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 Ricardian and Heckscher-Ohlin (1977, 1980). We structurally estimate the model. Besides the capital deepening which more than doubled the capital labor ratio, the technology improved significantly but favored more labor intensive industries, trade liberalization reduces the variable trade costs by more than one third. Counterfactual simulations show that the adjustment in production pattern is mainly driven by changes in endowment while the changes in export patterns is mostly driven by technology and trade liberalization. We also find that the Melitzian export selection mechanism contributes to about 12% productivity growth during this period.

Key Words: Structural Adjustments, Heterogeneous Firm, Comparative Advantage

JEL Classification Numbers: F12 and L16

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1 Introduction

China is one of the fastest growing economy over the past few decades. China has experienced sustained capital accumulation and major adjustment in the sectoral composition of output. At the same time, trade liberalization lowers the trade costs and better integrates China into the global economy. How do manufacturing production and exports adjust to trade liberalization and capital deepening in China? We try to answer this question in this paper. We document new facts about manufacturing firms in China and develop a model of trade with comparative advantage across sectors and intra-sectoral firm heterogeneity.

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 new empirical facts which seem puzzling. Comparing the data in 2007 with that in 1999, manufacturing productions became more capital intensive. On the other hand, exports became more labor intensive. This finding is at odds with the well-known story that over time, as a developing country accumulates capital, the specialization and export patterns change towards capital-intensive goods following a country's move towards free trade. 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 observed change in production structures is consistent with the classical HO theory, but the changes in export structures in the data seem to contradict this theory. To understand the seemingly puzzling data pattern and explore the driving forces behind, we construct a theoretical model introduce firm's heterogeneity into the HO and Ricardian framework. Using this unified model, we analyze the driving forces behind China's structural adjustments and quantify the the impact of these forces. We find that capital deepening, trade liberalization and technology progress collectively account for structural adjustment in China. Endogenous firm selection contributes 12 percent of total productivity growth. China and RoW benefit from China's structural adjustment.

First, we compare the production and export in China's manufactural industries between 1999 and 2007 using firm-level data. 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. In addition, 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.

Second, we construct a unified framework to explore the driving forces behind these structural adjustments. We introduce Melitz-type firm's heterogeneity into the DFS framework of continuous Ricardian and Heckscher-Olin model (Dornbusch, Fischer and Samuelson 1977, 1980, hence DFS). 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 export: 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 a country specialize, we show that the export participation (measured by export participation 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 structurally estimate the parameters of the model for both years by GMM. The estimation result indicates the following main findings: capital labor ratio more than doubled, technology improved significantly and favored more labor intensive industries, and trade liberalization mostly came from reduction in fixed cost of export 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 and technology 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. Lastly, our model estimation allows us to conduct the decomposition of the Ricardian comparative advantage and the welfare analysis. The results show that the endogenous firm selection contributes 12% of the productivity growth. Both China and RoW benefits from China's structural adjustment.

The remainder of the paper are organized as follows. The next subsection reviews the related literature. 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 presents the quantitative results, including the counterfactual experiments and welfare analysis. Section 6 concludes.

1.1 Literature Review

Our paper is related several strands of literature. First, There is long history to test the classic trade theory and examine the gains from trade. Trefler (1993, 1995), Harrigan (1995, 1997), Davis and Weinstein (2001), Schott (2003, 2004), Romalis (2004), Morrow (2010) all examine the Heckscher-Ohlin theory in the data to better understand the Leontief Paradox (1953). The key differences between our paper and ours is that we incorporate heterogeneous firm into the test. We also structurally estimate model primitives which allows us to do counterfactuals.

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.[1] We study the production and trade in a model with many industries and examine the data for China. 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 (2016) 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.

Several papers incorporate the heterogeneous firm into multisector models. Bernard, Redding and Schott (2007), Okubo (2009), Lu (2010), Fan et al (2011), Burstein and Vogel (2011, 2016). 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. With the exception of Burstein and Vogel (2016), these paper include only HO or Ricardian in a single framework (exception, Burstein and Vogel, as detailed below). Burstein and Vogel (2016) study a model with two sectors and incorporate HO, heterogenous firm as well as skill biased productivity (SBP). They find that HO interacts with SBP and that Ricardian CA is positively correlated with HO CA. We consider Ricardian and Heckscher-Ohlin models jointly. In addition, we allow for endogenous entry.

Lastly, our paper is related to the literature that study structural adjustment and growth in China. Song et al (2011), Hsieh and Ossa (2011), Karabarbounis and Neiman (2014), Zhu (2012), Tombe and Zhu (2015), Chang et al (2015), and Ju, Lin and Wang (2015) all belong to this literature. Yet they do not look at the adjustment in the international trade pattern in China. We take the capital deepening as given as we do not model the capital accumulation.[2] However, we study the structural adjustments in manufacturing production and exports in a quantitative model. Rodrik (2006), Schott (2008) and Wang and Wei (2010) study the change in the export contents. Although they examine how sophisticated the Chinese exports are, we use the firm level data to

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

[1] 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.

[2] In a work-in-progress, Ju, Yi, Zhang and Yue allow the capital accumulation to study the dynamic property of the model and evaluate the contribution of H-O channel to growth.

