# A Unified Model of Structural Adjustments and International Trade: Theory and Evidence from China

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**Abstract**

We document the patterns of structural adjustments in Chinese manufacturing production and export: the production became more capital intensive while export participation increased for labor intensive sectors and decreased for capital intensive sectors from 1999 to 2007. To explain these patterns, we embed heterogeneous firm (Melitz 2003) into the Dornbusch-Fischer-Samuelson model of both continuous Ricardian and Heckscher-Ohlin (1977, 1980) with home bias preference. We structurally estimate the model by GMM. The estimation result indicates the following main findings: capital labor ratio almost trippled, technology improved sinificantly and favored more labor intensive industries, trade libralization mostly came from reduction in fixed cost of export for China, and reduction in preference for home goods between 1999 and 2007. Counterfactual simulations show that the adjustment in production pattern is mainly driven by changes in endowment while the changes in export participation is driven by technology, trade liberalization and reduction of home bias preference, but mostly driven by changes in technology.

**Key Words:** Structural Adjustments, Heterogeneous Firm, Comparative Advantage

**JEL Classification Numbers:** F12 and L16

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# 1 Introduction

There is a great deal of empirical research linking changes in factor endowments to changes in specialization and trade patterns. This research is consistent with a well-known story following a country's move towards free trade: The country initially specializes in and exports labor-intensive goods. Over time, as the country accumulates capital, the specialization and export patterns change towards capital-intensive goods.

China is one of the most fast growing economy and has experienced fast capital deepening and trade liberalization. In this paper we study changes in firm's distribution within a sector and resource reallocations across sectors for China in recent years. Using the firm level data in China from 1999 to 2007, we document seemingly puzzling data patterns: comparing the data in 2007 with that in 1999, productions became more capital intensive. On the other hand, however, exports became more labor intensive.

Following Schott (2003), we define industries as "HO aggregate" and regroup firms into 100 industries according to their capital share. Comparing the data in 2007 with that in 1999, the distribution of firm and production across industries shift toward the capital intensive industries. However, across industries, the distribution of exporters shifts towards labor intensive industries. Moreover, within an industry, the fraction of firms which export increases in labor intensive industries but decreases in capital intensive industries; firms in labor intensive industries export a larger fraction of their total output while firms in capital intensive industries export a smaller fraction of their total output.

China was clearly more capital abundant in 2007 than in 1999. According to the classical Heckscher-Ohlin theory, China should produce and export more capital intensive goods. Thus the change in production structures we observed is consistent with the classical HO theory, but the changes in export structures in the data seem to contradict the theory. To understand the seemingly puzzling data pattern, we introduce firm's heterogeneity into the HO and Ricardian framework to explore the driving forces behind. To be more specific, we introduce Melitz-type of firm's heterogeneity into the DFS framework of continuous Ricardian and Heckscher-Olin model (Dornbusch, Fischer and Samuelson 1977, 1980, hence DFS).[1]

In the model, two countries differ in the capital endowment and technology. We assume the Ricardian comparative advantage are in line with the Heckscher-Ohlin comparative advantage. In each country, there are a continuum of industries differing in the capital intensity. An industry is inhabited by heterogeneous firms who produce using capital and labor and face idiosyncratic productivity shock as in Melitz (2003). We show that in equilibrium, there are two cut-offs on the capital intensities that determine the firms' production and trade across industries: the most capital intensive industries and labor intensive industries are specialized by the capital abundant country and labor abundant country respectively; for industries with intermediate factor intensities, both countries produce. In industries that

[1] The introduction of home bias preference is for quantative reasons as detailed later. It incorporates no-home-bias as a special case.

a country specialize, we show that the export participation (measured by export probability or export intensity) remains constant and does not vary with industrial factor intensity. In industries that both countries produce, the export participation decreases with the capital intensity in the labor abundant country whereas it increases with the capital intensity in the capital abundant country. The theoretical predictions on specialization and export participation for the labor abundant country are consistent with the Chinese data.

Using the framework, we numerically solve the model and examine the comparative statics regarding capital deepening, trade liberalization and technology changes. We find that capital deepening and technology changes make productions and exports more capital intensive in a labor abundant country: it produces and exports more in capital intensive industries and *vice versa* in labor intensive industries. However, trade liberalization makes productions and exports more labor intensive since its comparative advantage is strengthened. Given that we observe Chinese production became more capital intensive while export participation of labor intensive and capital intensive moves in different directions, none of these forces alone could explain what we observe in the Chinese data.

To find out the driving forces behind the structural adjustments, we structurally estimate the parameters of the model for both years by GMM. The estimation result indicates the following main findings: capital labor ratio almost tripled, technology improved significantly and favored more labor intensive industries, trade liberalization mostly came from reduction in fixed cost of export and reduction in preference for home goods between 1999 and 2007. By running counterfactual simulations that replace year 1999 parameters with year 2007 parameters, we find changes in endowments is the main driving force that shift production towards more capital intensive sectors. Changes in parameters governing trade costs, technology and preference contribute much less to the adjustments in production pattern. While changes of all the parameters affect the export participation, sector-biased technology improvement is the main driving force behind the adjustment of export participation.

Our paper is related several strands of literature. First, we contribute to the booming literature of structural approach in international trade (Eaton and Kortum 2002, Anderson and van Wincoop 2003 and among many others). The closest paper to ours is Eaton, Kortum and Kramarz (2011, hence EKK) in which they extend the standard trade model of heterogeneous firm with multiple countries and industries.[2] We study the production and trade in a model with many industries and examine the data for China. Secondly, similar to Morrow (2010), we structurally estimate Ricardian and Heckscher-Ohlin comparative advantage at the same time. The main difference is that we estimate the deep parameters of the model and discuss the counterfactual implication to understand the structural adjustment for China. Thirdly, our paper is related to the recent literature studying the effect of evolving comparative advantages. While Costinot et. al (forthcoming) and Levchenko and Zhang (2013) focus on the welfare implication of evolving comparative advantages across countries, our paper studies how evolving comparative advantage could shape the production and trade structure of one country, taking into account changes in trade costs and

[2] They define standard trade model as demand being Dixit-Stiglitz, firms' efficiencies follow a Pareto distribution, iceberg trade costs between markets and fixed cost of entry for export.

preference. Finally, several papers incorporate the heterogeneous firm with the DFS model. Lu (2010) embeds heterogeneous firm model into a Heckscher-Ohlin framework with multiple industries based on EKK. Okubo (2009) and Fan et. al (2011) combine DFS of Ricardian with Melitz type heterogeneous firm. This paper is different in that we consider Ricardian and Heckscher-Ohlin models jointly.

The remainder of the paper are organized as follows. Section 2 presents the data patterns we observed from the Chinese firm level data. Section 3 develops the model and the equilibrium analysis is in section 4. Section 5 structurally estimates the model and runs counterfactual simulation. Section 6 concludes.

# 2 Motivating Evidences

In this section we present several stylized facts about the adjustments in production and trade structure over time. The data we use is the Chinese Annual Industrial Survey. It covers all State Own Enterprise (SOE) and non-SOEs with sales higher than 5 million RMB Yuan. The dataset provides information on balance sheet, profit and loss, cash flow statements, and firm's identification, ownership, export, employment, capital stock, etc. Our focus is on manufacturing firms (thus exclude utility and mining firms) which contribute more than 90% of the total Chinese manufacturing exports in aggregate trade data. To clean the data, we follow Brandt *et al* (2011) and drop firms with missing, zero, or negative capital stock, export and value added, and only include firms with employment larger than 8. Finally, we define capital share defined as $1 - \frac{wage}{value\_added}$.[3] We drop firms with capital intensity larger than one or less than zero. Since the focus of this paper are changes overtime, we look at data of year 1999 and 2007.[4] The Statistics Summary of the data after cleaning is shown in Table A1. In this paper, we focus on the factor reallocation and export participation. Table 1 below depict the following picture. From 1999 to 2007, the average capital share in China has increased by about 4 percentage points. So the overall manufacture production is more capital intensive. At the same time, the exports increased, especially along the intensive margin. The fraction of firms which export remains at about 25 percent. Yet the share of gross production that is exported increases by 2.7 percentage point. Another interesting feature is that despite of the general increase in the capital share, the capital share for exporters decreases slightly. These features suggest that the changes in the factor share, endowment and exports are intervened.

[3] Wage is defined as the sum of wage_payable, labor and employment insurance fee, and total employee benefits payable. In the 2007 data, there are also information about housing fund and housing subsidy, endowment insurance and medical insurance, and employee educational expenses. Adding these 3 variables would increase the average labor share but only slightly (from 0.293 to 0.308). To be consistent, we don't include them.

[4] We don't use year 2008 and years after due to lack of data and the aftermath of the financial crisis is of great concern.

Table 1: Capital Share and Export Participation

| Variables | mean in 1999 | mean in 2007 |
|---|---|---|
| capital share | 0.669 | 0.707 |
| proportion of exporters | 0.252 | 0.248 |
| exports/gross sales | 0.181 | 0.207 |
| capital share for exporters | 0.624 | 0.619 |

Next, we examine the capital share across industries. Table 2 shows that there are large variations of capital share within the 2 digit Chinese Industry Classification (CIC) of industry, Moreover, the capital intensity between exporters and non-exporters differs significantly. We find that except for Tobacco (industry 16) and Recycling (industry 43), capital share is significantly lower for exporters.[5] This is different from Alvarez and López (2005)'s finding that Chilean exporters are more capital intensive than non-exporters. It is in line with Bernard *et al's* (2007b) speculation that exporters in developing countries should be more labor intensive than non-exporters given their comparative advantage in labor intensive goods.[6]

**Fact 1:** *Under the industry definition according to final end (CIC), there are large variations of capital share within each industry. Exporters are less capital intensive than non-exporters (exceptions would be tobacco and recycling in 2007).*

Motivated by this feature of the data as well as the study by Schott (2003), we instead define industries as "HO aggregate." Following Schott (2003), we put all firms in the same year together and then regroup them according to their capital share.[7] For example, firms with capital share between 0 and 0.01 are lumped together and defined as industry 1. In total, we have 100 industries.

[5] On average, exporters are less capital intensive than non-exporters for all firms. The gap is larger in 2007 than 1999.

[6] For the same data, Ma *et al* (2011) use capital labor ratio (or capital wage payment ratio) as indicator of factor intensity. They also find Chinese exporters are less capital intensive than non-exporters. Based on transaction data, they find exporters choose to produce more labor intensive products which is consistent with the comparative advantage of China. Thus our finding is consistent with their findings.

[7] Schott (2003) looks at product level variations, while we investigate variations at the firm level.

Table 2: Captial Share of Firms in 2007

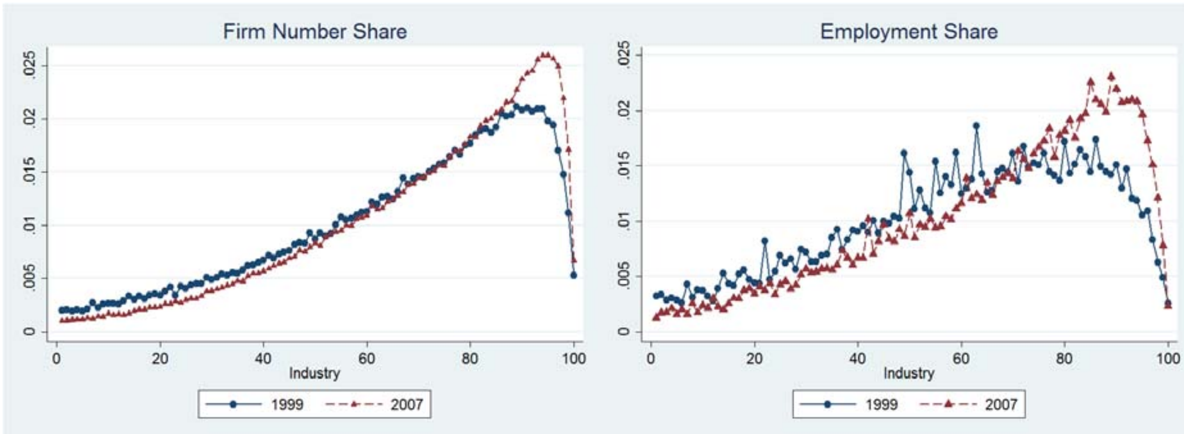
| 2 digit industry code | description | Capital Share of non-exporters | Std. Dev. of capital share for non-exporters | Capital Share for exporters | Std. Dev. of capital share for exporters |
|---|---|---|---|---|---|
| 13 | Processing of Food from Agriculture | 0.83 | 0.18 | 0.76 | 0.21 |
| 14 | Foods | 0.76 | 0.20 | 0.71 | 0.22 |
| 15 | Beverages | 0.80 | 0.18 | 0.78 | 0.18 |
| 16 | Tobacco | 0.74 | 0.19 | 0.90 | 0.11 |
| 17 | Textile | 0.72 | 0.20 | 0.63 | 0.22 |
| 18 | Wearing Apparel | 0.60 | 0.24 | 0.51 | 0.24 |
| 19 | Leather, Fur, Feather | 0.64 | 0.25 | 0.53 | 0.23 |
| 20 | Timber, Wood,etc | 0.74 | 0.20 | 0.69 | 0.21 |
| 21 | Furniture | 0.69 | 0.23 | 0.56 | 0.23 |
| 22 | Paper and Paper Products | 0.73 | 0.19 | 0.65 | 0.22 |
| 23 | Printing & Recording Media | 0.67 | 0.21 | 0.59 | 0.22 |
| 24 | Culture, Education related products | 0.64 | 0.24 | 0.54 | 0.24 |
| 25 | Processing of Petroleum, Coking & Nuclear Fuel | 0.85 | 0.16 | 0.78 | 0.20 |
| 26 | Raw Chemical Materials & Chemical Products | 0.79 | 0.19 | 0.75 | 0.19 |
| 27 | Medicines | 0.78 | 0.19 | 0.74 | 0.19 |
| 28 | Chemical Fibers | 0.80 | 0.17 | 0.77 | 0.19 |
| 29 | Rubber | 0.73 | 0.21 | 0.61 | 0.23 |
| 30 | Plastics | 0.72 | 0.21 | 0.60 | 0.23 |
| 31 | Non-metallic Mineral Products | 0.74 | 0.20 | 0.63 | 0.22 |
| 32 | Smelting and Pressing of Ferrous Metals | 0.82 | 0.17 | 0.82 | 0.15 |
| 33 | Smelting and Pressing of Non-ferrous Metals | 0.82 | 0.18 | 0.78 | 0.19 |
| 34 | Metal Products | 0.71 | 0.21 | 0.61 | 0.22 |
| 35 | General Purpose Machinery | 0.72 | 0.20 | 0.65 | 0.20 |
| 36 | Special Purpose Machinery | 0.72 | 0.21 | 0.63 | 0.21 |
| 37 | Transport Equipment | 0.70 | 0.21 | 0.65 | 0.21 |
| 39 | Electrical Machinery and Equipment | 0.73 | 0.21 | 0.61 | 0.23 |
| 40 | Communication Equipment, Computers | 0.65 | 0.23 | 0.58 | 0.25 |
| 41 | Measuring Instruments and other Machines | 0.69 | 0.22 | 0.56 | 0.23 |
| 42 | Artwork and Other Manufacturing | 0.66 | 0.23 | 0.57 | 0.24 |
| 43 | Recycling and Disposal of Waste | 0.79 | 0.21 | 0.81 | 0.18 |

