k = 1$). When we combine the Melitz selection effect, IRA effect and UL effect, the impact of asymmetric trade liberalization on real wage again turns from negative to positive as the comparative advantage of the sector increases, like in the case of symmetric liberalization. Thus, there is reverse-Melitz outcome only for the most comparative disadvantage sectors, as in the case with symmetric trade liberalization. We expect a large country undergoing asymmetric trade liberalization to be likely to exhibit reverse-Melitz outcome. The episode of trade liberalization by China following its accession to WTO in 2001 is a good candidate to test our theory, as China was large, and the trade liberalization episode then was quite asymmetric. Therefore, in Section 7 we shall test propositions 8 and 9 using Chinese data. Before that, we first discuss in the next section a possible extension of our model to capture another interesting phenomenon in China's trade recently documented.

6 Can firms that sell domestically be more productive than firms that don't?

Recently, there has been some discussion of the existence of another "reverse-Melitz outcome". Lu (2010) shows that, theoretically, in a multi-sector Melitz model, the average productivity of exporters can be lower than that of the firms that serve the domestic market in the comparative advantage sectors. She then supports her theory by the empirical finding that, in the comparative advantage sectors, the exporters in China have a relative lower average productivity compared with the firms that serve the domestic market. This effect, though also contrasts sharply with Melitz's one-sector result, is completely different from the one explained in section 5. Nonetheless, it is still worth asking whether our model can be made consistent with this effect. The answer is yes.

So far, we simplified our analysis by assuming that $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ so as to exclude the possibility that some firms only export but do not serve the domestic market. Our model can in fact be modified to accommodate this possibility by relaxing this assumption. First of all, we adopt the assumption that a firm needs to incur a market entry cost if it enters a market, be it domestic or foreign. Now, let f and f_x stand for the fixed market-entry cost plus the overhead cost for serving the domestic market and foreign market respectively.[17] In this case, we can relax the assumption $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ (only $\tau^{\sigma-1} f_x > f$ is needed), and all of our propositions still hold. In the appendix, we show that when f_x is sufficiently smaller than f, then we can have a situation where the cutoff productivity for exporting is lower than the cutoff productivity for selling domestically in the comparative advantage sectors. Thus, the average

[17] This is different from the original assumption in Melitz (2003) as well as in this paper so far.

productivity of the firms that export is lower than the average productivity of firms that both export and sell domestically in the comparative advantage sector. The main point is that it is possible that for some sector k, we have $\overline{\varphi}_{dk} > \overline{\varphi}_{xk}$. Once we have this outcome, we can have the situation where some firms in the sectors where a country has the strongest comparative advantage may only export; thus in these sectors the firms that only export are less productive than those that also serve the domestic market. This is also consistent with Lu's (2012) finding that in labor-intensive sectors, firms that serve domestic market have higher productivity than exporters, as China has comparative advantage in the labor-intensive industries.

Detailed calculation is given in the appendix. We state our result in

Proposition 10 *If the fixed entry cost for exporting is not too high, then in the sectors where a country has the strongest comparative advantage, the firms that do not serve the domestic market can have a lower average productivity than those that do.*

One major characteristic of the Chinese exporting sector is that a large fraction of exporting firms engage in processing trade, and they mostly concentrate in the labor-intensive sectors, which are the comparative advantage sectors of China. Export processing in China is subject to very different policy treatment compared to non-processing trade. First, processing activities enjoy favorable taxation. The amount of imported inputs actually used in the making of the finished products for export is exempt from tariffs and import-related taxes. All processed finished products for export are also exempt from export tariffs and value-added tax. Second, the finished products using the tax-exempted materials have to be re-exported, and enterprises are not allowed to sell the tax-exempted materials and parts or finished products in China. The assumption that the fixed cost for exporting firms is relatively low compared with the fixed cost for firms selling in the domestic market fits the observation that the cost of entry into processing trade in China is relatively low because of government policy.

According to Dai, Maitra and Yu (2011), "In China roughly a fifth of exporters, accounting for about one-third of total export value, are engaged in processing trade only. These firms are 4% to 30% less productive than non-exporters." They go on to say, "Our data shows that processing trade firms pay lower average wages implying that they are more unskilled labor intensive, are relatively less capital intensive, and have low profitability compared to non-processing ones. Given that processing firms pay lower fixed cost (due to government intervention) it makes sense that only the low productivity firms would select into processing trade." These findings are all consistent with this modified version of our model.

Thus, our theoretical model can indeed be extended to include both types of non-standard effects. Next, we move on to some emprical evidence. The empirical evidence for Lu's (2010) effect has already been offered by her. In the next section, we present the empirical tests of our two major propositions.

7 Empirical Tests of Propositions 8 and 9

Propositions 8 and 9 in section 5 predict the existence of a reverse-Melitz outcome: For a sufficiently large country, like China, in the sectors where it has the strongest comparative disadvantage but still produces, the fraction of firms that export and the share of revenue derived from exporting will both decrease upon asymmetric trade liberalization such that the percentage reduction of China's trade cost is lower than that of its trading partners. Can we find any evidence to support the existence of the reverse-Melitz outcome? This section shows that we indeed find evidence of such an effect.

China acceded to the WTO in December 2001. Since then there was a series of tariff reductions for a number of years. It is well-documented that the conditions of WTO accession require China to reduce its import barriers with very little corresponding changes in its trade partners' import barriers against China. Therefore, this kind of asymmetric trade liberalization (that the percentage reduction in China's iceberg import cost is higher than those of its trading partners) fits the description in Propositions 8 and 9 very well. We should therefore expect the comparative disadvantage sectors of China to exhibit reverse-Melitz outcome while the comparative advantage sectors to exhibit Melitz outcome.

We test the theory at the 4-digit CIC level, using Chinese industrial firm data from National Bureau of Statistics of China (NBSC), Chinese Customs data from China's General Administration of Customs and tariff data from the World Trade Organization (WTO). To get a panel of variables, we need to first tackle the problem caused by a major revision to the Chinese Industry Classification (CIC) in the year 2002. In order to have a consistent definition of sectors, we follow Brandt, Van Biesebroeck & Zhang (2012) by adjusting the 4-digit CIC so as to make the same industry classification code representing the same industry both before and after year 2002.[18] After adjusting the CIC code for each sector, we aggregate the variables at the 4-digit sector level and obtain a panel of aggregate variables (e.g. mass of firms, mass of firms that export, total revenue, total exporting revenue, etc.) from the years 2001 to 2006, and then calculate the variables we need.[19]

In order to test the effect of trade liberalization, we also need to establish a proper measure of trade cost τ. As transportation cost is hard to measure and should not vary much in a few years' time, we take the tariff rate, which decreased a lot after China joined the WTO, as the measure of trade cost. It is also noteworthy that the tariff rates for different sectors are different, which is not consistent with the assumption of our model. Fortunately, it turns out that the results and equations of the model will not be qualitatively affected by the heterogeneity of trade costs across sectors. Therefore, we take into consideration the heterogeneity of tariff rates across sectors in calculating which sectors are predicted to exhibit the reverse-Melitz outcome according to the theory. More explanation is provided below.

Following Amiti and Konings (2007), Goldberg, Khandelwal, Pavcnik and Topalova (2010) and Ge, Lai and Zhu (2011), we construct the industry tariff rate through aggregating tariffs to the 4-digit CIC

[18] The detail of the matching can be found at http://www.econ.kuleuven.be/public/N07057/CHINA/appendix/

[19] The choice of the years is based on the fact that China acceded to World Trade Organization in December 2001, which further integrated the country with the world. Under the WTO commitments, China cut average tariff from 15.4% in 2001 to 5.31% in 2006.

level. Like the CIC, there was a major reclassification in the international HS 6-digit codes in 2002. Hence we also construct a mapping of the 6-digit HS coding system from the pre-2002 to the post-2002 periods. With these matchings in place, we assign each 8-digit HS product to the 6-digit HS code to which it belongs, and then connect this 6-digits HS code with the standardized 4-digit CIC code, for each year.[20] Finally, we calculate the industry tariff as the import-value-weighted average of all 8-digit HS products which fall into the same 4-digit CIC code for each year. To be precise, the industry tariff is calculated from $\tau_{it} = \left(\sum_{g=1}^{G_i} v_{gt}\tau_{gt}\right) / \left(\sum_{g=1}^{G_i} v_{gt}\right)$, where τ_{gt} is the 8-digit HS level tariff of an imported good g at year t, v_{gt} is the import value of good g in that year, and G_i is the number of 8-digit HS sectors included in 4-digit CIC sector i. Later, we use these tariff data to test our theory. These industry tariffs are the tariffs faced by foreign firms entering the Chinese market. As a robustness check, we use the import value in 2003 (which is the middle year of our sample), v_{g2003} , as the weight for tariff calculation for all years and rerun all the tests. The purpose of doing so is to control for the variation of trade value within industry across years during the trade liberalization period so that we can get a clearer picture of the pure effect of tariff reduction.