(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, firm's identification, ownership, export, employment, and capital stock, etc. Our focus is on the 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* (2012) 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 over time, we look at data of year 1999 and 2007.[4] The Statistics Summary of the data after cleaning is shown in Table A1.

Table 1 presents the empirical features of Chinese manufacturing firms on the factor allocation and export participation. First, the overall capital share is 0.669 in 1999 and 0.707 in 2007.[5] Thus, from 1999 to 2007, the average capital share in China increased by about 4 percentage points. So the overall manufacture production is more capital intensive.[6] 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.

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.[7] This is different from Alvarez and López (2005)'s finding that Chilean exporters are more capital intensive than

[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.

[5]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.

[6]Karabarbounis and Neiman (2014) and Chang, Chen, Waggoner and Zha (2015) document the declining labor share in China and account for this feature of data.

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

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.[8] 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.[9] 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. We now examine how the production, exports and productivity of manufacturing firms are distributed across industries.

2.1 Production

In Figure 1, The horizontal axis of the graphs is the industry index. Higher numbers correspond to higher capital shares. Figure 1 shows that from 1999 to 2007, more firms are producing capital intensive industries while less firms are producing in labor intensive industries. Thus there is a significant reallocation of resources towards capital intensive industries. In terms of output, from Figure 2, we find that firms in capital intensive industries account for larger fractions of value added and sales.[10] The messages from Figure 1 and 2 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. We find the production structures became more capital intensive in 2007.

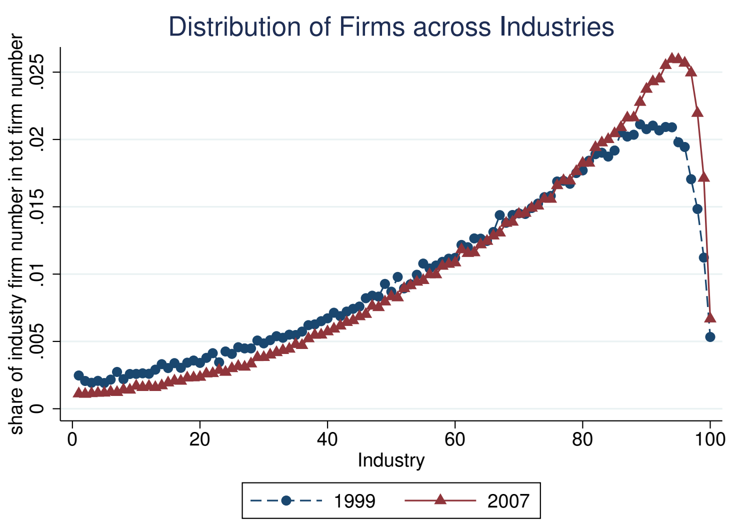


Figure 1: Distribution of Firms

[8]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.

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

[10]Real value added is calculated using the input and output pricing index constructed by Brandt *et al* (2012).

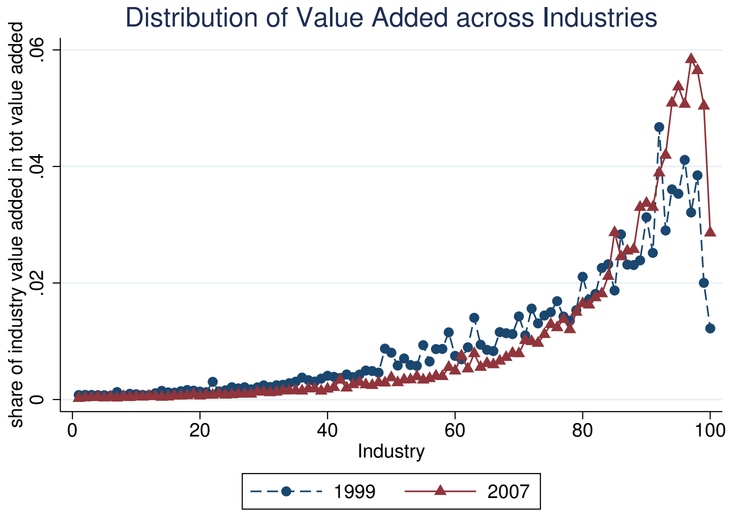


Figure 2: Distribution of Value Added

Table 3: Structural Adjustment of Production

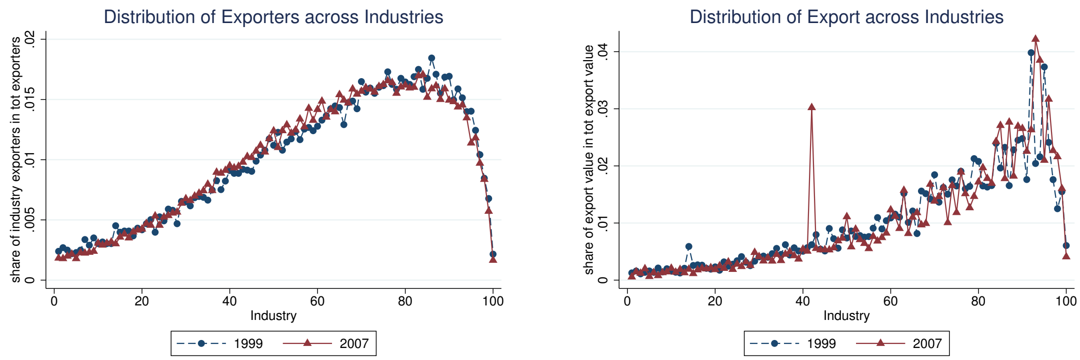
Variable	fraction of firms in high capital share industries	share of employment in high capital share industries	share of value added in high capital share industries
2007	0.648	0.585	0.860
1999	0.588	0.459	0.744
Difference	0.061	0.126	0.116

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).