*Notes: This is the 2-digit industry definition from Chinese National Bureau of Statics.*

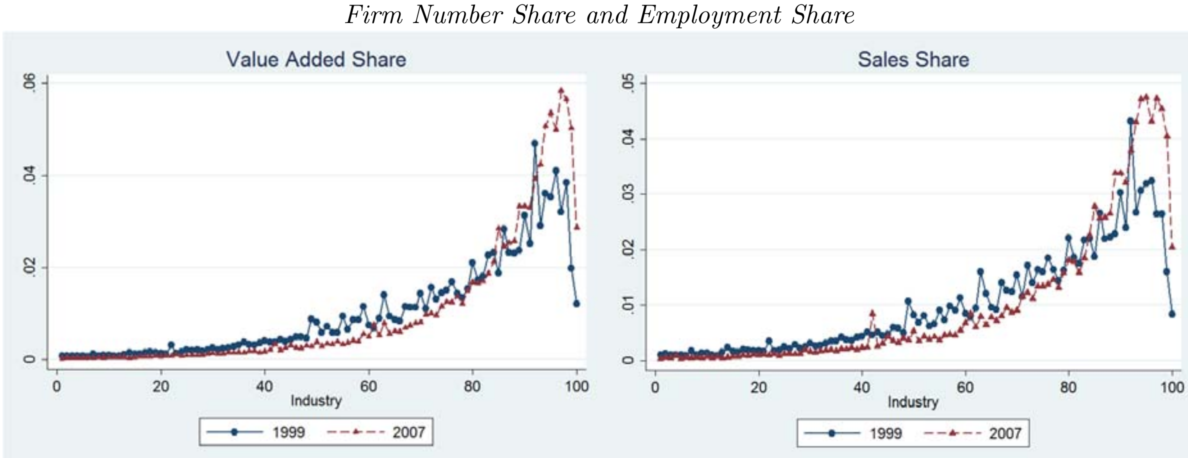
## 2.1 Production Structures

This subsection describes how the overall production structures change between 1999 and 2007. A direct evidence is from Table 1, the average of capital share is 0.669 in 1999 and 0.707 in 2007. Thus we do see the aggregate production became more capital intensive.[8]

[8] Thus the overall production is very concentrated on capital intensive industries. Hsieh and Klenow (2009) point out that labor share is significantly less than aggregate labor share in manufacturing reported in the Chinese input-output tables and the national accounts (roughly 50%). They argue that it could be explained by non-wage compensation and assume it a constant fraction of a plant's wage compensation and adjust it to be the same as aggregate reports. Since we only care about the distribution, a constant adjustment would not help thus we simple use the original value.




*Firm Number Share and Employment Share*




*Value Added Share and Sales Share*

**Fact 2:** *Compared with 1999, the overall Chinese production became more capital intensive in 2007.*

Next we examine the distribution of firm production across industries using different measures. We firstly look at number of firms and labor employment for each industry. In Figure **??**, industries are defined according to capital intensities of firms and we regroup firms into 100 industries. The horizontal axis of the graphs is the industry index. Higher numbers correspond to higher capital shares. Figure **??** shows that during 1999-2007, more firms are producing capital intensive industries while less firms are producing in labor intensive industries. At the same time, workers are moving out of labor intensive industries into more capital intensive industries. Thus there is a significant reallocation of resources towards capital intensive industries. In terms of output, from Figure **??**, we find that firms in capital intensive industries are accounting for larger fractions of value added and sales. The messages from Figure **??** and **??** could also be summarized by Table 3 below. In Table 3, we compute the share of firms with capital share higher than the average capital share in 1999. Clearly, we find the production structures become more capital intensive in 2007.

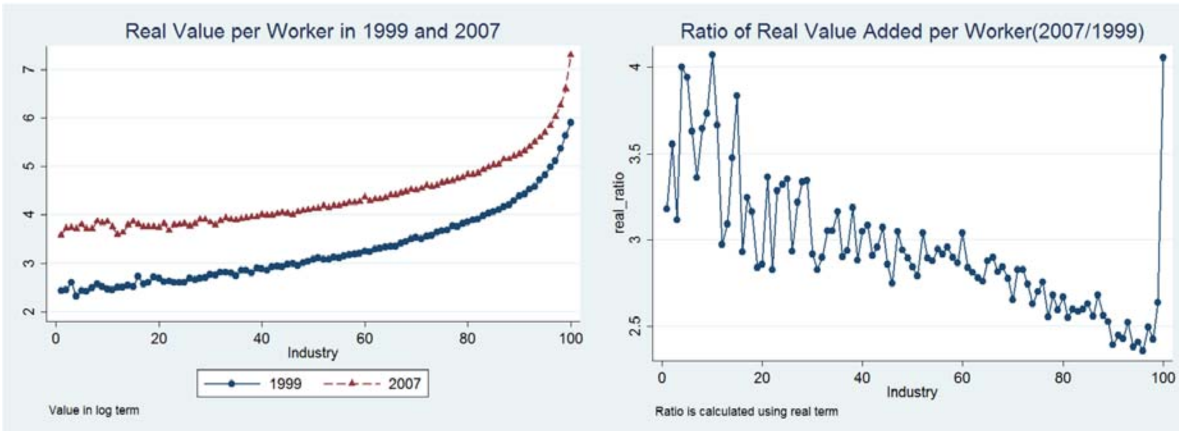



Figure 1: *Labor Productivity*

Table 3: Structural Adjustment of Production

| Variable | fraction of firms in high capital share industries | share of employment in high capital share industries | share of value added in high capital share industries |
|---|---|---|---|
| 2007 | 0.648 | 0.585 | 0.860 |
| 1999 | 0.588 | 0.459 | 0.744 |
| Difference | 0.061 | 0.126 | 0.116 |

*Notes: The numbers in the 1st and 2nd row are the corresponding share for firms with capital share higher than the average capital share in 1999 (0.669). The 3rd row is the difference between 2007 and 1999 (2007 minus 1999).*

We also compare the labor productivity between the two years in Figure 1. Labor productivity is in terms of real value added per worker so as to make it comparable over years. Real value added is calculated using the input and output pricing index constructed by Brandt *et al* (2011). According to the left panel, the labor productivity is higher for capital intensive industries, and it increases from 1999 to 2007 for all industries. From the right panel, we find that in general labor productivity increases more in labor intensive industries. We also estimate firm productivity using TFP measure,[9] similar results hold.

**Fact 3:** *The magnitude of labor productivity growth from 1999 to 2007 decreases with capital intensity; that is, labor productivity grows faster in labor intensive industries.*

[9] We estimate TFP in OP method using the code by Brandt et al (2012).

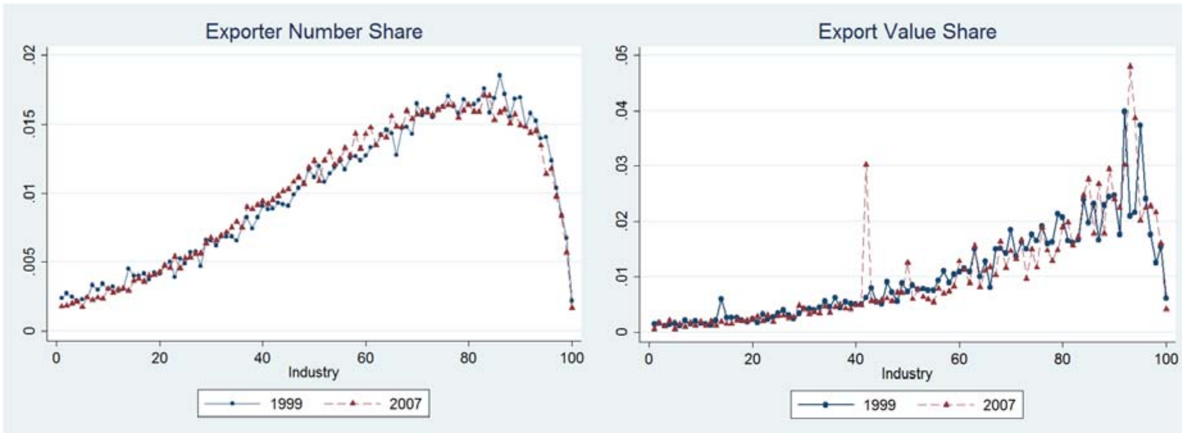



Figure 2: *Export Share in Terms of Firm Number and Value*

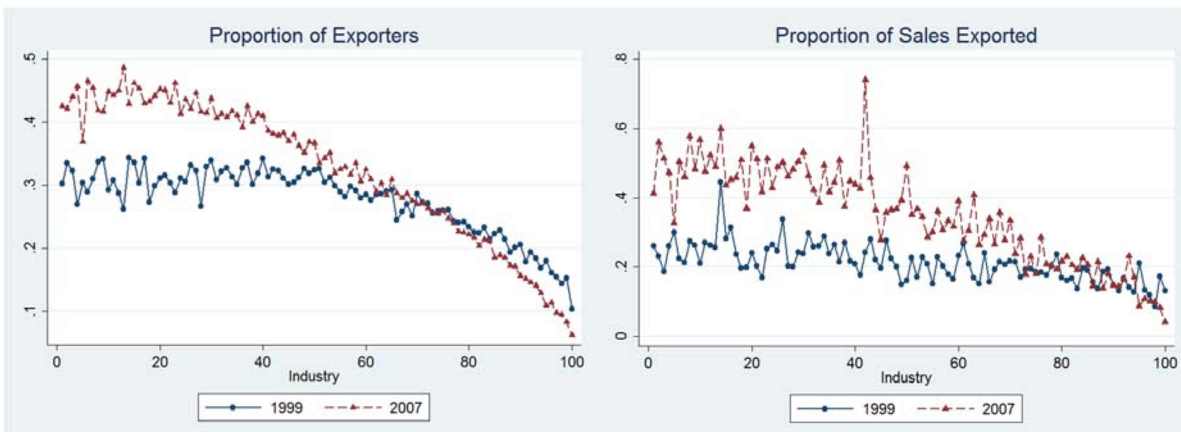



Figure 3: Export Participation

## 2.2 Trade Patterns

In this subsection, we focuses on how the trade patterns changes over time. The most important findings are:

**Fact 4:** *From 1999 to 2007, the distribution of exporting firms shift toward labor intensive industries.*

**Fact 5:** *Export participation (measured by fraction of exporters and sales exported) increases in labor intensive industries while the opposite is true in capital intensive industries.*

In Figure 2, we plot the distribution of exporting firms measured using firm number and value of export. From the left panel, we find the shares of firms which export *decrease* in capital intensive industries and increase in labor intensive industries in general. From the right panel, we find the distribution of export intensity across industries is more or less the same for both years. Next, we examine how export changes *within* each industries. From the left panel of Figure 3, we find that the proportion of exporters in 2007 is higher than 1999 in labor intensive industries while the opposite is true for capital intensive industries. In terms of sales exported, we find it increases in general over time but more significantly for labor intensive industries. In fact, for the most capital intensive ones, it even decreases.

Table 4 summarizes the structural adjustment of export patterns. By comparing it with Table 3, we find the following puzzling observation**.** The production clearly became more capital intensive in 2007 than 1999. However, exporters did not become as more capital intensive as production does. This feature of the data is puzzling because based on the standard trade theory, one would expect the export also becomes more capital intensive when the production becomes more capital intensive.