In addition to allowing tariff rate to be different across sectors, we also allow the elasticity of substitution σ, and the productivity dispersion level γ to be different across sectors. It can be shown that the results listed in Table 1A are qualitatively the same as before. The only change needed in Table 1A in the Appendix is to change B_1 to $B_1^k \equiv (\tau_k^*)^{\gamma_k^*}\left(\frac{f_x}{f}\right)^{\frac{\gamma_k^*}{\sigma_k^*-1}-1}$ and B_2 to $B_2^k \equiv (\tau_k)^{\gamma_k}\left(\frac{f_x}{f}\right)^{\frac{\gamma_k}{\sigma_k-1}-1}$. It follows that Propositions 8 and 9 continue to hold. We further assume that λ ($\equiv dB_1/dB_2$ where B_1 is import barrier of Foreign and B_2 is import barrier of Home) is different across sectors. Thus, we define B_1^k as the import barrier of Foreign in sector k and B_1^k as the import barrier of Home in sector k, and $\lambda_k \equiv dB_1^k/dB_2^k$. Now, different sectors have different threshold for a_k: $(a_k)^{\gamma_k} < \frac{B_1^k+\lambda_k B_2^k}{1+\lambda_k\left(B_2^k\right)^2}$ according to Lemma 3. In other words, the theory predicts that the reverse-Melitz outcome will occur in the two-way trade sectors in which the relative productivity index $(a_k)^{\gamma}$ is less than $\frac{B_1^k+\lambda_k B_2^k}{1+\lambda_k\left(B_2^k\right)^2}$. Furthermore, from the version of Table 1A modified for differences in γ and τ across sectors, we can easily verify that the fraction of firms that export in each sector satisfies:

$$\frac{\theta_{xk}}{\theta_{dk}} = \left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}_{xk}}\right)^{\gamma_k} = \frac{1}{B_2^k}\cdot\frac{B_2^k(a_k)^{\gamma_k}-1}{B_1^k-(a_k)^{\gamma_k}}\cdot\frac{f}{f_x}$$

$$\iff \quad \frac{\theta_{xk}}{\theta_{dk}}\left(B_2^k\right)^2 = B_2^k\left[\frac{B_2^k(a_k)^{\gamma_k}-1}{B_1^k-(a_k)^{\gamma_k}}\right]\frac{f}{f_x}$$

Thus, the condition for reverse-Melitz outcome to occur in sector k can be re-written as below:

$$(a_k)^{\gamma_k} < \frac{B_1^k+\lambda_k B_2^k}{1+\lambda_k\left(B_2^k\right)^2} \iff B_2^k\left[\frac{B_2^k(a_k)^{\gamma_k}-1}{B_1^k-(a_k)^{\gamma_k}}\right] < \frac{1}{\lambda_k}$$

$$\iff B_2^k\left[\frac{B_2^k(a_k)^{\gamma_k}-1}{B_1^k-(a_k)^{\gamma_k}}\right]\frac{f}{f_x} < \frac{f}{\lambda_k f_x} \iff \frac{\theta_{xk}}{\theta_{dk}}\left(B_2^k\right)^2 < \frac{f}{\lambda_k f_x}$$

where the last equivalence is obtained by invoking the previous equation.

[20] The NBSC provide a concordance table between the 6-digit HS code and the 4-digit Chinese industry code. Source of this table can be found at: http://www.5000.gov.cn/release/FrontManage/next_page.aspx?currentPosition=2&cateid=2.

Therefore, $\frac{\theta_{xk}}{\theta_{dk}}\left(B_2^k\right)^2 < \frac{f}{\lambda_k f_x}$ iff there is reverse-Melitz outcome in sector k. Unfortunately, we do not have data of λ_k, as it requires knowing the export barriers of China's exports to all its trading partners, which is a daunting task. Therefore, we take a short cut: we assume that λ_k is randomly distributed across sectors with mean $\overline{\lambda}$. As there is no reason to suspect that λ_k is correlated with k, this assumption is justifiable. This assumption is equivalent to saying that λ_k is i.i.d. with mean $\overline{\lambda}$, which in turn implies that there is more likely to be reverse-Melitz outcome in a sector k when $\frac{\theta_{xk}}{\theta_{dk}}\left(B_2^k\right)^2$ is smaller. We calculate the variable $\frac{\theta_{xk}}{\theta_{dk}}\left(B_2^k\right)^2$, which we call RATIO, for each of the twenty-nine 2-digit CIC sectors, and rank them. Note that a lower RATIO is assigned a lower rank. A higher RATIO implies that China has stronger comparative advantage in that sector.[21] Table 2 shows the ranking of these 2-digit CIC sectors and the corresponding sectoral information that determine the RATIO. We choose the eight sectors with the lowest RATIOs to test for the reverse-Melitz outcome and the eight sectors with the highest RATIOs to test for the Melitz outcome. We run (i) the fraction of exporting firms and (ii) the share of exporting revenue, on the tariff rate for each 4-digit sector, while controlling for the year and industry (2-digit CIC level) fixed effects and other relevant variables (including employment, capital-labor ratio, average wage in each 4-digit sector). Amongst these variables, employment stands for the size of the sector, and is used to control for the economies of scales; K/L = capital-labor ratio is used to control for production technique; average wage is used to control for the variable costs and worker skill. The right hand side variables we choose are similar to those of Bernard, Jensen and Schott (2006, Table 4). The results are shown in Tables 3A and 3B. (CA stands for comparative advantage.)

<Table 2 about here>

From Tables 3A and 3B, we see that all the coefficients for the variable "Tariff" are significant in both regressions. Most importantly, the signs are distinctly positive for the eight comparative-disadvantage sectors and distinctly negative for the eight comparative-advantage sectors. In other words, both the fraction of exporting firms and the share of exporting revenue decrease (increase) with trade liberalization for the sectors in which China has comparative disadvantage (comparative advantage). Therefore, we conclude that, consistent with our theory, there exists reverse-Melitz outcome in the sectors where China has the comparative disadvantage but still produces; while the Melitz outcome continues to prevail in the sectors in which China has comparative advantage. The coefficients of the other right hand side variables make sense too. For example, higher K/L signifies stronger comparative disadvantage, which lowers exporting ratio and share of export revenue according to our

[21] Based on a nested constant-elasticity-substitution utility function, Broda and Weinstein (2006) estimate product-specific elasticities of substitution at the HS 10-digit level. The data is available from Weinstein's website. We aggregate these numbers up to the HS6 level by taking means, and then use the concordance table from NBSC to calculate the elasticity of substitution of each sector as the average of all the 6-digit HS products which fall into the standardized 2-digit CIC code. For the Pareto location parameter γ_k, we estimate them using the estimates of σ_k and the theoretical prediction that firm sales follow a Pareto distribution with shape parameter $\frac{\gamma_k}{\sigma_k - 1}$ within industry k. We follow Eaton, Kortum and Kramarz (2011) in restricting attention to exporters only and back out the shape parameter of the firm sales distribution from a regression of the logarithm of the firm sales rank on the logarithm of firm sales. As in Axtell (2001), we find that $\frac{\gamma_k}{\sigma_k - 1}$ is close to 1 for each sector. Hence, we have $B_k \approx \tau_k^{\gamma_k}$ and we use $\tau_k^{\gamma_k}$ to approximate B_k, where τ_k is the average tariff rate in each 2-digit CIC industry and γ_k captures the productivity dispersion level in each 2-digit CIC industry.

theory. Higher wage signifies higher labor quality, which tends to induce higher propensity to export. Higher employment signifies higher economic scale, which also tends to induce higher propensity to export.