2.2 Trade Patterns

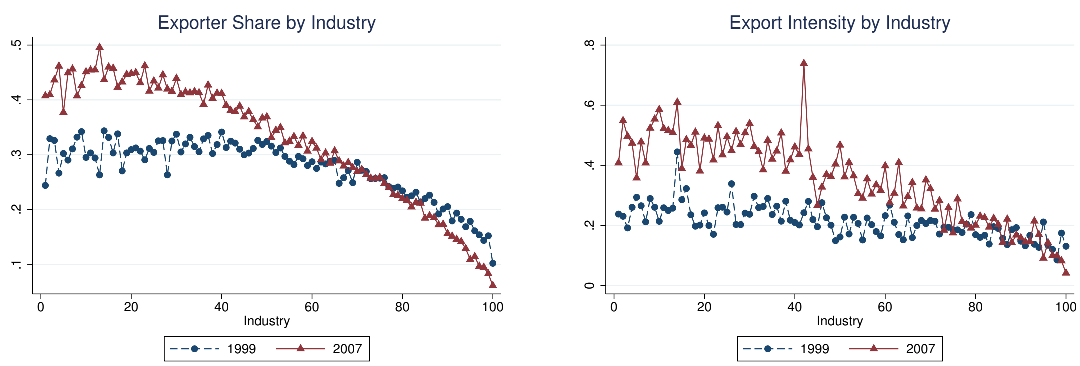
Now we turn to examine how the trade patterns change over time. We find that from 1999 to 2007, the distribution of exporting firms slightly shift toward labor intensive industries. The export participation (measured by fraction of exporters and sales exported) increases in labor intensive industries while the opposite is true in capital intensive industries.

In Figure 3, we plot the distribution of exporting firms measured using the number of firms and value of export. From the left panel, we find the number of firms which export slightly *decrease* in capital intensive industries and increase in labor intensive industries. From the right panel, we find the



(a) (b)

Figure 3: Distribution of Export



(a) (b)

Figure 4: Export within each Industry

distribution of export value across industries is more or less the same for both years. Next, we examine how export participation changes *within* each industry. From the left panel of Figure 4, we find that the proportion of firms that export in labor intensive industries is higher in 2007 than that in 1999 while the opposite is true for capital intensive industries. In terms of sales exported, we find the export intensity by industry increases in general over time but more significantly for labor intensive industries. In fact, for the most capital intensive ones, export intensity 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

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 although Chinese export overlaps more and more with OECD countries, it also becomes cheaper in terms of unit value.

2.3 Productivity

We also compare the TFP between 1999 and 2007. We first estimate TFP using Levinsohn and Petrin (2003) methodology. [11] Figure 5 shows the average TFP of each industry for 1999 and 2007. First, for both years, the productivity is higher for capital intensive industries, and it increases from 1999 to 2007 for all industries. Second, the magnitude of labor productivity growth from 1999 to 2007 decreases with capital intensity; that is, labor productivity grows faster in labor intensive industries. Therefore, we find that in general the growth of total factor productivity is biased toward labor intensive industries.

[11] Given the firm level data, productivity can be uncovered from regressing output on inputs. However, econometric identification of theses parameters may be problematic due the simultaneity problem. A common solution is the IV method. However, usual instruments are only weakly correlated to the explanatory variables. Levinsohn and Petrin (2003) build on Olley and Pakes (1996) and propose using a commonly observable variable (intermediate input) to control for unobserved productivity.

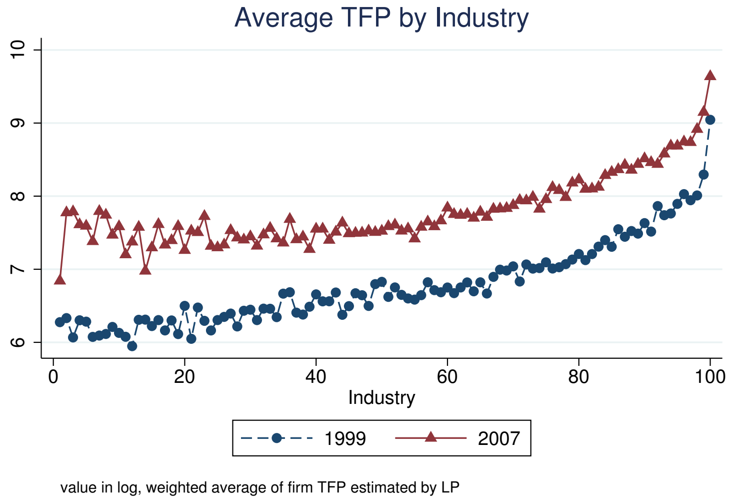


Figure 5: Total Factor Productivity

3 Model Setup

Motivated by the empirical features of the data, we now build a unified model that incorporate Ricardian comparative advantage, Heckscher-Ohline comparative advantage and firm hetergeniety. 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.[12] 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 monopolistic competitive market.