Table 4: Structural Adjustment of Export

| Variable | share of exporters in high capital share industries | share of exports in high capital share industries | average of export participation in high capital share industries |
|---|---|---|---|
| 2007 | 0.487 | 0.667 | 0.194 |
| 1999 | 0.505 | 0.654 | 0.217 |
| Difference | -0.018 | 0.013 | -0.023 |

*Notes: The numbers in the 1st and 2nd row are the corresponding share for firms with capital share higher than the average capital share in 1999 (0.669). The 3rd row is the difference between 2007 and 1999 (2007 minus 1999).*

Our finding that Chinese export didn't become more capital intensive seems to contradict earlier works on the rising sophistication of Chinese export (Schott 2008, Wang and Wei 2010). Though China might expand its export by increasing the extensive margin on more capital intensive industries, there is no guarantee that the overall share of exporters or export value in capital intensive industries also increases. If more firms became exporters in labor intensive and their export value increased more, the overall Chinese export could indeed become more labor intensive. In fact, Schott (2008) finds that though Chinese export overlaps more and more with OECD countries, it also becomes cheaper in terms of unit value.

# 3 Model Setup

Our model incorporates heterogenous firms (Melitz 2003) into a Ricardian and Heckscher-Ohlin theory with a continuum of industries (Dornbusch, Fisher and Samuelson 1977, 1980). There are two countries: North and South. We assume the home country to be South. The two countries only differ in their technology and factor endowment. Without loss of generality, we assume that home country is labor abundant, that is: $L/K > L^*/K^*$, and has Ricardian comparative advantage in more labor intensive industries. [10] There is a continuum of industries z on the interval of $[0,1]$. The index z is the industry capital intensity and higher z stands for higher capital intensity. Each industry is inhabited by heterogeneous firms which produce different varieties of goods and sell in a market with monopolistic competition.

## 3.1 Demand Side

The economy is inhabited by a continuum of identical and infinitely lived households that can be aggregated into a representative household. The representative household's preference over different goods is summarized by the following Cobb-Douglas utility function:

$$U = \int_0^1 b(z) \ln Q(z) dz, \quad \int_0^1 b(z) dz = 1$$

where $b(z)$ is the expenditure share on each industry and $Q(z)$ is the lower-tier utility function over consumption of individual varieties $q_z(\omega)$ given by the following CES aggregation. $P(z)$ is the dual price index of $Q(z)$ defined over price of different varieties $p_z(\omega)$.

$$\begin{aligned} Q(z) &= \left[ \int_{\omega \in \Omega_z} \gamma^{1-\rho} q_z(\omega)^\rho d\omega + \int_{\omega \in \Omega_z^*} (1-\gamma)^{1-\rho} q_z(\omega)^\rho d\omega \right]^{1/\rho}, \\ P(z) &= \left[ \int_{\omega \in \Omega_z} p_z(\omega)^{1-\sigma} d\omega + \int_{\omega \in \Omega_z^*} p_z(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}} \end{aligned}$$

$\Omega_z$ and $\Omega_z^*$ are the varieties available for industry z produced in home and foreign respectively. We assume $0 < \rho \leq 1$ so that the elasticity of substitution $\sigma = \frac{1}{1-\rho} > 1$. $\gamma \in [0,1]$ captures the home bias.[11] There is home bias if $\gamma > \frac{1}{2}$ and foreign bias if $\gamma < \frac{1}{2}$. The aggregates can be used to derive the demand function for individual varieties.

$$q_z(\omega) = \begin{cases} \gamma Q(z) (\frac{p_z(\omega)}{P(z)})^{-\sigma}, & \omega \in \Omega_z \\ (1-\gamma) Q(z) (\frac{p_z(\omega)}{P(z)})^{-\sigma}, & \omega \in \Omega_z^* \end{cases} \tag{3.1}$$

## 3.2 Production

Following the standard assumptions of Melitz (2003), we assume that production incurs a fixed cost each period which is the same for all firms in the same industry and the variable cost varies with firm

[10] Variables with "*" are foreign country ( North country) variables. To simplify the notation, we omit it except where important.

[11] This is standard assumption in the international macro literature, e.g., Coeurdacier and Rey (2013). For alternative way of modelling home bias, see Bilir, Chor and Manova (2013) in which they assume the elasticity of substitution for varieties from the same country exceeds the elasticity of substitution for varieties from different countries. We prefer the setting because it preserves the simplicity of the standard trade model.

productivity. Firm productivity is denoted as $A(z)\varphi$ where $A(z)$ is a common component for all firms in industry z while the heterogeneous productivity, $\varphi$, is drawn randomly by firms from a distribution $G(\varphi)$. Following Romalis (2004) and Bernard *et al* (2007a), we assume that fixed cost are paid using capital and labor with factor intensity the same as in the good production in that industry. To be specific, we assume that the total cost function is:

$$\Gamma(z,\varphi) = \left(f_z + \frac{q(z,\varphi)}{A(z)\varphi}\right) r^z w^{1-z} \tag{3.2}$$

And we assume that the relative industry specific productivity for home and foreign $\varepsilon(z)$ is:

$$\varepsilon(z) \equiv \frac{A(z)}{A^*(z)} = \lambda A^z, \lambda > 0,\ A > 0 \tag{3.3}$$

Here $\lambda$ is a parameter capturing the absolute advantage of home country: higher $\lambda$ means home has higher relative industry specific productivity for all industries. And $A$ is parameter capturing the comparative advantage. If $A > 1$, home country is relatively more productive in more capital intensive industries and has Ricardian comparative advantages in these industries. If $A = 1$, then $\varepsilon(z)$ doesn't vary with z and there is no role for Ricardian comparative advantage. Given our assumption that home has Ricardian comparative advantage in more labor intensive industries, we have $0 < A < 1$.

The presence of fixed cost implies that each firm will produce only one variety. Profit maximization implies that the equilibrium price is a constant mark-up over the marginal cost. Trade is costly and firms need to ship $\tau$ units of goods for 1 unit of goods to arrive in foreign market. This is the standard "iceberg cost" assumption. Then we have,

$$p_{zx}(\varphi) = \tau p_{zd}(\varphi) = \tau \frac{r^z w^{1-z}}{\rho A(z)\varphi} \tag{3.4}$$

where $p_{zx}(\varphi)$ and $\tau p_{zd}(\varphi)$ are the exporting and domestic price respectively. Given the pricing rule, the revenue from domestic and foreign market of firms are:

$$r_{zd}(\varphi) = b(z)R\left(\frac{\rho A(z)\varphi P(z)}{r^z w^{1-z}}\right)^{\sigma-1} \tag{3.5}$$

$$r_{zx}(\varphi) = \tau^{1-\sigma}\left(\frac{P(z)^*}{P(z)}\right)^{\sigma-1}\frac{R^*}{R} r_{zd}(\varphi) \tag{3.6}$$

Where R and R* are aggregate revenue for home and foreign respectively. Then the revenue of firms are:

$$r_z(\varphi) = \begin{cases} r_{zd} & \text{if it sells only domestically} \\ r_{zx} + r_{zd} & \text{if it exports} \end{cases}$$

For firms that export, they need to pay a per-period fixed cost $f_{zx} r^z w^{1-z}$ which requires both labor and capital. Therefore, the firms' profits could be divided into portions earned from domestic and foreign

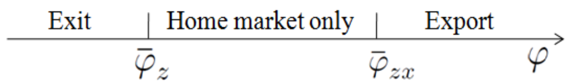



Figure 4: Production and Trade Pattern

market:

$$\begin{aligned}\pi_{zd}(\varphi) &= \frac{r_{zd}}{\sigma} - f_z r^z w^{1-z} \\ \pi_{zx}(\varphi) &= \frac{r_{zx}}{\sigma} - f_{zx} r^z w^{1-z}\end{aligned} \tag{3.7}$$

So the total profit is given by:

$$\pi_z(\varphi) = \pi_{zd}(\varphi) + \max\{0, \pi_{zx}(\varphi)\} \tag{3.8}$$

Then a firm that draws a productivity $\varphi$ produces if its revenue at least covers the fixed cost that is $\pi_{zd}(\varphi) \geq 0$ and exports if $\pi_{zx}(\varphi) \geq 0$. This defines the zero-profit productivity cut-off $\bar{\varphi}_z$ and costly trade zero profit productivity cut-off $\bar{\varphi}_{zx}$ which satisfy:

$$r_{zd}(\bar{\varphi}_z) = \sigma f_z r^z w^{1-z} \tag{3.9}$$

$$r_{zx}(\bar{\varphi}_{zx}) = \sigma f_{zx} r^z w^{1-z} \tag{3.10}$$

Using the two equations above and equation (3.5) (3.6), we could derive the relationship between the two productivity cut-offs:

$$\bar{\varphi}_{zx} = \Lambda_z \bar{\varphi}_z, \text{ where } \Lambda_z = \frac{\tau P(z)}{P(z)^*} \left[\frac{\gamma f_{zx} R}{(1-\gamma) f_z R^*}\right]^{\frac{1}{\sigma-1}} \tag{3.11}$$

$\Lambda_z > 1$ implies selection into export market: only the most productive firms export. The empirical literature strongly supports selection into market and we focus on parameters where exporters are always more productive following Melitz (2003) and Bernard *et al* (2007a).[12] Then the production and exporting decision of firms are shown in Figure 4**.** For all firms that enter each period, a fraction of $G(\bar{\varphi}_z)$ exit upon entry since they do not earn positive profit at all. And $1 - G(\bar{\varphi}_{zx})$ fraction of firms export since they draw sufficiently high productivity and earn positive profit from both domestic and foreign sales. As for firms whose productivity is between $\bar{\varphi}_{zx}$and $\bar{\varphi}_z$, they only sell in domestic market. So the *ex ante* probability of exporting conditional on successful entry is

[12] Lu(2010) explore the possibility that $\Lambda_z < 1$ and documents that in the labor intensive sectors of China, exporters are less productive. But our own empirical findings in the following section provides little support that. In fact, according to Dai *et al* (2011), Lu's result is solely driven by processing exporters. And using TFP as productivity measure instead of value added per worker, even including processing exporters still support that exporters are more productive.

$$\chi_z = \frac{1 - G(\bar{\varphi}_{zx})}{1 - G(\bar{\varphi}_z)} \tag{3.12}$$

## 3.3 Free entry

If a firm does produce, it faces a constant probability $\delta$ in every period of bad shock that would force it to exit. The steady-state equilibrium is characterized by a constant mass of firms entering an industry $M_{ez}$ and constant mass firms producing $M_z$.Then in a steady state equilibrium, the mass of firms that enter must equal to the firms that die:

$$(1 - G(\bar{\varphi}_z))M_{ez} = \delta M_z \tag{3.13}$$

In an equilibrium with positive production, we require that the value of entry $V_z$ equals to the cost of entry: $f_{ez}r^z w^{1-z}$. We assume that the entry cost $f_{ez}r^z w^{1-z}$ also uses capital and labor. The expected profit of entry $V_z$ comes from two parts: the *ex ante* probability of successful entry times the expected profit from domestic market until death and *ex ante* probability of exporting times the expected profit from the export market until death. Then we have the following free entry condition

$$V_z = \frac{1 - G(\bar{\varphi}_z)}{\delta}(\pi_{zd}(\widehat{\varphi}_z) + \chi_z \pi_{zx}(\widehat{\varphi}_{zx})) = f_{ez}r^z w^{1-z} \tag{3.14}$$

where $\pi_{zd}(\widehat{\varphi}_z)$ and $\chi_z \pi_{zd}(\widehat{\varphi}_{zx})$ are the expected profitability from successful entry. And $\widehat{\varphi}_z$ is the average productivity of all producing firms while $\widehat{\varphi}_{zx}$ is the average productivity of all exporting firms in industry z. They are defined as follows:

$$\begin{aligned}
\widehat{\varphi}_z &= [\frac{1}{1 - G(\bar{\varphi}_z)} \int_{\bar{\varphi}_z}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi]^{\frac{1}{\sigma-1}} \\
\widehat{\varphi}_{zx} &= [\frac{1}{1 - G(\bar{\varphi}_{zx})} \int_{\bar{\varphi}_{zx}}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi]^{\frac{1}{\sigma-1}}
\end{aligned} \tag{3.15}$$

Combining with the zero profit condition (3.9), (3.10), we can determine the two productivity cut-offs which satisfy the equation (3.11) and (3.16) below

$$\frac{f_z}{\delta} \int_{\bar{\varphi}_z}^{\infty} [(\frac{\varphi}{\bar{\varphi}_z})^{\sigma-1} - 1] g(\varphi) d\varphi + \frac{f_{zx}}{\delta} \int_{\bar{\varphi}_{zx}}^{\infty} [(\frac{\varphi}{\bar{\varphi}_{zx}})^{\sigma-1} - 1] g(\varphi) d\varphi = f_{ez} \tag{3.16}$$

### 3.4 Market Clearing

In equilibrium, we require that the sum of domestic and foreign spending on domestic varieties equals to the value of domestic production (total industry revenue, $R_z$) for every industry in both countries:

$$R_z = b(z)RM_z(\frac{p_{zd}(\widehat{\varphi}_z)}{P(z)})^{1-\sigma} + \chi_z b(z)R^* M_z(\frac{\tau p_{zd}(\widehat{\varphi}_{zx})}{P(z)^*})^{1-\sigma} \tag{3.17}$$

where the price index $P(z)$ is given by the equation below. $R_z^*$ and $P(z)^*$ follow symmetric definitions.

$$P(z) = [M_z(p_{zd}(\widehat{\varphi}_z))^{1-\sigma} + \chi_z^* M_z^*(\tau p_{zx}(\widehat{\varphi}_{zx}^*)^*)^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{3.18}$$

The factor market clearing condition is:

$$\begin{aligned} L &= \int_0^1 l(z)dz,\ L^* = \int_0^1 l^*(z)dz \\ K &= \int_0^1 k(z)dz,\ K^* = \int_0^1 k^*(z)dz \end{aligned} \tag{3.19}$$

Before we proceed, we make the following assumptions to simplify the algebra. Firstly, we assume that the productivity distribution is Pareto and the density function is given by

$$g(\varphi) = a\theta^a \varphi^{-(a+1)}, a+1 > \sigma$$

where $\theta$ is a lower bar of productivity: $\varphi \geq \theta$.Secondly, we assume that the coefficients of fixed costs are the same for all industries:[13]

$$f_z = f_{z'},\ f_{zx} = f_{z'x},\ f_{ez} = f_{ez'}, \forall z \neq z'.$$

Finally, we assume that the expenditure b(z) is the same for all industries at home and abroad, that is:

$$b(z) \equiv b(z^{'}), \forall z \neq z'.$$

### 3.5 Equilibrium

The equilibrium consists of the vector of $\{\bar{\varphi}_z$, $\bar{\varphi}_{zx}$, $P(z)$, $p_z(\varphi)$, $p_{zx}(\varphi)$, $r$, $w$, $R$, $\bar{\varphi}_z^*$, $\bar{\varphi}_{zx}^*$, $P(z)^*$, $p_z(\varphi)^*$, $p_{zx}(\varphi)^*$, $r^*$, $w^*$, $R^*\}$ for $z \in [0,1]$. The equilibrium vector is determined by the following conditions for each country:

(a) Firms' pricing rule (3.4) for each industry and each country;

[13] $f_z$ , $f_{ez}$, $f_{zx}$ could still differ from each other.