Fraction of exporting firms, year 2000-2006						
Regressor	eight sectors with weakest CA			eight sectors with strongest CA		
Tariff	0.593***	0.754***	0.542***	-0.420***	-0.180***	-0.144***
	(0.125)	(0.158)	(0.151)	(0.065)	(0.051)	(0.050)
log(employment)			-0.002			0.014***
			(0.005)			(0.004)
log(K/L)			-0.128***			-0.095***
			(0.015)			(0.015)
log(wage)			0.198***			0.087***
			(0.033)			(0.029)
Industry fixed effect	NA	Yes	Yes	NA	Yes	Yes
Year fixed effect	NA	Yes	Yes	NA	Yes	Yes
Observations	474	474	474	564	564	564

Note: ***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level.

Table 3A

Share of exporting revenue in total revenue, year 2000-2006						
Regressor	eight sectors with weakest CA			eight sectors with strongest CA		
Tariff	0.558***	0.646***	0.422***	-0.442***	-0.225***	-0.208***
	(0.133)	(0.150)	(0.139)	(0.068)	(0.052)	(0.049)
log(employment)			0.002			0.008**
			(0.005)			(0.004)
log(K/L)			-0.138***			-0.123***
			(0.014)			(0.015)
log(wage)			0.139***			-0.015
			(0.031)			(0.028)
Industry fixed effect	NA	Yes	Yes	NA	Yes	Yes
Year fixed effect	NA	Yes	Yes	NA	Yes	Yes
Observations	474	474	474	564	564	564

Note: ***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level.

Table 3B

The choice of the eight sectors with the lowest RATIOs to stand for comparative disadvantage sectors and the eight sectors with the highest RATIOs to stand for comparative advantage sectors may sound a bit arbitrary. Therefore, we check the robustness of the results by varying the set of sectors we choose. We run six regressions for each set of sectors we choose: we run (i) the fraction of exporting firms and (ii) the share of exporting revenue, on the tariff rate for each set of sectors, while controlling for the year and industry (2-digit CIC level) fixed effects and other relevant variables (including employment, capital-labor ratio, average wage in each 4-digit sector). Each regression is the same as the corresponding one shown in Tables 3A and 3B, though the set of sectors used is different. The result is shown in Figure 5.

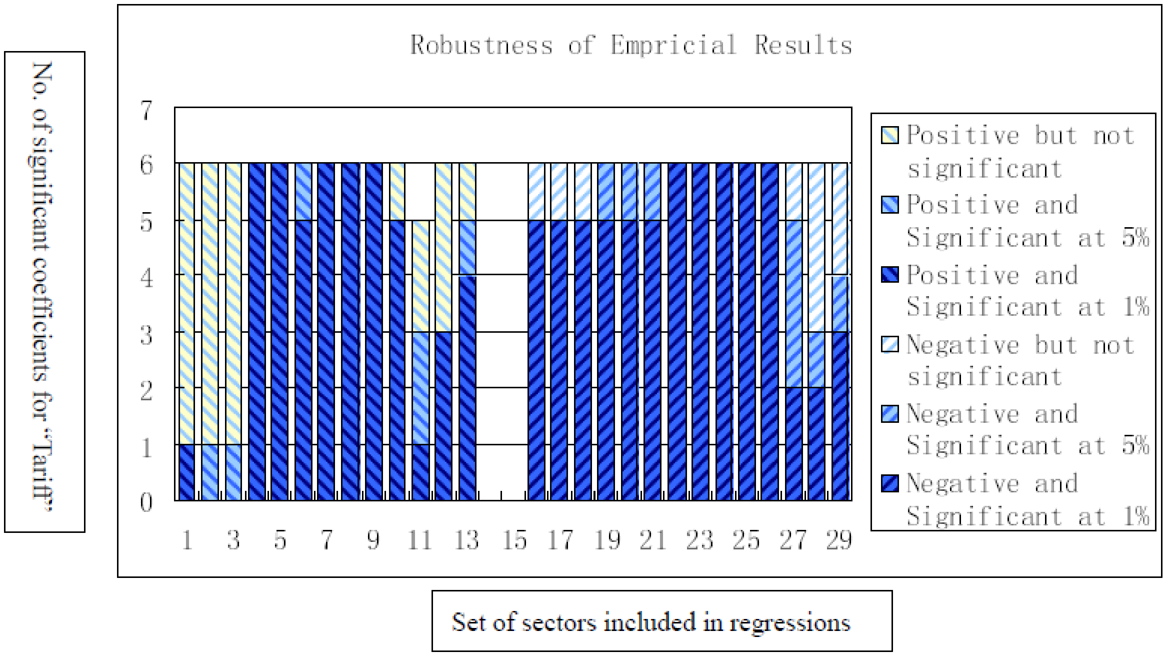


Figure 5.

The horizontal axis in Figure 5 indicates what sectors are included when running the regressions. Note that there is a set of bars on the left and another set of bars on the right. On the left, a number x on the horizontal axis indicates that sectors from the sector with ranking number 1 to the sector with ranking number x are included in the regressions. Therefore, as x increases, the number of comparative disadvantage sectors included in the regressions increase. On the right, a number x indicates that sectors from the sector with ranking number x to the sector with ranking number 29 are included in the regression. Therefore, as x decreases, the number of comparative advantage sectors included in the regressions increase. The vertical axis indicates the number of regressions for which the coefficient for the variable "Tariff" is statistically significant when the corresponding set of sectors indicated on the horizontal axis is included in the regressions. In the figure, the darkest bars represent the number of coefficients with the right sign (positive for the left group of sectors and negative for the right group of sectors) and significant at 1% level. The second darkest bars represent the number of coefficients with the right sign and significant at 5% level (but not significant at 1% level). The lightest bars represent the number of coefficients with the right sign, but not significant at 5% level.[22] From the

[22] For example, a number 9 on the horizontal axis indicates that sectors with rankings 1 through 9 are included in the regressions. Corresponding to that, all six regressions similar to the ones shown in Table 3A and 3B yield positive and significant coefficients (at 1% level) for variable "Tariff". A number 21 on the horizontal axis indicates that sectors with rankings 21 through 29 are included in the regressions. Corresponding to that, five of the regressions similar to the ones shown in Table 3A and 3B yield negative and significant coefficients (at 1% level) for "Tariff", while one regression yields

figure, it is clear that the reverse-Melitz outcome becomes significant when we include sufficiently large number of sectors with the smallest RATIOs (the figure shows that 4 is a sufficiently large number of sectors), and the effect remains significant till we include the 9 sectors with the smallest RATIOs. Likewise, the Melitz outcome becomes significant when we include sufficiently large number of sectors with the largest RATIOs (the figure shows that 4 is also a sufficiently large number of sectors), and the outcome continues to prevail till we include the 11 sectors with the highest RATIOs. The coefficients for the sectors at both ends of the ranking are mostly not very significant, probably due to the limited sample size (too few observations).[23] The coefficients are mostly not very significant when the sectors in the middle of the ranking are included. This is consistent with our theory, as they are sectors at the margin, and neither the Melitz outcome nor the reverse-Melitz outcome dominate. Thus, the total effect is ambiguous. Table 4 shows the results of the OLS regressions when the data of all sectors are pooled together.

Year 2000-2006	Fraction of exporting firms			Share of exporting revenue in total revenue		
Regressor	All sectors			All sectors		
Tariff	-0.010	0.011	0.022	-0.110**	-0.061	-0.051
	(0.040)	(0.041)	(0.038)	(0.044)	(0.044)	(0.042)
log(employment)			0.016***			0.013***
			(0.002)			(0.002)
log(K/L)			-0.112***			-0.142***
			(0.007)			(0.008)
log(wage)			0.124***			0.107***
			(0.013)			(0.014)
Industry fixed effect	NA	Yes	Yes	NA	Yes	Yes
Year fixed effect	NA	Yes	Yes	NA	Yes	Yes
Observations	2430	2430	2430	2430	2430	2430

Note: ***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level.