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

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

summarized by the following Cobb-Douglas utility function:

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

where $b(z)$ is the expenditure share on each industry and $Q(z)$ is the lower-tier utility function over the 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 $p_z(\omega)$:

$$Q(z) = \left[\int_{\omega \in \Omega_z} q_z(\omega)^\rho d\omega \right]^{1/\rho}, P(z) = \left[\int_{\omega \in \Omega_z} p_z(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}.$$

Ω_z is the varieties available for industry z. We assume $0 < \rho \leq 1$ so that the elasticity of substitution $\sigma = \frac{1}{1-\rho} > 1$. The demand function for individual varieties are given by:

$$q_z(\omega) = Q(z) (\frac{p_z(\omega)}{P(z)})^{-\sigma}. \tag{3.1}$$

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 the firm productivity. Firm productivity is denoted as $A(z)\varphi$ where $A(z)$ is a common component for all firms in industry z while firms randomly draw the heterogeneous productivity, φ, 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. Specifically, we assume that the total cost function is:

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

We also 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 λ is a parameter capturing the absolute advantage of home country: higher λ means that home has higher relative industry specific productivity for all industries. 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. We assume that home has Ricardian comparative advantage in more labor intensive industries, which requires $0 < A < 1$.

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. 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. In addition, firms need to ship τ units of goods for 1 unit of goods to arrive in foreign market, as in the standard "iceberg cost" assumption. Hence,the exporting and domestic price satisfy:

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

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

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

Therefore, the firm's profit can be divided into the two portions earned from domestic and foreign market:

$$\pi_{zd}(\varphi) = \frac{r_{zd}}{\sigma} - f_z r^z w^{1-z}$$

$$\pi_{zx}(\varphi) = \frac{r_{zx}}{\sigma} - f_{zx} r^z w^{1-z} \tag{3.7}$$

So the total profit is given by:

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

A firm that draws a productivity φ produces if its revenue at least covers the fixed cost that is $\pi_{zd}(\varphi) \geq 0$, and it 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, we could derive the relationship between the two productivity cut-offs:

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

$\Lambda_z > 1$ implies selection into export market: only the most productive firms export. The empirical literature strongly supports selection into market. So we focus on parameters where exporters are always more productive following Melitz (2003) and Bernard *et al* (2007a).[13] Then the production and exporting decision of firms are shown in Figure 6. Each period, $G(\bar{\varphi}_z)$ fraction of all the firms that enter exit upon entry because they do not earn positive profit. 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

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

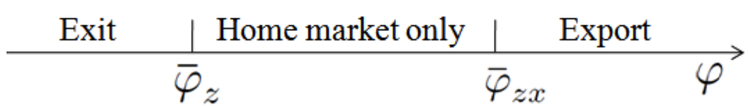


Figure 6: Productivity Cutoffs and Firm Decision

3.3 Free entry

If a firm does produce, it faces a constant probability δ 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:

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

We assume that the entry cost $f_{ez}r^z w^{1-z}$ also uses capital and labor. In equilibrium, the value of entry V_z equals to the cost of entry: $f_{ez}r^z w^{1-z}$. 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

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

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

[13] 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.

z. They are defined as follows:

$$\widehat{\varphi}_z = \left[\frac{1}{1-G(\bar{\varphi}_z)}\int\limits_{\bar{\varphi}_z}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi\right]^{\frac{1}{\sigma-1}}$$
$$\widehat{\varphi}_{zx} = \left[\frac{1}{1-G(\bar{\varphi}_{zx})}\int\limits_{\bar{\varphi}_{zx}}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi\right]^{\frac{1}{\sigma-1}} \quad (3.15)$$

Combining with the zero profit conditions (**??**), (**??**), we can determine the two productivity cut-offs which satisfy the equation (**??**) and (**??**) below:

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

3.4 Market Clearing

In equilibrium, 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:

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

where the price index $P(z)$ is given by the equation below. R_z^* and $P(z)^*$ are defined in a symmetric way.

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

The factor market clearing conditions are:

$$L = \int\limits_0^1 l(z)dz,\ L^* = \int\limits_0^1 l^*(z)dz \quad (3.19)$$
$$K = \int\limits_0^1 k(z)dz,\ K^* = \int\limits_0^1 k^*(z)dz$$

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 θ is a lower bar of productivity: $\varphi \geq \theta$. Secondly, we assume that the coefficients of fixed costs are the same for all industries:[14]

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

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 (**??**) for each industry and each country;

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

(c) Factor market clearing condition (**??**);

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

(e) The goods market clearing condition of world market (**??**).

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* $(\underline{z},\ \overline{z})$.

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

(b) If there is no variable trade cost ($\tau = 1$) 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.

Proof. *See Appendix.*■

This proposition is on the production and export pattern for each country. The basic result is illustrated in the Figure 7. 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 $\overline{z} = 1$.