(b) Free entry condition (3.14) and relationship between zero profit productivity cut-off and costly trade zero profit productivity cut-off (3.11) for each industry and both countries;

(c) Factor market clearing condition (3.19);

(d) The pricing index (3.18) implied by consumer and producer optimization;

(e) The goods market clearing condition of world market (3.17).

**Proposition 1** *There exists a unique equilibrium given by* $\{\bar{\varphi}_z, \bar{\varphi}_{zx}$, $P(z)$, $p_z(\varphi)$, $p_{zx}(\varphi)$, $r$, $w$, $R$, $\bar{\varphi}_z^*$, $\bar{\varphi}_{zx}^*$, $P(z)^*$, $p_z(\varphi)^*$, $p_{zx}(\varphi)^*$, $r^*$, $w^*$, $R^*\}$.

Proof. *See Appendix.*■

# 4 Equilibrium Analysis

The presence of trade cost, multiple factors, heterogeneous firms, asymmetric countries and infinite industry make it very difficult to find a close-form solution to the model. In this section, we firstly derive several analytical properties. Then we numerically solve the equilibrium factor prices and other endogenous variables.

## 4.1 Analytical Properties

**Proposition 2** *(a) As long as home and foreign country are sufficiently different in endowment or technology, then there exist two factor intensity cut-offs* $0 \leq \underline{z} < \overline{z} \leq 1$ *such that the labor abundant home country specializes in the production within* $[0, \underline{z}]$ *while the capital abundant foreign specializes in the production within* $[\overline{z}, 1]$ *and both countries produce within* $(\underline{z}, \overline{z})$.

*(b) If there is no variable trade cost* ($\tau = 1$), *no home bias* ($\gamma = \frac{1}{2}$), *and fixed cost of export equals to fixed cost of production for each industry* ($f_{zx} = f_z, \forall z$), *then* $\underline{z} = \overline{z}$. *This is the classic case of complete specialization. If there is home bias* ($\gamma > \frac{1}{2}$), *there is no complete specialization even under free trade.*

Proof. *See Appendix.*■

This proposition is on the production and export pattern for each country. The basic result is illustrated in the Figure 5. Countries engage in inter-industry trade for industries within $[0, \underline{z}]$ and $[\overline{z}, 1]$ due to specialization. This is where the comparative advantage in factor abundance or technology (classical trade power) dominates trade costs and the power of increasing return and imperfect competition (new trade theory). And the countries engage in intra-industry trade for industries within $(\underline{z}, \overline{z})$, this is where the power of increasing return to scale and imperfect competition dominates the power of comparative advantage (Romalis, 2004). Thus if the two countries are very similar in their technology and endowments, we would expect the power of comparative advantage is very weak. Then there will be no specialization and only intra-industry trade between the two countries. That is to say, $\underline{z} = 0$ and $\overline{z} = 1$.

In the classical DFS model with zero transportation costs, factor price equalization (FPE) prevails and the geographic patterns of production and trade are not determined when the two countries are not too

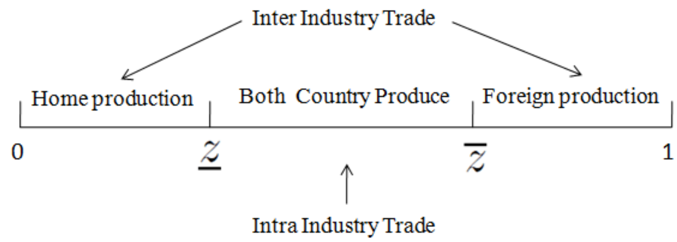



Figure 5: *Productivity Cutoffs and Firm Decision*

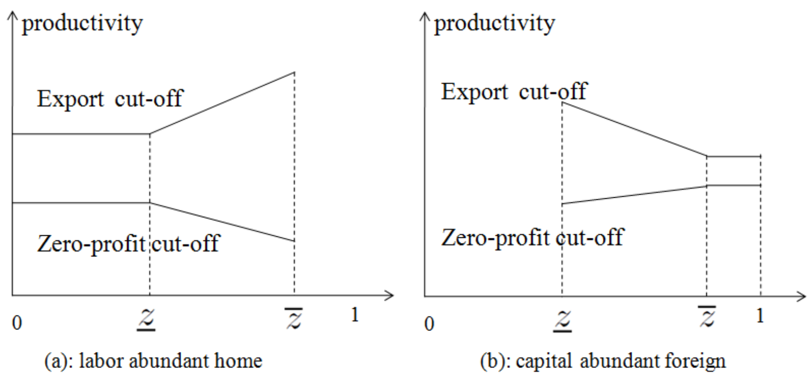



Figure 6: *Productivity Cut-offs across Industries in Home and Foreign Countries*

different. With costly trade and departure from FPE, we are able to determine the pattern of production. This model thus inherit the property of Romalis model (2004). However, his assumption of homogeneous firm leads to the stark feature that all firms export. With the assumption of firm heterogeneity, we have the following proposition 3 and 4 on the variation of export participation across industries.

**Proposition 3** *(a)Within ($\underline{z}$, $\overline{z}$), in home country, the zero profit productivity cut-off decreases with capital intensity while the export cut-off increases with capital intensity. The converse holds in foreign country.*

*(b) Both cut-offs remain constant in industries that either country specializes.*

Proof. *See Appendix.*■

Conclusion (a) of Proposition 3 does not depend on the assumption of Pareto distribution for firm specific productivity. Figure 6 illustrates the result of this proposition. It is a direct extension of Bernard *et al* (2007a). They prove that under the two-industry case, the productivity cut-offs for production and export will be closer in the comparative advantage industry. We generalize their result and an important extension is that the cut-offs do not vary with factor intensity in industries that countries specialize. And the nice property of this proposition is that home country and foreign country are symmetric.

**Proposition 4** *(a) Within the specialization zone* $[0, \underline{z}]$ *and* $[z, 1]$*, the export probability* $\chi_z$ *is a constant. For the industries that both countries produce* $(\underline{z}, \overline{z})$*, the export probability* $\chi_z$ *decreases with industry capital intensity in the labor abundant country and vice versa in the capital abundant country. To be specific, we have*

$$\chi_z = \begin{cases} \frac{R^*}{fR} & z \in [0, \underline{z}] \\ \frac{\widetilde{\tau}^{-a} f - \varepsilon^a g(z)}{\varepsilon^a f g(z) - \widetilde{\tau}^a} & z \in (\underline{z}, \overline{z}) \end{cases}$$

*where* $g(z) \equiv \left( \frac{w}{w^*} \left( \frac{r/w}{r^*/w^*} \right)^z \right)^{\frac{a\sigma}{1-\sigma}}$, $\widetilde{\tau} \equiv \tau \left( \frac{\gamma}{1-\gamma} f \right)^{\frac{1}{\sigma - 1}}$ *and*

$$\frac{\partial \chi_z}{\partial z} = \frac{(1 - \widetilde{\tau}^{-2a} f^2) \varepsilon^a g a}{(\varepsilon^a f g(z) - \widetilde{\tau}^a)^2} \left[ \ln(A) - \frac{\sigma}{\sigma - 1} \ln \left( \frac{r/w}{r^*/w^*} \right) \right], if\ z \in (\underline{z}, \overline{z})$$

*(b) The export intensity is:* $\gamma_z = \frac{f\chi_z}{1 + f\chi_z}$ *which follows the same pattern as* $\chi_z$.

Proof. *See Appendix.* ■

Proposition 4 is a straightforward implication of proposition 3. In general, it tells us that the stronger the power of comparative advantage is, the more that firms participate in international trade. However, for industries that countries specialize, export participation is a constant. Figure 7 depicts this idea. In panel a, the export probability (or intensity) decreases with the capital intensity in home country. Panel b shows the opposite pattern for foreign country.

We also find that the sign of $\frac{\partial \chi_z}{\partial z}$ depends on two terms within $(\underline{z}, \overline{z})$: the *Ricardian Comparative Advantage* $\ln(A)$ and the *Heckscher-Ohlin Comparative Advantage* $\ln \left( \frac{r/w}{r^*/w^*} \right)$. The magnitude of the HO Comparative Advantage depends on $\sigma$, the elasticity of substitution between varieties due to the imperfect competition: the smaller $\sigma$ is, the more that industries differ in their export participation. Since $A < 1$ and $\frac{K}{L} < \frac{K^*}{L^*}$ (or $\frac{r/w}{r^*/w^*} > 1$), home country has both Ricardian Comparative Advantage and Heckscher-Ohlin Comparative Advantage in more labor intensive industries. Thus we expect $\frac{\partial \chi_z}{\partial z} < 0$ and export probability decreases with capital intensities in home country. However, if $A > 1$ and home country has Ricaridan Comparative Advantage in more capital intensive industries. Then the sign of $\frac{\partial \chi_z}{\partial z}$ depends on which comparative advantage is stronger. If Ricardian Comparative Advantage is so strong that it overturns the Heckscher-Ohlin Advantage, then home country will export more in more capital intensive industries.

Fan *et al* (2011) incorporate Melitz (2003) into the DFS model (1977) with Ricardian Comparative Advantage and get very similar prediction on export participation. The key insight from Melitz model is that within sector resource reallocation generates productivity gain. Bernard et al (2007) find that the strength of reallocation is stronger in the industry uses more of the country's abundant factor. Such heterogeneous reallocation will generate endogenous Ricardian Comparative Advantage. We find that such endogenous comparative advantage could even overturn the exogenous Ricardian Comparative Advantage. This is elaborated in next proposition.

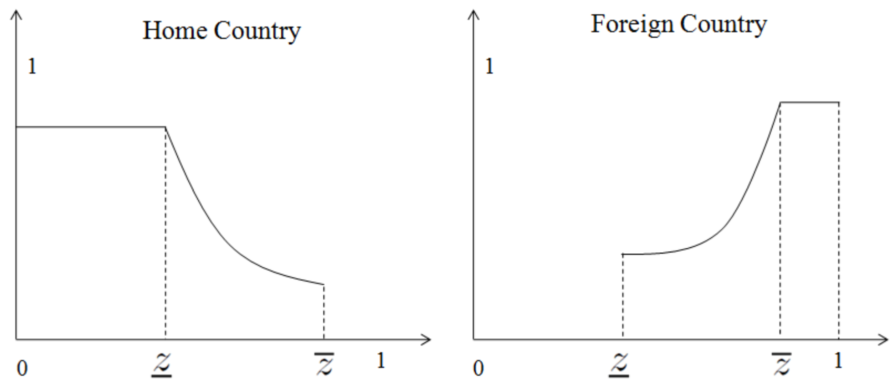



Figure 7: *Export Probability or Export Intensity in Home Country and Foreign Country*

**Proposition 5** *(a)The average firm productivity in each industry is*

$$\widehat{\varphi}_z = \left(\frac{a}{a+1-\sigma}\right)^{\frac{1}{\sigma-1}} \left[\frac{(\sigma-1)\theta^a}{\delta(a+1-\sigma)\widehat{f}}(1+f\chi_z)\right]^{1/a}$$

*It is a constant within the specialization zone* $[0, \underline{z}]$ *and* $[\underline{z}, 1]$. *Within* $(\underline{z},\overline{z})$, *it decreases with capital intensity for the labor abundant country and vice versa for the capital abundant country.*

*(b)The magnitude of Ricardian Comparative Advantage could be amplified by the endogenous technology difference generated by reallocation if the Heckscher-Ohlin Comparative Advantage is in line with it, or else it is dampened.*

Proof. *See Appendix.*■

According to Proposition 5 (a), we can decompose industrial average productivity. A(z) is industrial specific productivity while $\widehat{\varphi}_z$ is the average of firm specific productivity. From the expression of $\widehat{\varphi}_z$, it is quite obvious that opening to trade leads to productivity gain since $\chi_z$ increases from zero to a positive number. Also, the reallocation effect is stronger when there are more firms exporting in that industry. And the resulting average productivity would also be higher holding industry specific productivity A(z) constant. Then (b) in Proposition 5 naturally follows using Proposition 4: if $\ln(A) > 0$ while $\frac{\partial \chi_z}{\partial z} < 0$, $\frac{A(z)}{A^*(z)}$ will increase with z and $\frac{\widehat{\varphi}_z}{\widehat{\varphi}_z^*}$ decreases with z, then the overall average industry productivity ratio $\frac{A(z)\widehat{\varphi}_z}{A^*(z)\widehat{\varphi}_z^*}$ could become a decreasing function of z if the reallocation effect is very strong. If this is the case then the Ricardian comparative advantage is dampened. Otherwise, it is amplified.