Table 4

In Table 4, most of the coefficients are not statistically significant and even the signs of the coefficients are ambiguous. This is consistent with our theory, as some sectors exhibit reverse-Melitz outcome while others exhibit Melitz outcome, and therefore the total effect maybe ambiguous and statistically insignificant. This result contrast with that obtained by Bernard, Jensen & Schott (2006). They use plant level data of the U.S. and run a similar regression of the probability of exporting on change in trade cost. They get negative sign (Melitz outcome) at 10% level of significance for that regression. The main reason for the difference might be that, unlike China, the U.S. does not have many sectors in which it has strong comparative disadvantage but in which it still produces. As a result, fewer plants in the U.S. would show reverse-Melitz outcome. Therefore, the overall outcome is dominated by the Melitz selection effect. Moreover, the coefficient is also not very significant statistically as the Melitz

negative and significant coefficient at 5% level for "Tariff".

[23] Some 2-digit industries contain fewer than ten 4-digit sectors. Thus the degree of freedom of the regression may be limited if we choose too few 2-digit industries for testing our propositions.

selection effect is countered by the IRA effect in some sectors.

Robustness of the Result

For robustness check, we construct the tariff for each industry using the import value in 2003 (which is the middle year of our sample), v_{g2003} , as the weight for tariff calculation for all years and report the regression results in Figure 6. As in Figure 5, Figure 6 shows that the reverse-Melitz outcome becomes significant when we include sufficiently large number of sectors with the smallest RATIOs, and the effect remains significant until we include the 7 sectors with the smallest RATIOs. Likewise, the Melitz outcome becomes significant when we include sufficiently large number of sectors with the largest RATIOs, and the outcome continues to prevail until we include the 16 sectors with the highest RATIOs. Thus, these results are also consistent with the predictions of our theory. Furthermore, we report the results of the OLS regressions when the data of all sectors are pooled together in Table 5. Like in Table 4, the coefficients in Table 5 are not statistically significant either, as the reverse-Melitz outcome and the Melitz outcome cancel each other when all sectors are pooled together.

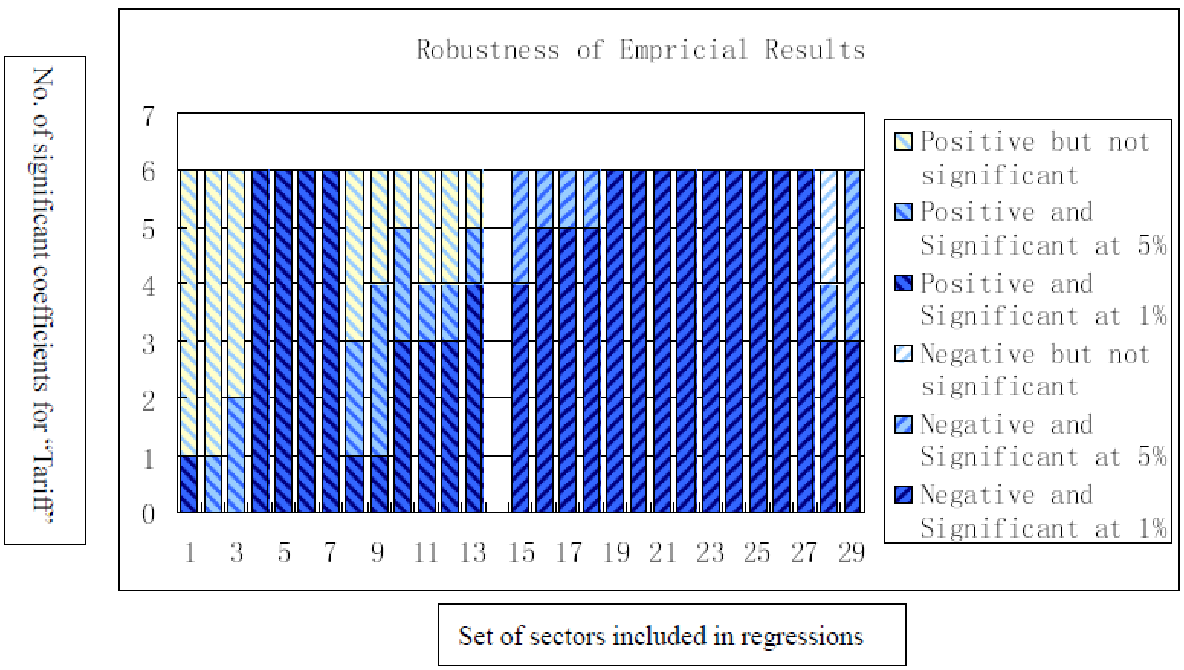


Figure 6.

Year 2000-2006	Fraction of exporting firms			Share of exporting revenue in total revenue		
Regressor	All sectors			All sectors		
Tariff	-0.011	0.011	0.024	-0.105**	-0.058	-0.045
	(0.039)	(0.039)	(0.037)	(0.043)	(0.043)	(0.040)
log(employment)			0.015***			0.013***
			(0.002)			(0.003)
log(K/L)			-0.111***			-0.140***
			(0.007)			(0.008)
log(wage)			0.122***			0.105***
			(0.013)			(0.014)
Industry fixed effect	NA	Yes	Yes	NA	Yes	Yes
Year fixed effect	NA	Yes	Yes	NA	Yes	Yes
Observations	2406	2406	2406	2406	2406	2406

Note: ***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level.

Table 5

8 Conclusion

In this paper, we incorporate Ricardian comparative advantage into a multi-sector version of Melitz's (2003) model to explain how the pattern of international specialization and trade is determined by the interaction of comparative advantage, economies of scale, country sizes and trade barriers. The model is able to capture the existence of inter-industry trade and intra-industry trade in a single unified framework. It explains how opening up to trade and trade liberalization affect the pattern of international specialization and welfare. The paper examines the generality of Melitz's firm selection effect in response to trade liberalization in a multi-sectoral setting.

Although, like Melitz (2003), opening up to trade is welfare-improving in both countries, trade liberalization can lead to a reverse-Melitz outcome in the two-way trade sectors in which the country has the strongest comparative disadvantage, if the country is sufficiently large or its tariff reduction is sufficiently asymmetric compared with its trading partners. In this case, the productivity cutoff for survival is lowered while the exporting cutoff increases in the face of trade liberalization, leading to reductions in real wage in terms of these goods. This is because the inter-sectoral resource allocation (IRA) effect together with the unilateral liberalization (UL) effect dominate the Melitz selection effect in these sectors.

Empirical evidence in the years 2000-2006 confirms that the fraction of exporting firms as well as the share of export revenue in total revenue both decreased in the comparative-disadvantage sectors of China in the face of trade liberalization, consistent with our hypothesis.

Our basic model can be easily modified to capture the existence of another type of reverse-Melitz outcome that, in the comparative advantage sector, it is possible that firms that sell domestically have higher average productivity than firms that do not, as documented by Lu (2010) and others.

Appendixes

A Solving for the System

In this appendix, we will show how to solve the model for the sectors where both countries produce. In other words, we solve for $(\overline{\varphi}_{dk}, \overline{\varphi}^*_{dk}, \overline{\varphi}_{xk}, \overline{\varphi}^*_{xk}, \theta_{dk}, \theta^*_{dk})$ from the system constituted of the four zero cutoff profit conditions and two free entry conditions. Combining the two zero cutoff conditions for firms serving the Home market, (11) and (14), we have

$$\frac{\overline{\varphi}^*_{xk}}{\overline{\varphi}_{dk}} = a_k \left(\frac{Bf_x}{f}\right)^{\frac{1}{\gamma}} \tag{29}$$

Similarly, combining those for firms serving Foreign's market, (12) and (13), we can get

$$\frac{\overline{\varphi}_{xk}}{\overline{\varphi}^*_{dk}} = \frac{1}{a_k} \left(\frac{Bf_x}{f}\right)^{\frac{1}{\gamma}} \tag{30}$$

Equations (29), (30), and the FE conditions (15), and (16) now form a system of four equations and four unknowns, $\overline{\varphi}_{dk}$,$\overline{\varphi}_{xk}$,$\overline{\varphi}^*_{dk}$ and $\overline{\varphi}^*_{xk}$. Solving, we obtain (17), (18), (19) and (20).