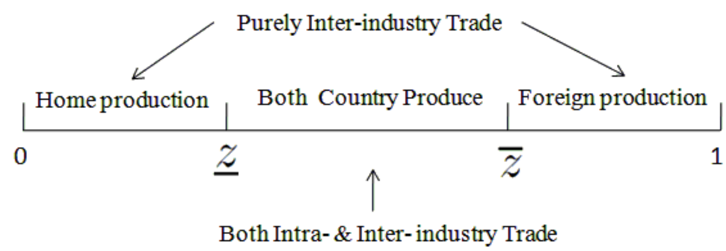


Figure 7: Production and Trade Pattern

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 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 obtain 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 8 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. 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.

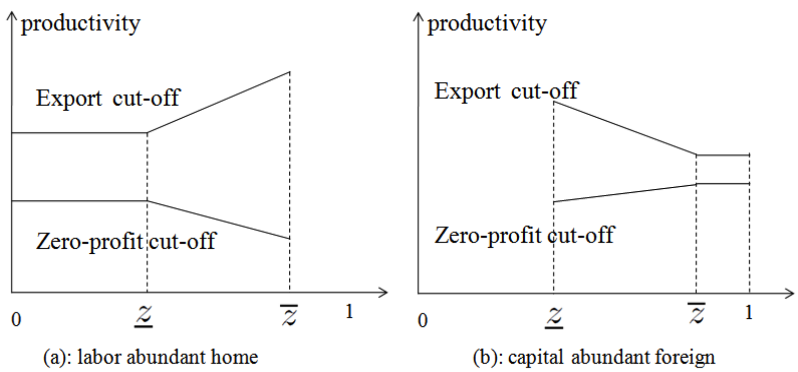


Figure 8: Productivity Cut-offs across Industries in Home and Foreign Countries

Proposition 4 *(a)Within the specialization zone* $[0, \underline{z}]$ *and* $[z, 1]$*,the export probability* χ_z *is a constant. For the industries that both countries produce* $(\underline{z}, \overline{z})$*, the export probability* χ_z *decreases with industry capital intensity in the labor abundant country and vice versa in the capital abundant country. Specifically, 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 $g(z) \equiv \left(\frac{w}{w^*} \left(\frac{r/w}{r^*/w^*} \right)^z \right)^{\frac{a\sigma}{1-\sigma}}$, $\widetilde{\tau} \equiv \tau(f)^{\frac{1}{\sigma-1}}$ *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* χ_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 9 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.

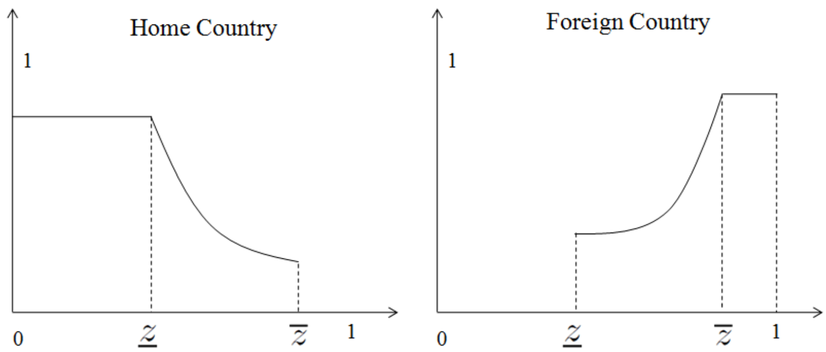


Figure 9: Export Probability or Export Intensity in Home Country and Foreign Country

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 σ, the elasticity of substitution between varieties due to the imperfect competition: the smaller σ 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 that 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.

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

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

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 tech-

nology 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 χ_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.

5 Quantitative Analysis

In this section, we conduct a quantitative analysis of the model economy. We treat China as Home and the rest of world as Foreign. We first calibrate and structurally estimate the model parameters. Then we examine the model prediction on the aggregate and disaggregate moments of firm production and exports. We also decompose the Ricardian comparative advantage, conduct welfare analysis run three counterfactual experiments.

5.1 Parameterization

We first parameterize the model. We calibrate a subset of the parameters based on the data statistics and the literature. We set $\sigma = 3.43$, which is taken from Broda and Weinstein (2006). The distribution parameter a is set to 2.76, following Defever and Riano (2014). We normalize the labor supply for China as 1. The ratio of foreign and home labor is calculated for both 1999 and 2007 using the data from the World Bank. Next, using the model result that the export intensity and export probability for each industry has a closed form $\gamma_z = \frac{f\chi_z}{1+f\chi_z}$, We calibrate $f = f_{zx}/f_z$ as the average of all sectors. [15] Lastly, we get the expenditure share function b(z) from the data. We match the firm data with the custom data for year 2000-2006 to infer the import data for each industry (industry 1 to 100) in 1999 and 2007. Then using the output data, we calculate the expenditure share of each industry for 1999 and 2007. The expenditure share function $b(z)$ in the preference is the linear interpolation using the 1999 and 2007 average of expenditure shares for the 100 industries in the data.