## 4.2 Numerical Solution

In this subsection, we find the numerical solution to the model and discuss other equilibrium properties of the model. The algorithm is in Appendix 6 and the parameters chosen are in Table 5. The equilibrium factor prices and cut-off industries are in table 6. It is easy to see that $\frac{r/w}{r^*/w^*} = 1.165 > 1$. Also $A < 1$, thus we would expect $\frac{\partial \chi_z}{\partial z} < 0$ between $(\underline{z},\overline{z})$.

Table 5: Parameters used in simulation

| Variables | meaning | value |
|---|---|---|
| $K$ | home capital stock | 100 |
| $L$ | home labor stock | 300 |
| $K^*$ | foreign capital stock | 300 |
| $L^*$ | foreign labor stock | 100 |
| $f$ | relative fixed cost of export $\frac{f_{zx}}{f_z}$ | 6.5 |
| $\widetilde{f}$ | relative fixed cost of entry $\frac{f_{ez}}{f_z}$ | 20*f |
| $\tau$ | iceberg cost | 1.05 |
| $a$ | shape parameter of Pareto Distribution | 3.8 |
| $\theta$ | lower bound of Pareto Distribution | 0.2 |
| $\delta$ | exogenous death probability of firms | 0.025 |
| $\sigma$ | elasticity of substitution | 3.4 |
| $A$ | strength of comparative advantage | 0.5 |
| $\lambda$ | strength of absolute advantage | 1 |
| $\gamma$ | home bias | $\frac{1}{2}$ |

Notes: most of parameters follow Bernard et al(2007a) and Romalis(2004). A is chosen to be less than 1 so that home country has Ricardian comparative advantage in more labor intensive industries.

Table 6: Equilibrium Factor Prices and Cut-off Industry

| Variables | meaning | value |
|---|---|---|
| $r$ | domestic interest rate | 0.0681 |
| $w$ | domestic wage rate | 0.0705 |
| $r^*$ | foreign interest rate | 0.0799 |
| $w^*$ | foreign wage rate | 0.0964 |
| $\underline{z}$ | lower cut-off industry | 0.276 |
| $\overline{z}$ | higher cut-off industry | 0.655 |

Figure 10 depicts this case: export probability and intensity first stays constant and then decreases with capital intensity, the opposite is true for foreign country. Firm mass follows similar patterns but it doesn't stay constant in industries that countries specialize in. We should point out that firm mass, industrial output and export also depend on household's expenditure share b(z): for industries with higher demand, firm mass industrial output and export will also be higher. Since we normalize b(z) to be 1 for all industries, this channel is shut down.

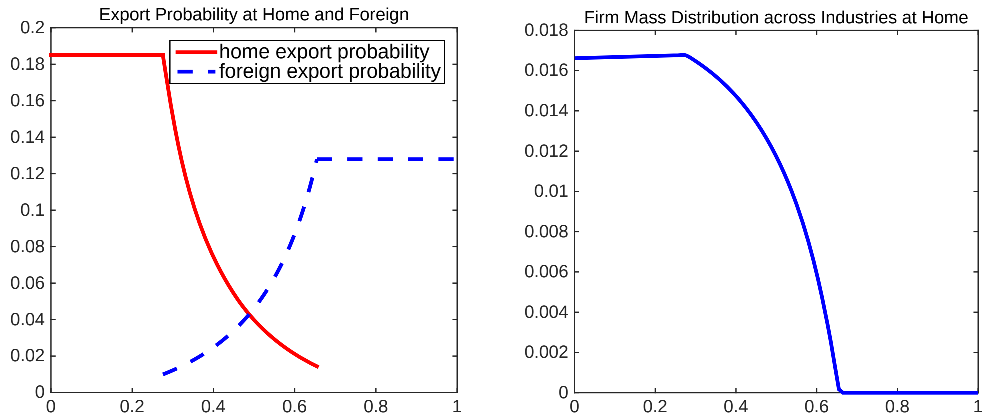


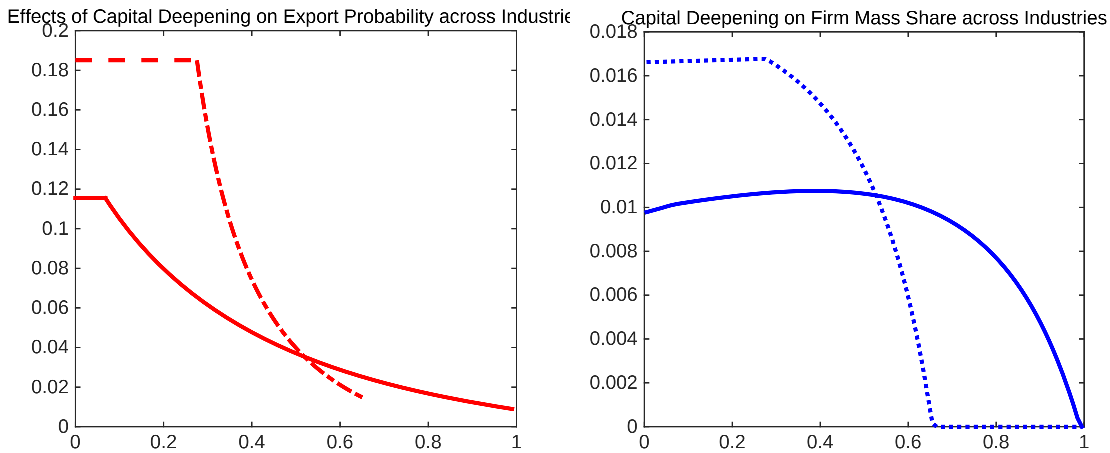

Figure 10: Baseline Simulation

## 4.3 Comparative Statics

In this section, we focus on the comparative statics with respect to endowments and technology. We first look at the effect of capital deepening, i.e., increasing the stock of capital at home country. Then we look at the effect of technology progress such that home country has larger Ricardian comparative advantage in labor intensive sectors.

### 4.3.1 Capital Deepening

By increasing home country capital stock K, we increases the capital labor ratio of home country. As can be seen in Figure 11, firm mass increases in home country and the increase is bigger in more capital intensive industries. As for export, home country export more in capital intensive industries: export probability and export volume both increase for more capital intensive industries. The opposite is true for foreign country. If we believe that China is becoming more capital abundant comparing to rest of world, both the Chinese production and export would become more capital intensive. This is not consistent with the pattern of adjustment in export in the data. Thus capital deepening alone cannot explain what we observe.

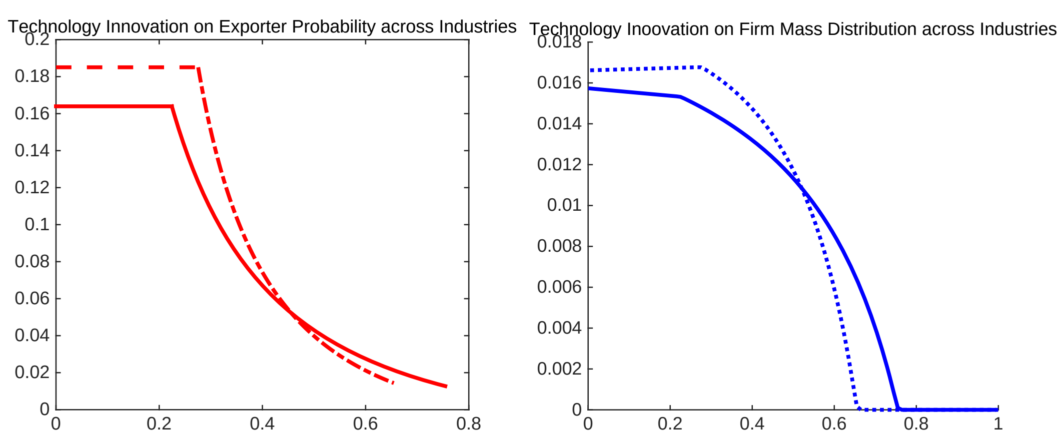



Notes: from solid lines to thin dash lines & thick dash lines is the direction that K rises.

Figure 11: Capital Deepening

#### 4.3.2 Technology Changes

In this subsection, we focus on the effect of technological changes such that home has larger Ricardian comparative advantage in more labor intensive sectors. This is captured by decreasing $A$. As is shown in Figure 12, when A decreases, home country becomes relatively more productive in labor intensive industries than foreign country. Thus the production shifts towards more labor intensive industries. Moreover, the share of exporters increases in labor intensive sectors and decreases in capital intensive sectors. Thus the adjustment in export is consistent with the data but the adjustment in production is not.



Notes: from thick dash lines and thin dash lines to solid lines is the direction that $A$ decreases.

Figure 12: Comparative Advantage: $A$

For brevity, we do not put the comparative statics on trade costs. For trade liberalization, if we decrease the fixed cost, export increases in all sectors and production moves towards more labor intensive sectors in home country. And we get similar results if we decrease the variable trade costs.

In summary, none of these forces alone could explain the data pattern that we observe. Thus we need to estimate the model and understand the movement of each force overtime. Then we could do counterfactual simulation to disentangle the effect of each forces. This is what we do in next section.

# 5 Estimation

## 5.1 Strategy

Our Proposition 4 relates the export probability $\chi_z$ to the deep parameters of our model. It turns out that in our model, the export probability $\chi_z$ only depends on the following parameters$\{\frac{L^*}{L}, \frac{K^*}{K}, A, \lambda, a, \tau, f, \sigma, b(z), \gamma\}$ which are parameters describing the relative endowments, the relative technology, trade costs and preference. To fully pin down the economy, we still need to know $f_z$ and $\frac{K}{L}$ after normalizing $f_{ez} = 1$ and $L = 1$ (or equivalently$\frac{K^*}{L^*}$ if we normalized $L^* = 1$). We also set $\sigma = 3$ as a baseline and get the expenditure share function b(z) from the data.[14] The parameters that we estimate are $\Theta \equiv \{\frac{K}{L}, \frac{K^*}{K}, \frac{L^*}{L}, A, \lambda, \tau, f, a, f_z\}$. Since $\chi_z$ doesn't depend on $f_z$ and $\frac{K}{L}$, we have another moment $m_z$ which is the firm number share of industry z which intuitively should depend on $f_z$ and $\frac{K}{L}$. Finally, we require our model to fit the relative size of China and RoW: $\frac{R^*}{R}$.[15] Given the restriction that $\sum_{i=1}^{100} m_i = 1$, we have in total 200 moment conditions (100 from $\chi_z$, 99 from $m_z$ and 1 from $\frac{R^*}{R}$) which we define as

$$Y(\Theta) = \begin{pmatrix} \chi_i \\ m_i \\ \frac{R^*}{R} \end{pmatrix}$$

Following EKK and Chaney (2014), we estimate $\Theta$ using the moment conditions above. For each $\Theta$, we could compute the corresponding $\widehat{Y}(\Theta)$. Define the deviation $\Delta(\Theta) \equiv Y - \widehat{Y}(\Theta)$.where Y is the data correspondent of each moments. Under the H0 that E($\Delta(\Theta)$)=0, the GMM estimator is as follows:

$$\widehat{\Theta} = \arg\min_{\Theta}\{\Delta(\Theta)' W \Delta(\Theta)\}$$

[14] We first construct the average output share of each industries for 1999 and 2007. Ideally, we want expenditure share to construct b(z). But it requires import data. Given that the firm data doesn't report import data. We assume that trade is balanced sector by sector here.

[15] We measure R*/R using PPP based real GDP from Penn World Table (version 7.1). For China there are two versions. And there are three measures of real GDP. We take the simple average and the relative GDP between RoW and China is 12.17 in 1999 and 7.52 in 2007.

where $W$ is an appropriate weighting variance-covariance matrix.[16]

To search for $\widehat{\Theta}$, we use a simulated annealing algorithm as in Chaney (2014). Then we compute the standard errors by bootstrapping.[17] We estimate the model separately for year 1999 and 2007. The results are in the next subsection.

## 5.2 Results

Our baseline estimation results are shown in Table 7 and the fitted curves are shown in Figure 13. With the estimated parameters in Table 7, after normalizing L=1, we could solve all the endogenous variables. The results are in Table 8. As can be seen from Table 7 and Table 8, China became more capital abundant in 2007, the capital labor ratio almost tripled. Technology increased overtime relative to RoW and it favored more labor intensive industries.[18] Trade liberalization decreased the coefficient of fixed cost $f_{ez}$ of export by almost 50% while the variable trade cost did not decrease but increase by about 12%. Finally, the home bias preference parameters decreased slightly.