Then recall that the aggregate price indexes are given by $P_k = \theta_k^{\frac{1}{1-\sigma}} p_{dk}(\widetilde{\varphi}_k)$ and $P^*_k = (\theta^*_k)^{\frac{1}{1-\sigma}} p^*_{dk}(\widetilde{\varphi}^*_k)$. Substituting these price indexes into Zero Cutoff Conditions (11) and (12), and with the help of equation (9) and (10), we have

$$\sigma f = \frac{b_k L}{\theta_k} \left(\frac{\overline{\varphi}_{dk}}{\widetilde{\varphi}_k}\right)^{\sigma-1} = \left(\frac{\gamma-\sigma+1}{\gamma}\right) \cdot \frac{b_k L}{\theta_{dk} + \theta^*_{xk}\frac{f_x}{f}} \tag{31}$$

$$\sigma f = \frac{b_k L^*}{\theta^*_k} \left(\frac{\overline{\varphi}^*_{dk}}{\widetilde{\varphi}^*_k}\right)^{\sigma-1} = \left(\frac{\gamma-\sigma+1}{\gamma}\right) \cdot \frac{b_k L^*}{\theta^*_{dk} + \theta_{xk}\frac{f_x}{f}} \tag{32}$$

From the equilibrium productivity cutoffs (17) and (18) in both countries, we get

$$\left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}^*_{dk}}\right)^{\gamma} = \frac{B-(a_k)^{-\gamma}}{B-(a_k)^{\gamma}} \tag{33}$$

Therefore, the number of exporting firms in Home and Foreign are respectively:

$$\theta_{xk} = \left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}_{xk}}\right)^{\gamma} \theta_{dk} = \left(a_k \frac{\overline{\varphi}_{dk}}{\overline{\varphi}^*_{dk}}\right)^{\gamma} \left(\frac{f}{Bf_x}\right) \theta_{dk} \tag{34}$$

$$\theta^*_{xk} = \left(\frac{\overline{\varphi}^*_{dk}}{\overline{\varphi}^*_{xk}}\right)^{\gamma} \theta^*_{dk} = \left(\frac{\overline{\varphi}^*_{dk}}{a_k \cdot \overline{\varphi}_{dk}}\right)^{\gamma} \left(\frac{f}{Bf_x}\right) \theta^*_{dk} \tag{35}$$

Equations (31), (32), (33), (34), (35) then imply (21) and (22).

θ_{xk} and θ^*_{xk} can be obtained by substituting (33), (21), (22) into (34) and (35) respectively.

B Impacts of opening up to trade on welfare

For sectors in which **both countries produce**, i.e. when $(a_k)^\gamma \in \left(\frac{B\left(\frac{L}{L^*}+1\right)}{B^2\frac{L}{L^*}+1}, \frac{B^2\frac{L^*}{L}+1}{B\left(\frac{L^*}{L}+1\right)}\right)$, we can write Home's aggregate price index in the sector as:

$$P_k = (\theta_{dk} + \theta^*_{xk})^{\frac{1}{1-\sigma}} p_{dk}(\widetilde{\varphi}_k) = \left(\theta_{dk} + \theta^*_{xk}\frac{f_x}{f}\right)^{\frac{1}{1-\sigma}} p_{dk}(\widetilde{\varphi}_{dk})$$

Substituting the equilibrium values of θ_{dk}, θ^*_{xk}, θ^*_{dk}, θ_{xk} into the above equation, we find that $\theta_{dk} + \theta^*_{xk}\frac{f_x}{f} = \theta_{ck}$. Therefore, we can simplify the price index as:

$$P_k = (\theta_{ck})^{\frac{1}{1-\sigma}} \frac{1}{\rho A_k \widetilde{\varphi}_{dk}}$$

Therefore, Home's real wage in terms of the aggregate good in this sector (hereinafter we shall refer to real wage in terms of the aggregate good in sector k as the "real wage in terms of good k") is given by:

$$\frac{1}{P_k} = (\theta_{ck})^{\frac{1}{\sigma-1}} \rho A_k \widetilde{\varphi}_{dk} = \left[\frac{B - B^{-1}}{B - (a_k)^\gamma}\right]^{\frac{1}{\gamma}} \frac{1}{P_{ck}} > \frac{1}{P_{ck}} \tag{36}$$

In a sector where **Foreign completely dominates**, i.e. when $(a_k)^\gamma \in \left(0, \frac{B\left(\frac{L}{L^*}+1\right)}{B^2\frac{L}{L^*}+1}\right)$, Home's real wage in terms of the aggregate good in this sector is given by:

$$\frac{1}{P_k} = (\theta^*_{xk})^{\frac{1}{\sigma-1}} \rho A^*_k \widetilde{\varphi}^*_{xk} \frac{1}{\tau} = a_k^{-1} B^{-\frac{1}{\gamma}} \left(\frac{L + L^*}{L}\right)^{\frac{1}{\gamma}} \frac{1}{P_{ck}} > \frac{1}{P_{ck}} \tag{37}$$

In a sector where **Home completely dominates**, i.e. when $(a_k)^\gamma \in \left(\frac{B^2\frac{L^*}{L}+1}{B\left(\frac{L^*}{L}+1\right)}, \infty\right)$, Home's real wage in terms of the aggregate good in this sector is given by:

$$\frac{1}{P_k} = (\theta_{dk})^{\frac{1}{\sigma-1}} \rho A_k \widetilde{\varphi}_{dk} = \left(\frac{L + L^*}{L}\right)^{\frac{1}{\gamma}} \frac{1}{P_{ck}} > \frac{1}{P_{ck}} \tag{38}$$

Therefore, the welfare increases after trade integration. The following proposition and Figure 3 summarize the analysis above.

C Welfare Impact of Trade Liberalization

In this appendix, we will prove how the real wage in terms of the aggregate good of sector k (thereafter called real wage in terms of good k) changes after trade liberalization in three cases. Without loss of generality, we assume that $L > L^*$.

1. Foreign-dominated sectors: $k \in (0, k_1)$. The real wage in terms of good k in this zone in Home and Foreign are, respectively:

$$\frac{1}{P_k} = (\theta^*_{xk})^{\frac{1}{\sigma-1}} \rho A^*_k \widetilde{\varphi}^*_{xk} \frac{1}{\tau} = \rho A^*_k B^{-\frac{1}{\gamma}} \left(\frac{L+L^*}{L} D_1 \right)^{\frac{1}{\gamma}} \left(\frac{\gamma}{\gamma-\sigma+1} D_2(k) L \right)^{\frac{1}{\sigma-1}}$$

$$\frac{1}{P^*_k} = (\theta^*_{dk})^{\frac{1}{\sigma-1}} \rho A^*_k \widetilde{\varphi}^*_{dk} = \rho A^*_k \left(\frac{L+L^*}{L^*} D_1 \right)^{\frac{1}{\gamma}} \left(\frac{\gamma}{\gamma-\sigma+1} D_2(k) L^* \right)^{\frac{1}{\sigma-1}}$$

Since trade liberalization will increase $\frac{1}{P_k}$ as B falls, the real wage in terms of good k in Home will be improved. However, the real wage in Foreign, $\frac{1}{P^*_k}$, is not related to the trade barriers. That's, trade liberalization does not affect the real wage in Foreign.