Table 5: Calibrated Parameters

[15] For each industry, $f = f_{zx}/f_z$ is estimated as $f = \frac{\gamma_z}{\chi_z(1-\gamma_z)}$. Figure in the appendix shows the distribution of sector-specific f from the data for 1999 and 2007.

parameters pre-chosen	value	source
σ	3.43	Broda & Weinstein (2006)
a	2.76	Defever & Riaño (2014)
L^*/L	$year_{1999}: 2.49$ $year_{2007}: 2.22$	World Bank
f	$year_{1999}: 1.00$ $year_{2007}: 1.77$	Industry average. Own calculation
$b(z)$		Linear interpolated from industry expenditure data. Own calculation

Notes: Estimate f as the average of $\frac{\gamma_z}{\chi_z(1-\gamma_z)}$ across all sectors. Expenditure function $b(z)$ the expenditure share function $b(z)$ in the preference is the linear interpolation using the 1999 and 2007 average of expenditure shares for the 100 industries in the data. Details are in the text.

Turning to the remaining parameters, we estimate $\{\frac{K^*}{K}, K/L, A, \lambda, \tau\}$ by minimizing the distance between the target moments from the data and from the model. The first target moment is the relative size of China and RoW. R^*/R is calculated using the ratio of manufacturing output for RoW and China using the data from the World Bank. Secondly, we target on the empirical feature on industry-level exporter share and capital intensity. The average exporter share for the capital intensive industry ($z \geq 1$) and labor intensive industry ($z \leq 1$) are chose as the estimation target moments. Lastly, average capital intensity and capital intensity for exporters are included as the target moments. We estimate the model parameters separately for year 1999 and 2007. The baseline results are reported in Table 7 and 8. Table 7 shows the the target moments calculated in the data and in the model based on the structural estimation for 1999 and 2007. The target moments are matched well. Table 8 reports the estimated parameters. First, China became more capital abundant in 2007. The relative capital stock compared to the RoW increased. The capital labor ratio in China almost doubled. Second, relative productivity between RoW and China for each industry according to our assumption that $\frac{A(z)}{A(z)^*} = \lambda A^z$. The estimation results imply that the relative productivity increased overtime relative to RoW. The TFP growth of China relative to RoW is labor-biased as shown by the reduction of A. The more labor intensive sectors growth enjoys a faster productivity growth relative to RoW. This result is consistent with the empirical finding in Figure 5. Lastly, trade liberalization decreased the variable trade cost τ from 2.95 to 2.09. [16]

[16]The magnitude of the variable trade cost is in line with the existing estimate in the literature.

	data	data	model	model
year	1999	2007	1999	2007
R^*/R	16.74	7.47	16.74	7.47
exporter share: $z \leq 0.5$	0.311	0.419	0.313	0.423
exporter share: $z \geq 0.5$	0.239	0.233	0.236	0.228
capital intensity for all firms	0.667	0.703	0.660	0.687
capital intensity for exporters	0.623	0.619	0.631	0.633

Table 7: Target Moments: data v.s. model

parameters	$\frac{K^*}{K}$	K/L	A	λ	τ
1999	3.45	0.93	1.25	0.132	2.95
2007	2.90	2.04	0.85	0.378	2.09

Table 8: Estimated Parameters

5.2 Results

With the estimated parameters in Table 8, we now examine the quantitative properties of the baseline model. Based on the estimated parameters, we can examine the model's performance in accounting for the cross-sectional distribution of output and exports as well as structural adjustment of production and exports from 1999 to 2007. First, Figure 10 shows that the model can account for the firm distribution across industries relatively well. The firm distribution shifts towards the capital intensive industries, as in the data. Figure 11 shows the share of exporters by industry. The model is able to generate the inverse relationship between the share of exporters in a industry with the capital share of this industry. The share of firms that export in labor intensive sectors increases, yet it decreases in the capital intensive industries in 2007.

Lastly, we compare some additional nontarget statistics calculated from the model simulation and the ones in the data. Table 9 shows the results. The baseline model can match the aggregate exporter share and aggregate export intensity relatively well. The aggregate export intensity in the model has a slightly higher level and shows a bigger increase compared to the data. Next, the magnitude of the capital income share in the model is close to that in the data. Yet the model does not generate the increase in the capital income share in the data. Karabarbounis and Neiman (2014) emphasizes the declining price of investment goods and relies on the calibration where the elasticity of substitution between capital and labor to be greater than 1 to explain the decline of labor income share. Chang *et al* (2015) introduced