Table 7: Estimated Parameters

| Year | $\frac{L^*}{L}$ | $\frac{K^*}{K}$ | $\frac{K}{L}$ | $A$ | $\lambda$ | a | $\tau$ | $f$ | $f_z$ | $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 2.28 | 2.18 | 0.749 | 0.614 | 0.491 | 2.02 | 1.64 | 0.686 | 0.771 | 0.856 |
| | (0.0281) | (0.0256) | (0.007) | (0.012) | (0.019) | (0.011) | (0.013) | (0.018) | (0.137) | (0.001) |
| 2007 | 2.21 | 2.28 | 2.21 | 0.534 | 0.665 | 2.33 | 1.84 | 0.539 | 0.497 | 0.856 |
| | (0.018) | (0.013) | (0.013) | (0.004) | (0.041) | (0.014) | (0.013) | (0.005) | (0.178) | (0.001) |

*Notes: The parameters in the parentheses are Bootstrap standard errors. All coefficients are statistically different from zero at significant level of 1%.*

[16] We construct the weighting matrix by boostrapping as EKK and Chaney (2014). For each year, we draw 10,000 samples from the cleaned data with replacements. For each draw, we have the same number of firms as the data and compute the moments $Y_i$.Then the weighting matrix is $W=(\frac{1}{10{,}000}\sum_{i=1}^{10{,}000}(Y_i-\overline{Y})(Y_i-\overline{Y}))^{-1}$ where $\overline{Y}$ is the sample mean.

[17] We perform 25 bootsraps for each year. In each bootstrap, we resample the moments with replacement from the data and estimate with the original weigthing matrix (same as EKK and Chaney (2014)). Then the variance and covariance matrix fo the estimator is: $V(\widehat{\Theta})=\frac{1}{25}\sum_{i=1}^{25}(\widehat{\Theta}-\overline{\overline{\Theta}})(\widehat{\Theta}-\overline{\overline{\Theta}})'$ where $\overline{\overline{\Theta}}$ is the average.

[18] We could compute the relative productivity between RoW and China for each industry according to our assumption that $\frac{A(z)}{A(z)^*}=\lambda A^z$. With the estimated parameters for both years. We find it relative productivity increased for all industries (the average is increase of relative productivity is 26.4%) and higher for more labor intensive industries (for the most labor intensive industries, it is 35.3%; for th most capital intensive industries, it is 17.9%). This is consistent with fact 3.

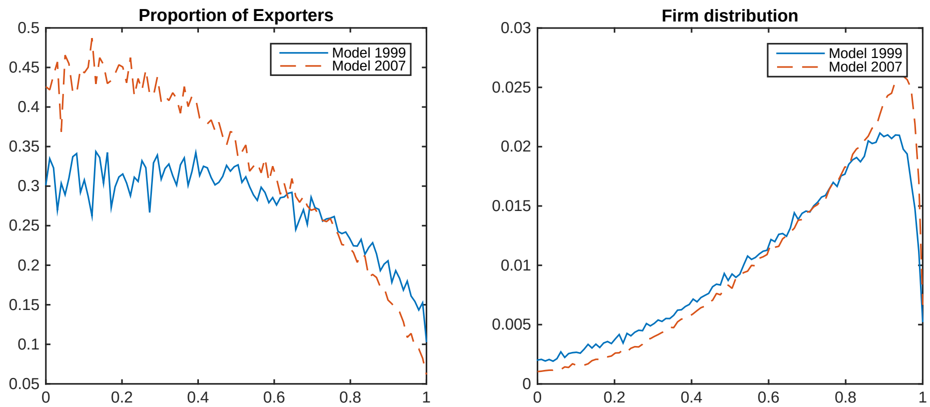



Figure 13: Model Fitted Curve

Table 8: Factor Prices and Cut-off Industries

| Year | $f_{zx}$ | $\frac{R^*}{R}$ | $w$ | $r$ | $w^*$ | $r^*$ |
|---|---|---|---|---|---|---|
| 1999 | 0.529 | 5.97 | 0.020 | 0.085 | 0.050 | 0.236 |
| 2007 | 0.27 | 5.08 | 0.055 | 0.077 | 0.118 | 0.175 |

This model can account for many features in the data both for the cross-sectional distribution of output and exports as well as the aggregate allocation of factors. Figure 14 below shows distribution of output and export share from the model along with the empirical distribution from the data for the two years.

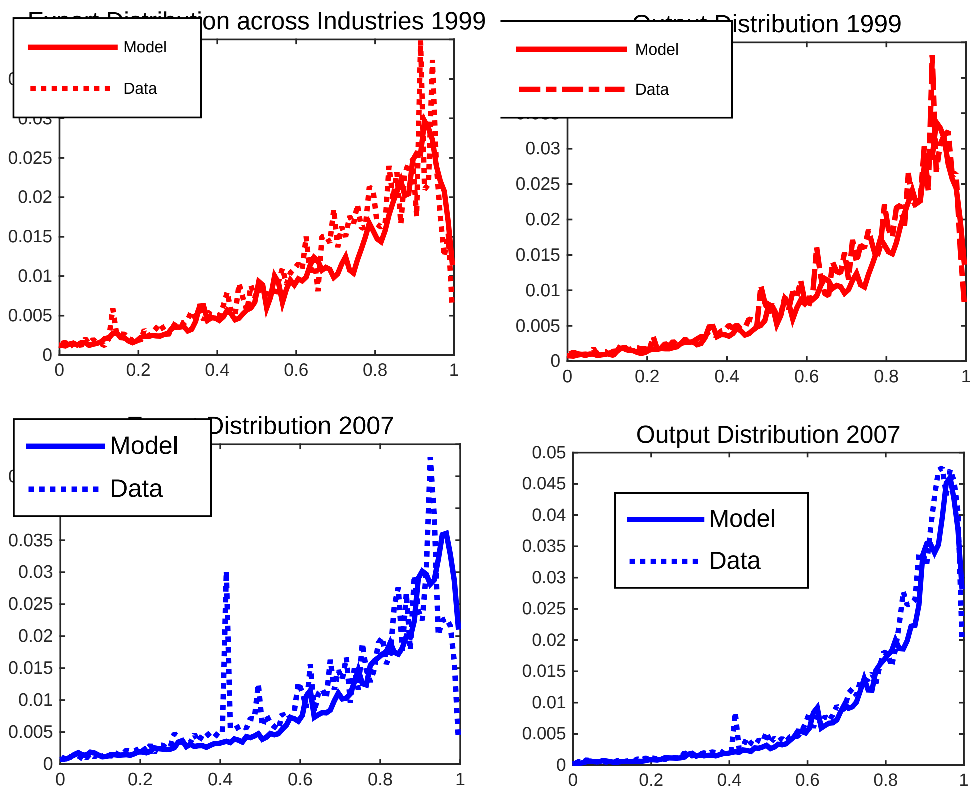
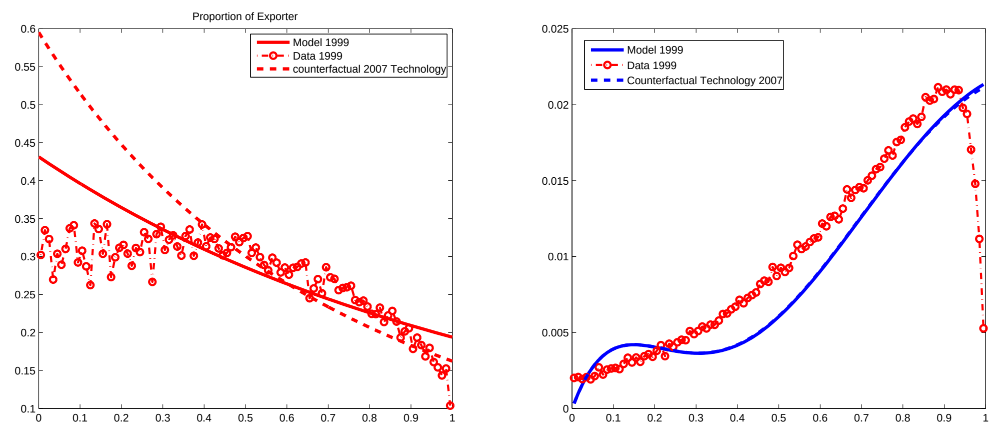



Figure 14: Distribution of Export and Output in the model and in the data

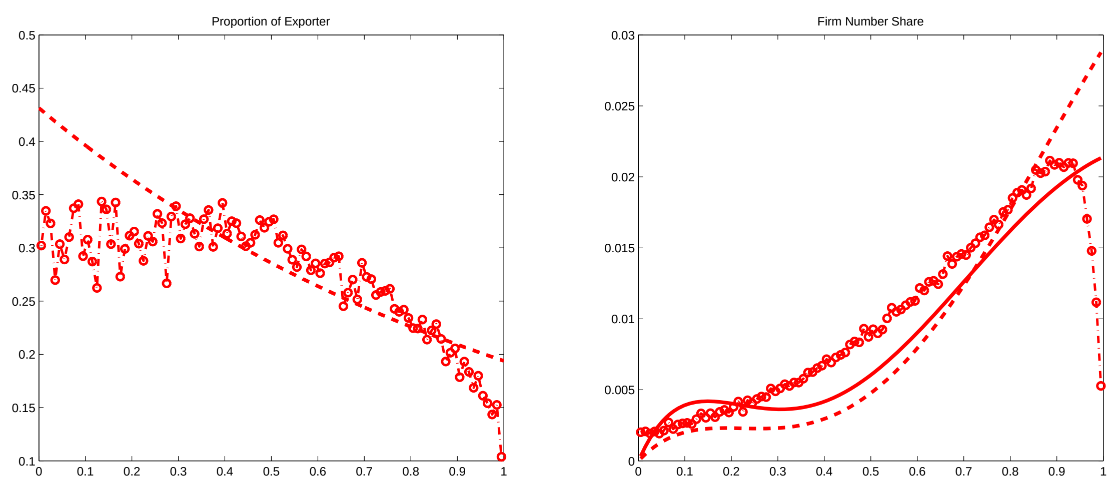
## 5.3 Counterfactual

In this session, we are going to do several counterfactual experiments to investigate the driving forces behind the structural adjustments of Chinese production and export. The experiments is to replace the estimated parameters of 1999 by those of 2007, one type of parameters in one time. The first experiment is to replace the technology parameter $\{A,\lambda\}$. The results are shown in the following figures. As we can see from the figures. Only the increase of $\frac{K}{L}$ significantly changes the firm mass distribution. On the other hand, changes in technology and trade costs both contribute to the movement of export participation. But technology seems to be the main contributor of the movements that we observe in the data.



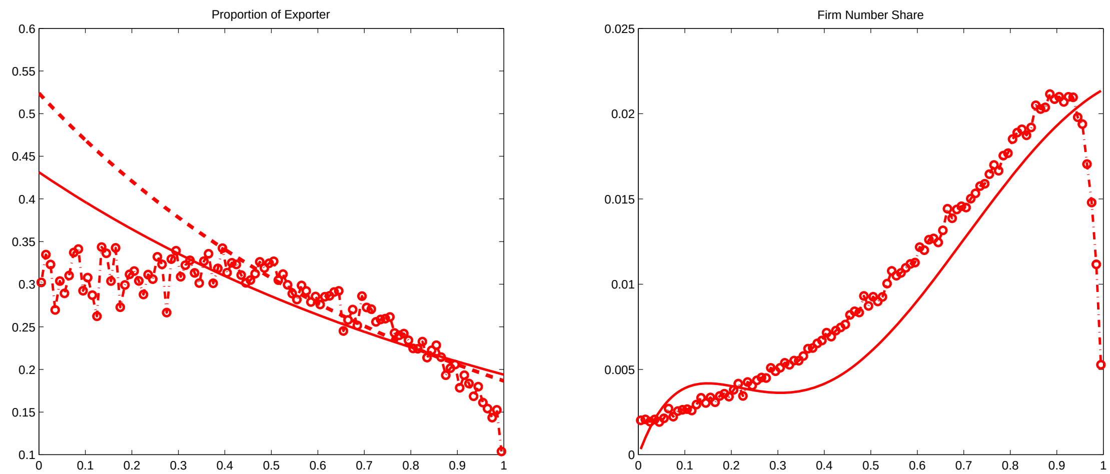

Note: The dash lines are the counterfactuals. In this figure, we replace $\{A, \lambda\}$ for year 1999 with that of year 2007 and keep other parameters unchanged in the counterfactual. The dash lines are the counterfactual.

Figure 15: Counterfactual on Technology




Note: The dash lines are the counterfactuals. In this figure, we replace $\frac{K}{L}$ for year 1999 with that of year 2007 and keep other parameters unchanged in the counterfactual. The dash lines are the counterfactual.

Figure 16: Counterfactual on Endowment




Note: The dash lines are the counterfactuals. In this figure, we replace $\{f, \tau\}$ for year 1999 with that of year 2007 and keep other parameters unchanged in the counterfactual. The dash lines are the counterfactual.

Figure 17: Counterfactual on Trade Costs

# 6 Conclusion

In this paper, we first document the seemingly puzzling patterns of structural adjustments in production and export based on a comprehensive Chinese firm level data: the overall manufacturing production became more capital intensive while export became more labor intensive between 1999-2007. It counters our understanding from Rybczynski Theorem of HO theory. To explain these findings, we embed Melitz-type heterogeneous firm model into the Ricardian and Heckscher-Ohlin trade theory with *continuous* industries. The theory predicts that export probability and export intensity decrease with comparative advantage. And they remain *constant* for industries where countries specialize and conduct inter-industry trade. Such predictions are supported by data.

We structurally estimate the model and find that capital labor ratio almost tripled, technology improved significantly and favored more labor intensive industries between 1999 and 2007. Trade liberalization mostly came from reduction in fixed cost of export for China. And by running counterfactuals, we find the adjustment in production pattern is mainly driven by changes in endowment while the changes in export participation is driven by technology and trade liberalization, but mostly driven by changes in technology.