2. Both countries produce: $k \in (k_1, k_2)$. The real wage in Home and Foreign in terms of good k are equal to:

$$\frac{1}{P_k} = (\theta_{ck})^{\frac{1}{\sigma-1}} \rho A_k \widetilde{\varphi}_{dk} = \rho A_k \left(D_1 \frac{B - B^{-1}}{B - (a_k)^{\gamma}} \right)^{\frac{1}{\gamma}} \left(\frac{\gamma}{\gamma-\sigma+1} D_2(k) L \right)^{\frac{1}{\sigma-1}}$$

$$\frac{1}{P^*_k} = (\theta^*_{ck})^{\frac{1}{\sigma-1}} \rho A^*_k \widetilde{\varphi}^*_{dk} = \rho A^*_k \left(D_1 \frac{B - B^{-1}}{B - (a_k)^{-\gamma}} \right)^{\frac{1}{\gamma}} \left(\frac{\gamma}{\gamma-\sigma+1} D_2(k) L^* \right)^{\frac{1}{\sigma-1}}$$

This zone is divided into two cases:

(a) Scenario A: $(a_k)^{\gamma} < \frac{2B}{1+B^2}$.

Note that $\frac{B-B^{-1}}{B-(a_k)^{\gamma}}$ decreases but $\frac{B-B^{-1}}{B-(a_k)^{-\gamma}}$ increases as trade barrier B falls, as $(a_k)^{\gamma} < \frac{2B}{1+B^2}$. Therefore, the real wage in terms of good k in Home will decline, but the real wage in Foreign rises. This is the case with reverse-Melitz outcome in Home.

(b) Scenario B: $(a_k)^{\gamma} \in \left(\frac{2B}{1+B^2}, \frac{1+B^2}{2B} \right)$.

Since both $\frac{B-B^{-1}}{B-(a_k)^{\gamma}}$ and $\frac{B-B^{-1}}{B-(a_k)^{-\gamma}}$ increase as trade barrier B falls when $(a_k)^{\gamma} \in \left(\frac{2B}{1+B^2}, \frac{1+B^2}{2B} \right)$, the real wages in terms of good k in both countries increase in this zone.

3. Home-dominated sectors: $k \in (k_2, 1)$. Real wages in terms of good k are given by

$$\frac{1}{P_k} = (\theta_{dk})^{\frac{1}{\sigma-1}} \rho A_k \widetilde{\varphi}_{dk} = \rho A_k \left(\frac{L+L^*}{L} D_1 \right)^{\frac{1}{\gamma}} \left(\frac{\gamma}{\gamma-\sigma+1} D_2(k) L \right)^{\frac{1}{\sigma-1}}$$

$$\frac{1}{P^*_k} = (\theta_{xk})^{\frac{1}{\sigma-1}} \rho A_k \widetilde{\varphi}_{xk} \frac{1}{\tau} = \rho A_k B^{-\frac{1}{\gamma}} \left(\frac{L+L^*}{L^*} D_1 \right)^{\frac{1}{\gamma}} \left(\frac{\gamma}{\gamma-\sigma+1} D_2(k) L^* \right)^{\frac{1}{\sigma-1}}$$

It is clear that real wage in terms of good k in Home is unchanged but that in Foreign increases as B falls.

D Asymmetric Trade Liberalization

Let τ_1 represents trade cost of exporting from Home to Foreign, τ_2 represents trade cost of exporting from Foreign to Home. Then, some of the equations have to be modified, as shown below.

$$p_{dk}(j) = \frac{1}{\rho A_k \varphi_k(j)},\ p_{xk}(j) = \frac{\tau_1}{\rho A_k \varphi_k(j)}$$
$$p^*_{dk}(j) = \frac{1}{\rho A^*_k \varphi^*_k(j)},\ p^*_{xk}(j) = \frac{\tau_2}{\rho A^*_k \varphi^*_k(j)}$$

$$r_{dk}(j) = b_k L \left[\frac{p_{dk}(j)}{P_k}\right]^{1-\sigma},$$
$$\pi_{dk}(j) = \frac{r_{dk}(j)}{\sigma} - f.$$

$$r_{xk}(j) = b_k L^* \left[\frac{p_{xk}(j)}{P^*_k}\right]^{1-\sigma},$$
$$\pi_{xk}(j) = \frac{r_{xk}(j)}{\sigma} - f_x.$$

$$\theta_{xk} = \frac{1 - G(\overline{\varphi}_{xk})}{1 - G(\overline{\varphi}_{dk})}\theta_{dk} = \left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}_{xk}}\right)^{\gamma}\theta_{dk}$$
$$P_k = (\theta_k)^{\frac{1}{1-\sigma}}\, p_{dk}(\widetilde{\varphi}_k), \qquad P^*_k = (\theta^*_k)^{\frac{1}{1-\sigma}}\, p^*_{dk}(\widetilde{\varphi}^*_k) \tag{8'}$$

$$(\widetilde{\varphi}_k)^{\sigma-1} = \frac{1}{\theta_k}\left[\theta_{dk}\,(\widetilde{\varphi}_{dk})^{\sigma-1} + \theta^*_{xk}\left(\tau_2^{-1}\frac{1}{a_k}\widetilde{\varphi}^*_{xk}\right)^{\sigma-1}\right], \tag{9'}$$
$$(\widetilde{\varphi}^*_k)^{\sigma-1} = \frac{1}{\theta^*_k}\left[\theta^*_{dk}\,(\widetilde{\varphi}^*_{dk})^{\sigma-1} + \theta_{xk}\left(\tau_1^{-1}a_k\widetilde{\varphi}_{xk}\right)^{\sigma-1}\right] \tag{10'}$$

Thus we have the following six equations

$$r_{dk}(\overline{\varphi}_{dk}) = b_k L\,(P_k\rho A_k\overline{\varphi}_{dk})^{\sigma-1} = \sigma f \tag{11'}$$
$$r^*_{dk}(\overline{\varphi}^*_{dk}) = b_k L^*\,(P^*_k\rho A^*_k\overline{\varphi}^*_{dk})^{\sigma-1} = \sigma f \tag{12'}$$
$$r_{xk}(\overline{\varphi}_{xk}) = b_k L^*\left(\frac{P^*_k}{\tau_1}\rho A_k\overline{\varphi}_{xk}\right)^{\sigma-1} = \sigma f_x \tag{13'}$$
$$r^*_{xk}(\overline{\varphi}^*_{xk}) = b_k L\left(\frac{P_k}{\tau_2}\rho A^*_k\overline{\varphi}^*_{xk}\right)^{\sigma-1} = \sigma f_x \tag{14'}$$

$$f_e = [1 - G(\overline{\varphi}_{dk})]\,\widetilde{\pi}_k = \left(\frac{\sigma-1}{\gamma-\sigma+1}\right)\left[f\cdot(\overline{\varphi}_{dk})^{-\gamma} + f_x\cdot(\overline{\varphi}_{xk})^{-\gamma}\right] \tag{15'}$$
$$f_e = [1 - G(\overline{\varphi}^*_{dk})]\,\widetilde{\pi}^*_k = \left(\frac{\sigma-1}{\gamma-\sigma+1}\right)\left[f\cdot(\overline{\varphi}^*_{dk})^{-\gamma} + f_x\cdot(\overline{\varphi}^*_{xk})^{-\gamma}\right] \tag{16'}$$

Solving for them, we get

$$(\overline{\varphi}_{dk})^{\gamma} = D_1 \left[\frac{B_1 - B_2^{-1}}{B_1 - (a_k)^{\gamma}} \right] \tag{17'}$$

$$(\overline{\varphi}_{dk}^{*})^{\gamma} = D_1 \left[\frac{B_2 - B_1^{-1}}{B_2 - (a_k)^{-\gamma}} \right] \tag{18'}$$

$$\overline{\varphi}_{xk} = \left(\frac{B_1 f_x}{f} \right)^{\frac{1}{\gamma}} \frac{\overline{\varphi}_{dk}^{*}}{a_k} \tag{19'}$$

$$\overline{\varphi}_{xk}^{*} = \left(\frac{B_2 f_x}{f} \right)^{\frac{1}{\gamma}} a_k \overline{\varphi}_{dk} \tag{20'}$$

$$\theta_{dk} = D_2(k) \left[\frac{B_1 L - \frac{B_1 - (a_k)^{\gamma}}{B_2 (a_k)^{\gamma} - 1} L^{*}}{B_1 - B_2^{-1}} \right] \tag{21'}$$

$$\theta_{dk}^{*} = D_2(k) \left[\frac{B_2 L^{*} - \frac{B_2 (a_k)^{\gamma} - 1}{B_1 - (a_k)^{\gamma}} L}{B_2 - B_1^{-1}} \right] \tag{22'}$$

where $B_1 \equiv \tau_1^{\gamma} \left(\frac{f_x}{f} \right)^{\frac{\gamma}{\sigma-1} - 1}$, $B_2 \equiv \tau_2^{\gamma} \left(\frac{f_x}{f} \right)^{\frac{\gamma}{\sigma-1} - 1}$.

$$(a_{k_1})^{\gamma} = \frac{B_1 \left(\frac{L}{L^{*}} + 1 \right)}{B_1 B_2 \frac{L}{L^{*}} + 1} \tag{39}$$

$$(a_{k_2})^{\gamma} = \frac{B_1 B_2 \frac{L^{*}}{L} + 1}{B_2 \left(\frac{L^{*}}{L} + 1 \right)} \tag{40}$$

The equations for the one-way trade sectors will not change.