Figure 10: Structural Adjustment of Production in the Model and in the Data

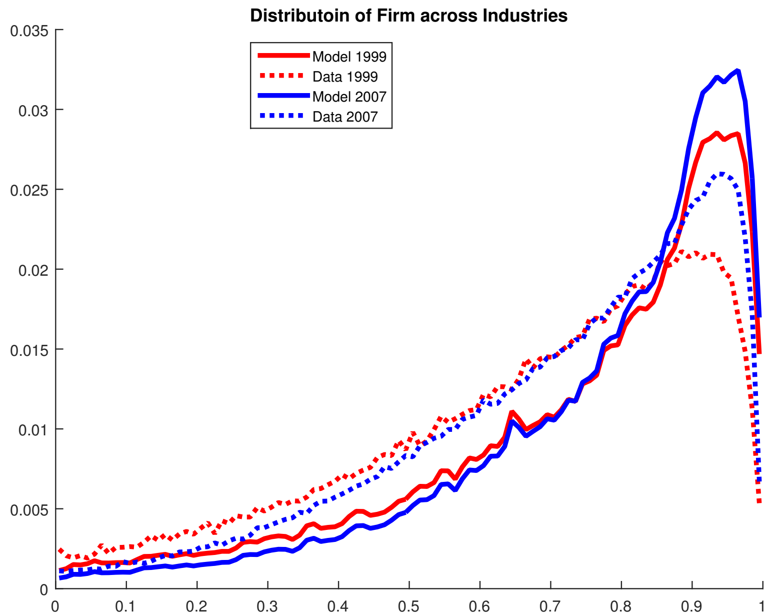
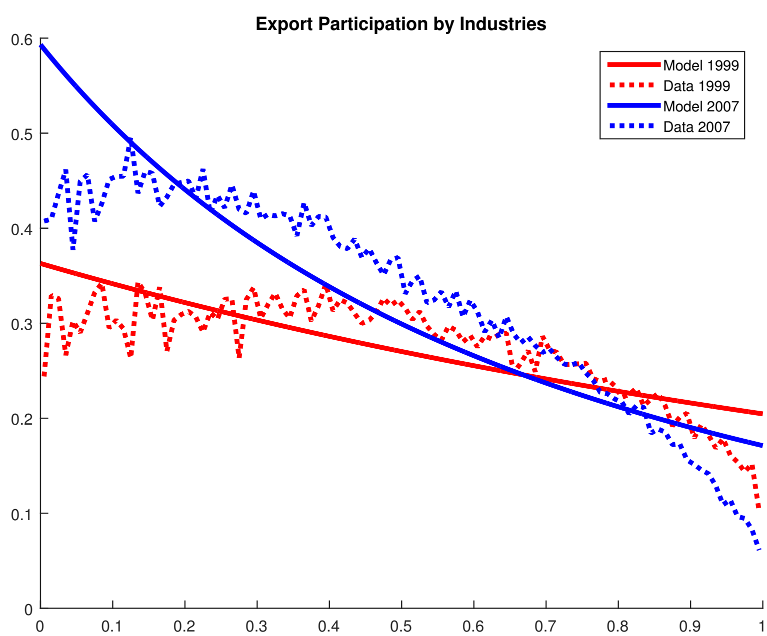


Figure 11: Structural Adjustment of Exports in the Model and in the Data



a credit channel into a model with light and heavy industry where the between-sector reallocation effect dominates to generate the declining labor income share. Our model does not feature a credit channel. We examine the relative wage rate in the model as discussed below. Yet with the Cobb-Douglas production function, the increase in the wage counteract with the reallocation of factors across industries and thus generate a slight increase in the labor income share.

	data	data	model	model
year	1999	2007	1999	2007
aggregate exporter share	0.252	0.248	0.240	0.230
aggregate export intensity	0.181	0.208	0.188	0.284
capital income share	0.761	0.830	0.790	0.768
wage RoW vs China: w*/w			6.43	2.90

Table 9: Non-target Moments: data v.s. model

There is no good estimation of wage for RoW, we instead compare the wage Growth for China and the whole world using data from ILO. According to ILO (2013, 2014), the world real wage growth between 1999 and 2007 is 20.3%. And from world bank data, we know that the world CPI grew by 33.5% during 1999-2007. Thus the nominal wage grew by 60.6% ((1+20.3%)(1+33.5%)-1). And from the estimation of ILO, the nominal wage of China growth by 168% percent during 1999-2007. Thus, we could have an estimate of relative wage growth for China and RoW :

$$\frac{w^W_{2007}/w^C_{2007}}{w^W_{1999}/w^C_{1999}} = \frac{w^W_{2007}}{w^W_{1999}}/\frac{w^C_{2007}}{w^C_{1999}} = (1+60.6\%)/(1+168\%) = 59.9\%$$

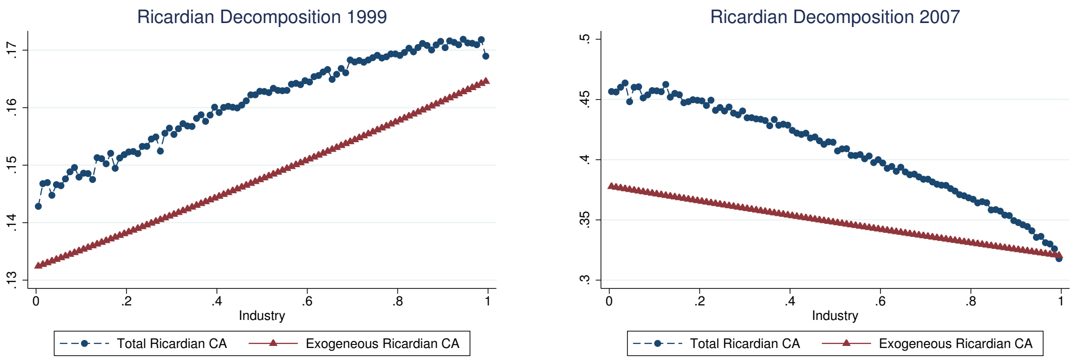
If we are willing to accept that the wage of RoW for China is very close to the whole world $w^W_{2007} = w^*_{2007}$ and $w^W_{1999} = w^*_{1999}$, the same calculation using the model estimate

$$\frac{w^*_{2007}/w_{2007}}{w^*_{1999}/w^C_{1999}} = \frac{2.90}{6.43} = 45.1\%$$

Thus our estimate of the relative wage growth of China to the rest of world from our model accounts a significant proportions of wage growth in China.