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# 7 Appendix

Table A1: Statistical Summary of Main Variables

| Variables | mean in 1999 | mean in 2007 |
|---|---|---|
| number of firms | 116,890 | 291,286 |
| revenue(¥*1,000*) | 50,808 | 117,744 |
| value_added(¥*1,000*) | 14,098 | 31,942 |
| newly_sales(¥*1,000*) | 49,187 | 115,296 |
| export(¥*1,000*) | 8,880 | 23,896 |
| employee | 328 | 218 |
| total profit(¥*1,000*) | 1,854 | 6,804 |
| wage(¥*1,000*) | 3,363 | 5,417 |
| profit/revenue | 0.011 | 0.043 |
| proportion of exporters | 0.252 | 0.248 |
| proportion of SOE | 0.258 | 0.041 |
| capital share | 0.669 | 0.707 |

*Notes: This is for the sample after data cleaning.*

## 7.1 Proof of Proposition 1

The proof goes in this way: suppose that factor prices $\{w, w^*, r, r^*\}$ are known, and we find the factor demands as functions of them. Then market clearing condition will pin down the unique equilibrium. Firstly, we have the national revenue for home country and foreign country: $R = wL + rK$ and $R^* = w^*L^* + r^*K^*$. Potentially, there could be industries that either country specializes.[19] The factor demands in home country for these industries are $l(z) = (1-z)b(z)(R+R^*)/w$, $k(z) = zb(z)(R+R^*)/r$. Factor demands in foreign country have symmetric expressions. For industries that both country produce, the industry revenue function is given by equation(3.17) , thus we need to know the firm mass $M_z, M_z^*$,the pricing index $P(z)$ and $P(z)^*$ and industry average productivity $\widehat{\varphi}_z$ and $\widehat{\varphi}_z^*$ (average price p($\widehat{\varphi}_z$) and p($\widehat{\varphi}_z^*$ )) in order to find its factor demand. Firstly, from equation (3.17), we find that:

$$\frac{r(\widehat{\varphi}_z)}{r(\widehat{\varphi}_z^*)} = \widetilde{p}_z^{1-\sigma} \frac{(\frac{P(z)}{P(z)^*})^{\sigma-1} + \frac{R^*}{R}\tau^{1-\sigma}\chi_z^{\frac{a+1-\sigma}{a}}}{\frac{R^*}{R} + \chi_z^{*\frac{a+1-\sigma}{a}}\tau^{1-\sigma}(\frac{P(z)}{P(z)^*})^{\sigma-1}} \tag{7.1}$$

Here $r(\widehat{\varphi}_z) = \frac{R_z}{M_z}$ is the average firm revenue and $\widetilde{p}_z \equiv \frac{p_{zd}(\widehat{\varphi}_z)}{p_{zd}(\widehat{\varphi}_z^*)} = \frac{\widehat{\varphi}_z^* w}{\varepsilon(z)\widehat{\varphi}_z w^*}(\frac{r/w}{r^*/w^*})^z$ is the relative average domestic price between the two countries. Using the zero profit condition(3.9),(3.10) and $\frac{r(\widehat{\varphi}_z)}{r(\bar{\varphi}_z)} =$

[19] We are going to show how to determine the specialization pattern in proposition 2. And greater detailed could be found in the algorithm of numerical solution.

$(\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1}$,[20] it is obvious that $r(\widehat{\varphi}_z) = (f_z(\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1} + \chi_z f_{zx}(\frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}})^{\sigma-1})\sigma r^z w^{1-z}$. Combing with the free entry condition, we could find that the average productivity between home and foreign country is $\frac{\widehat{\varphi}_z^*}{\widehat{\varphi}_z} = (\frac{1+f\chi_z^*}{1+f\chi_z})^{\frac{1}{a}}$ while $f \equiv \frac{f_{zx}}{f_z}$.Using the Pareto distribution assumption, we can easily solve that $\frac{\widehat{\varphi}_z}{\bar{\varphi}_z} = \frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}} = (\frac{a}{a+1-\sigma})^{\frac{1}{\sigma-1}}$ and $\chi_z = \frac{1-G(\bar{\varphi}_{zx})}{1-G(\bar{\varphi}_z)} = \Lambda_z^{-a}$ while $\Lambda_z$ is the productivity cut-off ratio given by (3.11). Then we have:

$$\frac{r(\widehat{\varphi}_z)}{r(\widehat{\varphi}_z^*)} = \varepsilon\widetilde{p}_z(\frac{1+f\chi_z}{1+f\chi_z^*})^{\frac{a+1}{a}} \tag{7.2}$$

Using the definition of $\widetilde{p}_z$ and combining (7.1) and (7.2), we have:

$$\chi_z = \frac{\widetilde{\tau}^{-a} f - \varepsilon^a g(z)}{\varepsilon^a f g(z) - \widetilde{\tau}^a} \tag{7.3}$$

$g(z) = (\frac{w}{w^*}(\frac{r/w}{r^*/w^*})^z)^{\frac{a\sigma}{1-\sigma}}$ and $\widetilde{\tau} = \tau(\frac{\gamma}{1-\gamma}f)^{\frac{1}{\sigma-1}}$.[21] From (7.3), we see that $\chi_z$ is a function of the factor price. From equation (3.11) we have $\Lambda_z = \chi_z^{-1/a} = \frac{\tau P(z)}{P(z)^*}(\frac{\gamma f R}{(1-\gamma)R^*})^{1/(\sigma-1)}$,then $\frac{P(z)}{P(z)^*} = \frac{\chi_z^{-1/a}}{\tau}(\frac{(1-\gamma)R^*}{\gamma f R})^{1/(\sigma-1)}$.So we can find that for those industries that both country produce:

$$\begin{aligned} R_z &= b(z)[\frac{R}{1-\widetilde{\tau}^{-a}\varepsilon^a f g(z)} - \frac{fR^*}{\widetilde{\tau}^a\varepsilon^a g(z) - f}] \qquad (7.4) \\ R_z^* &= b(z)\varepsilon^a g(z)[\frac{R^*}{\varepsilon^a g(z) - f\widetilde{\tau}^{-a}} - \frac{fR}{\widetilde{\tau}^a - \varepsilon^a f g(z)}] \qquad (7.5) \end{aligned}$$

So both could be written as a function of the factor price. Again using $l(z) = (1-z)b(z)R_z/w$ and $k(z) = zb(z)R_z/r$. Then the factor demand for industries that both country produce as:

$$\begin{aligned} \int_{I(s)} (1-z)\frac{b(z)(R+R^*)}{w}dz + \int_{I(b)} (1-z)\frac{R_z}{w} &= L \\ \int_{I(s)} z\frac{b(z)(R+R^*)}{r}dz + \int_{I(b)} z\frac{R_z}{r} &= K \end{aligned}$$

Another 2 symmetric equations could be written for the case of foreign country. I(s) is set of the industries that home country specializes and while I(b) is the set of industries that both countries produce. It is determined where either domestic or foreign firm mass is zero. From the definition of price index (3.18), we have $\frac{M_z}{M_z^*} = \widetilde{p}_z^{\sigma-1}\frac{(\frac{P(z)}{P(z)^*})^{1-\sigma} - \chi_z^{-\frac{a+1-\sigma}{a}}\widetilde{\tau}^{-2(a+1-\sigma)}\tau^{1-\sigma}}{1-\chi_z^{\frac{a+1-\sigma}{a}}\tau^{1-\sigma}(\frac{P(z)}{P(z)^*})^{1-\sigma}}$. Thus it is also determined by factor prices.[22] So there are 4 equations for 4 unknowns, given reasonable parameters the equilibrium factor prices could be uniquely pinned down.■

[20] This is a typical property of Melitz(2003) type model.

[21] Here it can be proved that $\frac{\partial\chi_z}{\partial z} < 0$ which is one of the conclusions in proposition 3. However, here we rely on the Pareto distribution while proposition 3 doesn't need that.

[22] We provide more details in next proof.

## 7.2 Proof of Proposition 2

In the proof of Proposition 1, we mention that the relative firm mass at home and abroad is:

$$\frac{M_z}{M_z^*} = \frac{\gamma}{1-\gamma}\widetilde{p}_z^{\sigma-1}\frac{(\frac{P(z)}{P(z)^*})^{1-\sigma} - \chi_z^{-\frac{a+1-\sigma}{a}}\widetilde{\tau}^{-2(a+1-\sigma)}\tau^{1-\sigma}}{1-\chi_z^{\frac{a+1-\sigma}{a}}\tau^{1-\sigma}(\frac{P(z)}{P(z)^*})^{1-\sigma}}$$

Since $\frac{P(z)}{P(z)^*} = \frac{\chi_z^{-1/a}}{\tau}(\frac{R^*}{fR})^{1/(\sigma-1)}$ and $\widetilde{p}_z = \frac{\widehat{\varphi}_z^* w}{\varepsilon(z)\widehat{\varphi}_z w^*}(\frac{r/w}{r^*/w^*})^z$, we find it could be further simplified as:

$$\frac{M_z}{M_z^*} = \frac{\gamma}{1-\gamma}\varepsilon^{1-\sigma}(\frac{1+f\chi_z^*}{1+f\chi_z})^{\frac{\sigma-1}{a}}[\frac{w}{w^*}(\frac{r/w}{r^*/w^*})^z]^{\sigma-1}\frac{\frac{fR}{R^*} - \chi_z^{-1}\widetilde{\tau}^{-2a}f^2}{1-\chi_z\frac{fR}{R^*}}\tau^{\sigma-1}\chi^{\frac{\sigma-1}{a}}$$

Then $\exists\ \chi_z = \frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2$ such that $\frac{M_z}{M_z^*} = 0$.Since $M_z^* > 0$ ($M_z^* \neq 0$), it must be that $M_z = 0$. And as $\chi_z$ decreases such that $\chi_z < \frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2$,it must be that$\frac{M_z}{M_z^*} < 0$. If $\chi_z$ increases such that $\chi_z$ approaches $\frac{R^*}{fR}$ we have $\frac{M_z}{M_z^*} \to +\infty$,or say $\frac{M_z^*}{M_z} \to 0$, so again we have $M_z^* = 0$.If $\chi_z$ further increases such that $\chi_z > \frac{R^*}{fR}$, we again have $\frac{M_z^*}{M_z} < 0$.Thus to maintain positive firm mass for both home and foreign in certain industry z, we must have:

$$\frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2 < \chi_z < \frac{R^*}{fR}$$

where $\frac{f}{\widetilde{\tau}^a} = \frac{f}{\tau^a f^{\frac{a}{\sigma-1}}} < \frac{f}{f^{\frac{a}{\sigma-1}}} < 1, (a > \sigma-1 > 0)$,if $\tau > 1$ and $f > 1$. And if $\chi_z$ falls out of this range. One of the countries' firm mass is zero (it cannot be negative which is meaningless) and the other is positive. This is where specialization happens! For industries that both country produces, we have

$$\chi_z = \frac{\widetilde{\tau}^{-a}f - \varepsilon^a g(z)}{\varepsilon^a f g(z) - \widetilde{\tau}^a} \tag{7.6}$$

which is a continuous and monotonic function between $[\underline{z}, \overline{z}]$,[23] Then we have

$$\chi_{\underline{z}} = \frac{R^*}{fR} \text{ and } \chi_{\overline{z}} = \frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2$$

and $(\underline{z}, \overline{z})$ are given by equalizing equation (7.6) with $\chi_{\underline{z}}$ and $\chi_{\overline{z}}$ at $\underline{z}$ and $\overline{z}$.

$$\begin{aligned}
\underline{z} &= \frac{\ln(\frac{\chi_{\underline{z}}\widetilde{\tau}^a + f\widetilde{\tau}^{-a}}{1+f\chi_{\underline{z}}}) - \frac{a\sigma}{1-\sigma}\ln(\frac{w}{w^*}) - a\ln(\lambda)}{\frac{a\sigma}{1-\sigma}\ln(\frac{r/w}{r^*/w^*}) + a\ln(A)} \\
\overline{z} &= \frac{\ln(\frac{\chi_{\overline{z}}\widetilde{\tau}^a + f\widetilde{\tau}^{-a}}{1+f\chi_{\overline{z}}}) - \frac{a\sigma}{1-\sigma}\ln(\frac{w}{w^*}) - a\ln(\lambda)}{\frac{a\sigma}{1-\sigma}\ln(\frac{r/w}{r^*/w^*}) + a\ln(A)}
\end{aligned}$$

And if trade is complete free $\tau = f = 1$ and no home bias $\gamma = \frac{1}{2}$ we have $\chi_{\underline{z}} = \chi_{\overline{z}} = \frac{R^*}{R}$. So $\underline{z} = \overline{z}$ and there are intra-industry trade. Under home bias, $\widetilde{\tau} = \tau(\frac{\gamma}{1-\gamma}f)^{\frac{1}{\sigma-1}} = (\frac{\gamma}{1-\gamma})^{\frac{1}{\sigma-1}} > 1$, so

[23] This is true given our assumption of home country is labor abundant and has Ricardian comparative advantage in more labor intensive industries.