Sector type	Foreign-dominated	Two-way trade	Home-dominated
	$k < k_1$	$k_1 < k < k_2$	$k > k_2$
$(\overline{\varphi}_{dk})^\gamma$	$\varnothing$	$D_1 \frac{B_1 - B_2^{-1}}{B_1 - (a_k)^\gamma}$	$D_1 \frac{L+L^*}{L}$
$(\overline{\varphi}_{xk})^\gamma$	$\varnothing$	$D_1 \frac{B_2 - B_1^{-1}}{B_2 - (a_k)^{-\gamma}} \left(\frac{1}{a_k}\right)^\gamma \left(\frac{B_1 f_x}{f}\right)$	$D_1 \frac{f_x}{f} \left(\frac{L+L^*}{L^*}\right)$
$(\overline{\varphi}^*_{dk})^\gamma$	$D_1 \frac{L+L^*}{L^*}$	$D_1 \frac{B_2 - B_1^{-1}}{B_2 - (a_k)^{-\gamma}}$	$\varnothing$
$(\overline{\varphi}^*_{xk})^\gamma$	$D_1 \frac{f_x}{f} \frac{L+L^*}{L}$	$D_1 \frac{B_1 - B_2^{-1}}{B_1 - (a_k)^\gamma} (a_k)^\gamma \left(\frac{B_2 f_x}{f}\right)$	$\varnothing$
θ_{dk}	0	$D_2 \frac{B_1 L - \frac{B_1 - (a_k)^\gamma}{B_2 (a_k)^\gamma - 1} L^*}{B_1 - B_2^{-1}}$	$D_2 L$
θ_{xk}	0	$\left(\frac{\overline{\varphi}_{dk}}{\overline{\varphi}_{xk}}\right)^\gamma \theta_{dk}$	$D_2 \frac{f}{f_x} L^*$
θ^*_{dk}	$D_2 L^*$	$D_2 \frac{B_2 L^* - \frac{B_2 (a_k)^\gamma - 1}{B_1 - (a_k)^\gamma} L}{B_2 - B_1^{-1}}$	0
θ^*_{xk}	$D_2 \frac{f}{f_x} L$	$\left(\frac{\overline{\varphi}^*_{dk}}{\overline{\varphi}^*_{xk}}\right)^\gamma \theta^*_{dk}$	0
P_k	$[D_2 L]^{\frac{1}{1-\sigma}} a_k B_2^{\frac{1}{\gamma}} \left(\frac{L}{L+L^*}\right)^{\frac{1}{\gamma}} \frac{1}{\rho A_k \widetilde{\varphi}_{ck}}$	$[D_2 L]^{\frac{1}{1-\sigma}} \frac{1}{\rho A_k \widetilde{\varphi}_{dk}}$	$[D_2 L]^{\frac{1}{1-\sigma}} \frac{1}{\rho A_k \widetilde{\varphi}_{dk}}$
P^*_k	$[D_2 L^*]^{\frac{1}{1-\sigma}} \frac{1}{\rho A^*_k \widetilde{\varphi}^*_{dk}}$	$[D_2 L^*]^{\frac{1}{1-\sigma}} \frac{1}{\rho A^*_k \widetilde{\varphi}^*_{dk}}$	$[D_2 L^*]^{\frac{1}{1-\sigma}} \frac{B_1^{\frac{1}{\gamma}}}{a_k} \left(\frac{L^*}{L+L^*}\right)^{\frac{1}{\gamma}} \frac{1}{\rho A^*_k \widetilde{\varphi}^*_{ck}}$

Table 1A: Solution of the System Under Asymmetric Iceberg Trade Costs

(B_1 = import cost of Foreign; B_2 = import cost of Home)

$$D_1 = \left(\frac{\sigma - 1}{\gamma - \sigma + 1}\right) \frac{f}{f_e} \ ; \quad D_2 = \left(\frac{\gamma - \sigma + 1}{\gamma}\right) \frac{b_k}{\sigma f} \ ; \quad (a_{k_1})^\gamma = \frac{B_1 \left(\frac{L}{L^*} + 1\right)}{B_1 B_2 \frac{L}{L^*} + 1}; \quad (a_{k_2})^\gamma = \frac{B_1 B_2 \frac{L^*}{L} + 1}{B_2 \left(\frac{L^*}{L} + 1\right)}$$

$$\frac{d\left(\overline{\varphi}_{dk}\right)^\gamma}{dB_2} = D_1 \frac{B_2^{-2}}{B_1 - (a_k)^\gamma} > 0 \text{ iff } B_1 > (a_k)^\gamma \tag{41}$$

$$\frac{d\left(\overline{\varphi}_{xk}\right)^\gamma}{dB_2} = D_1 \frac{B_1^{-1} - (a_k)^{-\gamma}}{\left[B_2 - (a_k)^{-\gamma}\right]^2} \left(\frac{1}{a_k}\right)^\gamma \left(\frac{B_1 f_x}{f}\right) < 0 \text{ iff } B_1 > (a_k)^\gamma$$

Thus, $\overline{\varphi}_{dk}$ decreases as B_2 decreases iff $B_1 > (a_k)^\gamma$, and $\overline{\varphi}_{xk}$ increases as B_2 decreases iff $B_1 > (a_k)^\gamma$. However, $B_1 > (a_k)^\gamma$ must be true. Thus $\frac{\overline{\varphi}_{xk}}{\overline{\varphi}_{dk}}$ increases as B_2 decreases, in all sectors. (There is reverse-Melitz outcome (Home's real wage falls) in all sectors as Home unilaterally reduces its tariffs against Foreign's exports.)

On the other hand,

$$\frac{d\left(\overline{\varphi}_{dk}\right)^\gamma}{dB_1} = D_1 \frac{B_2^{-1} - (a_k)^\gamma}{\left[B_1 - (a_k)^\gamma\right]^2} < 0 \text{ iff } 1/B_2 < (a_k)^\gamma \tag{42}$$

$$\frac{d\left(\overline{\varphi}_{xk}\right)^\gamma}{dB_1} = D_1 \frac{B_2}{B_2 - (a_k)^{-\gamma}} \left(\frac{1}{a_k}\right)^\gamma \left(\frac{f_x}{f}\right) > 0 \text{ iff } 1/B_2 < (a_k)^\gamma$$

Thus, $\overline{\varphi}_{dk}$ increases as B_1 decreases iff $B_1 > (a_k)^\gamma$, and $\overline{\varphi}_{xk}$ decreases as B_1 decreases iff $B_1 > (a_k)^\gamma$. However, $1/B_2 < (a_k)^\gamma$ must be true. Therefore, $\frac{\overline{\varphi}_{xk}}{\overline{\varphi}_{dk}}$ decreases as B_1 decreases, in all sectors. (There is

Melitz outcome (Home's real wage rises) in all sectors as Foreign unilaterally reduces its tariffs against Home's exports.)

E When the assumption $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ is relaxed

Table 1 shows that that $\overline{\varphi}_{dk} > \overline{\varphi}_{xk}$ is equivalent to $\frac{f_x}{f} < \frac{L^*}{L}$ in the Home-dominated sectors $k \in (k_2, 1]$. In the Foreign-dominated sectors $k \in [0, k_1)$, $\overline{\varphi}^*_{dk} > \overline{\varphi}^*_{xk}$ is equivalent to $\frac{f_x}{f} < \frac{L}{L^*}$. In the two-way trade sectors $k \in (k_1, k_2)$, $\overline{\varphi}_{dk} > \overline{\varphi}_{xk}$ is equivalent to $(a_k)^\gamma > \frac{B^2 \frac{f_x}{f}+1}{B\left(\frac{f_x}{f}+1\right)}$ and $\overline{\varphi}^*_{dk} > \overline{\varphi}^*_{xk}$ is equivalent to $(a_k)^\gamma < \frac{B\left(\frac{f_x}{f}+1\right)}{B^2 \frac{f_x}{f}+1}$. Here, we can introduce two new thresholds k_3 and k_4, such that, $(a_{k_4})^\gamma = \frac{B^2 \frac{f_x}{f}+1}{B\left(\frac{f_x}{f}+1\right)}$ and $(a_{k_3})^\gamma = \frac{B\left(\frac{f_x}{f}+1\right)}{B^2 \frac{f_x}{f}+1}$.

It is clear that the assumption $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ ensures that $k_3 < k_1 < k_2 < k_4$. Thus $\overline{\varphi}_{dk} < \overline{\varphi}_{xk}$ and $\overline{\varphi}^*_{dk} < \overline{\varphi}^*_{xk}$ in all sectors $k \in [0, 1]$, and all firms either only serve the domestic market, or export and sell to domestic market at the same time. If the assumption $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ is relaxed, some Home producers can only sell to the Foreign market if $\frac{f_x}{f} < \frac{L^*}{L}$ (which is equivalent to $k_4 < k_2$). Furthermore, some Foreign producers can only sell to Home's market if $\frac{f_x}{f} < \frac{L}{L^*}$ (which is equivalent to $k_1 < k_3$).

Now relax the assumption $\frac{f_x}{f} > \max\{\frac{L}{L^*}, \frac{L^*}{L}\}$ while maintaining the assumption $\tau^{\sigma-1} f_x > f$ (which ensures that some firms produce exclusively for their domestic market in both countries in some sectors, i.e., $k_3 < k_4$). Under the condition that $L^* < L$, we have the following three cases:

(a): If $\frac{L^*}{L} < \frac{f_x}{f} < \frac{L}{L^*}$and $B^2 \frac{f_x}{f} \frac{L^*}{L} > 1$, then we have $k_1 < k_3 < k_2 < k_4$.

(b): If $\frac{L^*}{L} < \frac{f_x}{f} < \frac{L}{L^*}$and $B^2 \frac{f_x}{f} \frac{L^*}{L} < 1$, then we have $k_1 < k_2 < k_3 < k_4$.

(c): If $\frac{f_x}{f} < \min\{\frac{L}{L^*}, \frac{L^*}{L}\}$, then we have $k_1 < k_3 < k_4 < k_2$.

In all those three cases, there are some sectors in which the firms in some country that do not serve the domestic market can have a lower average productivity than those that do. In the following discussion, we focus our attention on case (c), i.e., $k_1 < k_3 < k_4 < k_2$. In zone $[0, k_1)$, only Foreign's firms produce; some of them only export, while others serve both markets. In zone (k_1, k_3), firms in both countries produce; Home's firms either serve both markets or Home's market only, while Foreign's firms either only export or sell to both markets. In zone (k_3, k_4), firms in both countries produce; they either serve both markets or their own domestic market only. In zone (k_4, k_2), firms in both countries produce; Home's firms either only export or sell to both markets, while Foreign's firms either serve both markets or their domestic market only. In zone $(k_2, 1]$,only Home's firms produce; some of them only export, and some serve both markets. **Consequently, in zone $(k_4, 1)$, where Home has comparative advantage, we have $\overline{\varphi}_{dk} > \overline{\varphi}_{xk}$, provided that $\frac{1}{\tau^{\sigma-1}} < \frac{f_x}{f} < \min\{\frac{L}{L^*}, \frac{L^*}{L}\}$.**

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	2-digit CIC Sector	Ranking	RATIO	γ_k	$\tau_k - 1$	Exporting Ratio	Revenue†	Exporting Revenue†	Firm number	Employment
23	Printing	1	0.105	3.83	0.022	0.089	1.13E+08	1.55E+07	4469	620409
33	Nonferrous Metal	2	0.318	7.41	0.050	0.154	5.42E+08	4.99E+07	3768	1065850
32	Ferrous Metal	3	0.439	12.6	0.064	0.092	1.42E+08	7.88E+07	5343	2693066
31	Non-metallic Minerals	4	0.504	5.74	0.115	0.145	6.86E+08	6.82E+07	17823	4039000
30	Plastic	5	0.583	3.56	0.107	0.283	3.80E+08	9.70E+07	10124	1579186
21	Furniture	6	0.635	2.65	0.087	0.407	1.00E+08	4.93E+07	2523	545313
27	Medicine	7	0.703	10.6	0.059	0.207	3.14E+08	3.44E+07	4469	1172301
28	Chemical Fiber	8	0.727	10.4	0.070	0.176	1.84E+08	1.11E+07	1117	385184
39	Electrical machinery	9	0.729	7.26	0.062	0.304	1.02E+09	2.66E+08	12875	3093539
40	Electronics	10	0.737	6.25	0.031	0.501	1.93E+09	1.15E+09	7227	3366607
26	Chemicals	11	0.741	7.06	0.093	0.210	1.09E+09	1.04E+08	13887	2976213
34	Fabricated Metal	12	0.759	5.50	0.084	0.311	4.48E+08	1.30E+08	10768	1805457
41	Instruments	13	0.887	5.94	0.069	0.403	2.01E+08	1.06E+08	3015	768286
20	Lumber	14	0.994	11.2	0.065	0.242	1.40E+08	2.85E+07	4666	724751
22	Paper	15	1.108	14.5	0.080	0.118	3.09E+08	2.47E+07	6451	1230160
25	Petroleum	16	1.215	18.5	0.065	0.117	8.79E+08	3.07E+07	1945	733549
29	Rubber	17	1.543	7.41	0.116	0.304	1.63E+08	4.00E+07	2528	714132
36	Equipments	18	1.748	14.1	0.077	0.212	4.60E+08	5.45E+07	8842	2178881
24	Education & Sports Tools	19	2.250	5.93	0.102	0.709	1.05E+08	7.07E+07	2687	884694
35	Industrial Machinery	20	4.421	17.4	0.087	0.243	7.33E+08	1.19E+08	15471	3074107
17	Textile	21	4.782	9.04	0.150	0.382	8.06E+08	2.14E+08	16632	4905468
19	Leather	22	5.154	8.42	0.137	0.589	2.61E+08	1.40E+08	5244	1865653
14	Food Manufacturing	23	6.640	14.1	0.130	0.213	2.77E+08	2.99E+07	5146	1069526
42	Handicrafts, etc	24	10.26	7.75	0.192	0.674	1.39E+08	7.69E+07	4247	1034364
15	Drinks	25	10.41	9.64	0.259	0.122	2.40E+08	9.38E+06	3297	860402
13	Food Processing	26	15.15	10.3	0.241	0.181	7.71E+08	8.48E+07	12920	1989242
16	Tobacco	27	15.51	12.5	0.189	0.204	2.44E+08	2.22E+06	240	212850
18	Apparel	28	93.44	24.8	0.185	0.610	3.86E+08	1.96E+08	10509	3053321
37	Transportation Equipments	29	1976	27.6	0.178	0.235	1.25E+09	1.40E+08	9225	3238818

Table 2. Ranking of Chinese sectors according to RATIO (strength of comparative advantage)

Note 1: † In thousand yuan.

Note 2: Columns 6-11 represent the mean of the tariff, exporting ratio, total revenue, total exporting revenue, firm number and total employment within each industry across years.