$\chi_{\underline{z}} = \frac{R^*}{R} > \chi_{\overline{z}} = \frac{R^*}{R}\frac{1}{\overline{\tau}^{2a}}$.Then $\overline{z} \neq \underline{z}$ and there no complete specialization. ■

### 7.3 Proof of Proposition 3

Let's focus on the labor abundant home country: for any 2 industries z and z', suppose z<z'. From the definition of $\Lambda_z$ (3.11) and using the assumption that trade costs and fixed costs are the same all industries, we have:

$$\frac{\Lambda_z}{\Lambda_{z'}} = \frac{P(z)/P(z')}{P(z)^*/P(z')^*}.$$

Thus if $\frac{P(z)}{P(z')} < \frac{P(z)^*}{P(z')^*}$, or say labor intensive products are relatively cheaper in home country, then we have $\Lambda_z < \Lambda_{z'}$. This is exactly what we are going to prove. If $\frac{P(z)}{P(z')} < \frac{P(z)^*}{P(z')^*}$ under autarky and $\frac{P(z)}{P(z')} = \frac{P(z)^*}{P(z')^*}$ under free trade, then the costly trade case will fall between and establishes our proof. When there is free trade (no variable costs or fixed costs of trade), all firms will export, the price of each variety and number of varieties will be the same for both countries. Thus the pricing index P(z)=P(z)* for all industries and $\frac{P(z)}{P(z')} = \frac{P(z)^*}{P(z')^*}$. On the other extreme of close economy, no firms export and from (3.18) we have $P(z) = M_z^{\frac{1}{1-\sigma}} p_{zd}(\widehat{\varphi}_z)$.Firm mass for each industry is $M_z = \frac{b(z)R}{r(\widehat{\varphi}_z)} = \frac{b(z)R}{r(\varphi_z)}(\frac{\overline{\varphi}_z}{\widehat{\varphi}_z})^{\sigma-1}$.So $\frac{P(z)}{P(z')} = (\frac{w}{r})^{(z'-z)/\rho}(\frac{b(z)}{b(z')})^{\frac{1}{1-\sigma}}\frac{A(z')\overline{\varphi}_{z'}}{A(z)\overline{\varphi}_z}$. Using (3.16) we have homogeneous cut-offs for all industries under autarky:$\overline{\varphi}_{z'} = \overline{\varphi}_z$.Then it can be verified that

$$\frac{P(z)/P(z')}{P(z)^*/P(z')^*} = (\frac{w/r}{w^*/r^*})^{\frac{z'-z}{\rho}}A^{z'-z}$$

Since z'>z and $A<1$, then$\frac{w}{r} < \frac{w^*}{r^*} \iff \frac{P(z)}{P(z')} < \frac{P(z)^*}{P(z')^*}$. So our next task is to prove $\frac{w}{r} < \frac{w^*}{r^*}$ under autarky. Because of the factor market clearing condition and the Cobb-Douglas production function for production, entry and payments of fixed costs, we find that:

$$\frac{K}{L} = \frac{w}{r}\frac{\int_0^1 zb(z)dz}{\int_0^1 (1-z)b(z)dz}, \quad \frac{K^*}{L^*} = \frac{w^*}{r^*}\frac{\int_0^1 zb(z)dz}{\int_0^1 (1-z)b(z)dz}$$

Thus $\frac{K}{L} < \frac{K^*}{L^*} \iff \frac{w}{r} < \frac{w^*}{r^*}$ and we establish that $\Lambda_z < \Lambda_{z'}$, or say $\Lambda_z$ increases with z in home country. For industries that home country specializes: $\Lambda_z = \chi_z^{-1/a} = (\frac{fR}{R^*})^{1/a}$ and doesn't vary with z. This is also true for foreign country.

As for intra-industry trade zone, by referring back to (3.16) which determines the two cut-offs, we see that the first term of left hand side is a decreasing function of $\overline{\varphi}_z$. Since $\Lambda_z$ increases with z, it can be easily shown that $\overline{\varphi}_z' > 0$ or $\overline{\varphi}_z' = 0$ cannot maintain the equation, so it must be the case that $\overline{\varphi}_z' < 0$. Then the first term will increase as z increases. To maintain the equation the second term must decrease with z. So $\overline{\varphi}_{zx} = \Lambda_z\overline{\varphi}_z$ should be an increasing function of z. Applying the same logic, we can get the opposite results for foreign country: $\bar{\varphi}_z^{*\prime} > 0$ and $\bar{\varphi}_{zx}^{*\prime} < 0$. And this result rely on any assumption of the distribution here.■

## 7.4 Proof of Proposition 4

From the proof of proposition 4, we know that $\Lambda_z < \Lambda_{z'}$ if $z < z\prime$ within the intra-industry trade region. Within the specialization zone, it can be easily found that $\Lambda_z = (\frac{fR}{R^*})^{1/a}$ which doesn't do with z. Since exporting probability $\chi_z = \frac{1-G(\bar{\varphi}_{zx})}{1-G(\bar{\varphi}_z)} = \Lambda_z^{-a}$ $(a > 1)$, conclusion (a) is obvious. For industries that both country produce, we know that $\chi_z = \frac{\widetilde{\tau}^{-a} f - \varepsilon^a g(z)}{\varepsilon^a f g(z) - \widetilde{\tau}^a}$ from the proof of proposition 1. Using chain rule, we have

$$\frac{\partial \chi_z}{\partial z} = \frac{(1 - \widetilde{\tau}^{-2a} f^2)\varepsilon^a g a}{(\varepsilon^a f g(z) - \widetilde{\tau}^a)^2}(\ln(A) - \frac{\sigma}{\sigma - 1}\ln(\frac{r/w}{r^*/w^*}))$$

For average export intensity $\gamma_z \equiv \frac{\chi_z r(\widehat{\varphi}_{zx})}{r(\widehat{\varphi}_z) + \chi_z r(\widehat{\varphi}_{zx})} = \frac{\chi_z f_{zx} (\frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}})^{\sigma-1} \sigma r^z w^{1-z}}{(f_z (\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1} + \chi_z f_{zx} (\frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}})^{\sigma-1}) \sigma r^z w^{1-z}} = \frac{f_{zx}\chi_z}{f_z + f_{zx}\chi_z} = \frac{f\chi_z}{1+f\chi_z}$, thus $\frac{\partial \gamma_z}{\partial \chi_z} = \frac{f}{(1+f\chi_z)^2} > 0$.So $\gamma_z$ is a monotonic increasing function of $\chi_z$ and should follow the same pattern.■

## 7.5 Proof of Proposition 5

Again from equation (3.16), we could calculate that:

$$\widehat{\varphi}_z = (\frac{a}{a+1-\sigma})^{\frac{1}{\sigma-1}}\bar{\varphi}_z = (\frac{a}{a+1-\sigma})^{\frac{1}{\sigma-1}}[\frac{(\sigma-1)\theta^a}{(a+1-\sigma)\delta\widetilde{f}}(1+f\chi_z)]^{\frac{1}{a}}$$

where $\widetilde{f} = \frac{f_{ez}}{f_z}$.Again it is monotonic function of $\chi_z$ and should follow the same pattern of it. Since we assume A(z) is the same for all industries, conclusion (a) is established. For conclusion (b), the average productivity for exporters and non-exporters are given by:

$$\begin{aligned}
\widehat{\varphi}_{zx} &= [\frac{1}{1-G(\bar{\varphi}_{zx})}\int_{\bar{\varphi}_{zx}}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi]^{\frac{1}{\sigma-1}} = (\frac{a}{a+1-\sigma})^{\frac{1}{\sigma-1}}\bar{\varphi}_{zx} \\
\widehat{\varphi}_{znx} &= [\frac{1}{G(\bar{\varphi}_{zx}) - G(\bar{\varphi}_z)}\int_{\bar{\varphi}_z}^{\bar{\varphi}_{zx}}\varphi^{\sigma-1}g(\varphi)d\varphi]^{\frac{1}{\sigma-1}} = (\frac{a}{a+1-\sigma})^{\frac{1}{\sigma-1}}(\frac{1-\Lambda_z^{\sigma-1-a}}{1-\Lambda_z^{-a}})^{\frac{1}{\sigma-1}}\bar{\varphi}_z
\end{aligned}$$

Thus the ratio of average productivity for exporters and non-exporters are:

$$\begin{aligned}
\frac{\widehat{\varphi}_{zx}}{\widehat{\varphi}_{znx}} &= \Lambda_z(\frac{1-\Lambda_z^{\sigma-1-a}}{1-\Lambda_z^{-a}})^{-\frac{1}{\sigma-1}} \\
&= \chi_z^{-\frac{1}{a}}(\frac{1-\chi_z}{1-\chi_z^{\frac{1+a-\sigma}{a}}})^{\frac{1}{\sigma-1}}
\end{aligned}$$

It is a decreasing function of $\chi_z$ and follows the opposite pattern of it within the intra-industry zone and remain constant within the specialization zone.■

## 7.6 Numerical Solution

Given the exogenous parameters, the algorithm below will enable us to solve the equilibrium variables. The idea is very much the proof of Proposition 1: suppose that the wage factor {w, w*, r, r*} is known, we could find the factor demand as a function of it. Then market clearing condition will pin down the unique solution. We set b(z)=1 for all z so as to satisfied $\int_0^1 b(z) = 1$ and in principle we specify other kind of utility functions. But this is the simplest one to use.

The aggregate revenue for home and foreign are:

$$\begin{aligned} R &= wL + rK \\ R^* &= w^*L^* + r^*K* \end{aligned}$$

Factor intensity cut offs are:

$$\begin{aligned} \underline{z} &= \frac{\ln(\frac{\chi_{\underline{z}}\widetilde{\tau}^a + f\widetilde{\tau}^{-a}}{1+f\chi_{\underline{z}}}) - \frac{a\sigma}{1-\sigma}\ln(\frac{w}{w^*}) - a\ln(\lambda)}{\frac{a\sigma}{1-\sigma}\ln(\frac{r/w}{r^*/w^*}) + a\ln(A)} \\ \overline{z} &= \frac{\ln(\frac{\chi_{\overline{z}}\widetilde{\tau}^a + f\widetilde{\tau}^{-a}}{1+f\chi_{\overline{z}}}) - \frac{a\sigma}{1-\sigma}\ln(\frac{w}{w^*}) - a\ln(\lambda)}{\frac{a\sigma}{1-\sigma}\ln(\frac{r/w}{r^*/w^*}) + a\ln(A)} \end{aligned}$$

where $\chi_{\underline{z}} = \frac{R^*}{fR}$ and $\chi_{\overline{z}} = \frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2$ are what we find in the proof of proposition 2. We also know that the equation solving home exporting probability within the intra-industry trade region is equation (7.6). Then the factor demand within the specialization region are:

$$\begin{aligned} L_s &= \int_0^{\underline{z}} l(z)dz = (\underline{z} - \frac{1}{2}\underline{z}^2)\frac{R+R^*}{w} \\ K_s &= \int_0^{\underline{z}} k(z)dz = \frac{1}{2}\underline{z}^2\frac{R+R^*}{r} \\ L_s^* &= \int_{\overline{z}}^1 l^*(z)dz = (\frac{1}{2} - \overline{z} + \frac{1}{2}\overline{z}^2)\frac{R+R^*}{w^*} \\ K_s^* &= \int_{\overline{z}}^1 k^*(z)dz = (1 - \overline{z}^2)\frac{R+R^*}{2r^*} \end{aligned}$$

Using (7.4) we find that the factor demand within the intra-industry trade region are:

$$
\begin{aligned}
L_{int} &= \int_{\underline{\underline{z}}}^{\overline{\overline{z}}} \frac{(1-z)R_z}{w} dz = \frac{1}{w} \int_{\underline{\underline{z}}}^{\overline{\overline{z}}} (1-z)[\frac{R}{1-\widetilde{\tau}^{-a}\varepsilon^a f g(z)} - \frac{fR^*}{\widetilde{\tau}^a \varepsilon^a g(z) - f}]dz \\
K_{int} &= \int_{\underline{\underline{z}}}^{\overline{\overline{z}}} \frac{zR_z}{r} dz = \frac{1}{r} \int_{\underline{\underline{z}}}^{\overline{\overline{z}}} z[\frac{R}{1-\widetilde{\tau}^{-a}\varepsilon^a f g(z)} - \frac{fR^*}{\widetilde{\tau}^a \varepsilon^a g(z) - f}]dz \\
L^*_{int} &= \int_{\underline{\underline{z}}}^{\overline{\overline{z}}} \frac{(1-z)R^*_z}{w^*} dz = \frac{1}{w^*} \int_{\underline{\underline{z}}}^{\overline{\overline{z}}} (1-z)\varepsilon^a g(z)[\frac{R^*}{\varepsilon^a g(z) - f\widetilde{\tau}^{-a}} - \frac{fR}{\widetilde{\tau}^a - \varepsilon^a f g(z)}]dz \\
K^*_{int} &= \int_{\overline{\overline{z}}}^{1} \frac{zR^*_z}{r^*} dz = \frac{1}{r^*} \int_{\underline{\underline{z}}}^{\overline{\overline{z}}} z\varepsilon^a g(z)[\frac{R^*}{\varepsilon^a g(z) - f\widetilde{\tau}^{-a}} - \frac{fR}{\widetilde{\tau}^a - \varepsilon^a f g(z)}]dz
\end{aligned}
$$

In the equations above we use the goods market clearing condition and the definition of $P(z)$ and $P^*(z)$ to find out $R^*_z$ and $R_z$.The factor Market Clearing condition is:

$$
\begin{aligned}
L_s + L_{int} &= L && (7.7) \\
K_s + K_{int} &= K && (7.8) \\
L^*_s + L^*_{int} &= L^* && (7.9) \\
K^*_s + K^*_{int} &= K^* && (7.10)
\end{aligned}
$$

From the market clearing condition we then pin down the equilibrium factor prices and other variables are simply function of factor prices.