5.3 Decompose Ricardian Comparative advantage

With the estimated parameters, we can decompose Ricardian comparative advantage into an exogenous and endogenous components. This channel was first discovered in Bernard, Redding and Schott (2007) who conduct a numerical exercise. As far as we know, this is the first time that this channel is quantified based on a model structural estimation to the data. According to our model, the average TFP for each sector is



(a) (b)

Figure 12: Decomposition of Ricardian Comparative Advantage

$$\widehat{A(z)} = E_\varphi\{A(z)\varphi|\varphi > \overline{\varphi}_z\} = A(z)\widetilde{\varphi}_z$$

Thus the measured Ricardian Comparative advantage is

$$\frac{\widehat{A(z)}}{\widehat{A^*(z)}} = \frac{A(z)}{A^*(z)}\frac{\widetilde{\varphi}_z}{\widetilde{\varphi}^*_z}$$

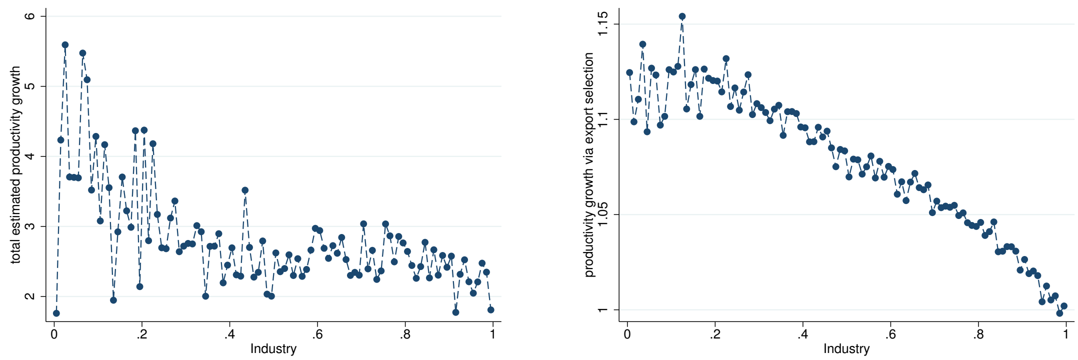
Given our functional assumptions, we can prove that

$$\frac{\widehat{A(z)}}{\widehat{A^*(z)}} = \underbrace{\lambda A^z}_{exo.}\underbrace{(\frac{1+f\chi_z}{1+f\chi^*_z})^{1/a}}_{endo.}$$

The first component is the exogenous Ricardian component which is estimated. The second component is the endogenous Ricardian component which is related to the observable χ_z , the estimated f, the given Pareto shape a and unobserved χ^*_z. As we can see, the higher the relative selection of home industry z relative to RoW (χ_z relative to χ^*_z), the higher the measured Ricardian comparative advantage. [17]

Figure 12 compares the results of the Ricardian comparative advantage decomposition for 1999 and 2007. In 1999, we estimate an exogenous Ricardian comparative advantage for China for the capital intensive sectors. In 2007, we estimate an exogenous Ricardian comparative advantage for China for the labor intensive sectors. In both case, the total Ricardian comparative advantage are amplified by the endogenous firm selection mechanism. This channel is stronger in 2007. Figure 13 shows the comparison of the endogenous Ricardian comparative advantage contributed by the firm selection for the two years.

[17] To quantify the endogenous component, we need to know the unobserved χ^*_z. Fortunately, the model implies that $\chi_z\chi^*_z = \widetilde{\tau}^{-2a}$. Thus we could measure χ^*_z as $\widetilde{\tau}^{-2a}\chi_z^{-1}$. Figure A2 shows the share of foreign exporters to China across industries. As we can see, there are more exporters to China from RoW in the more capital intensive sectors.



(a) (b)

Figure 14: Total Productivity Growth and Productivity Growth due to Exporter Selection

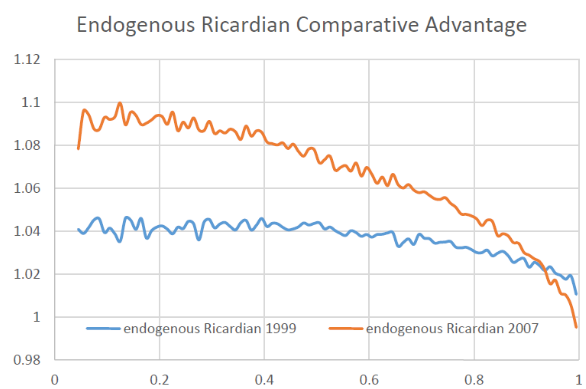


Figure 13: Endogenous Ricardian Comparative Advantage

With the estimated parameters, we could also estimate the contribution of endogenous selection to productivity growth in China. Let x and x' denote for variable x for current period and next period respectively. The sectoral productivity growth overtime could be decomposed as:

$$\frac{E(A(z)\varphi|\varphi \geq \bar{\varphi}_z)'}{E(A(z)\varphi|\varphi \geq \bar{\varphi}_z)} = \frac{A(z)'}{A(z)}\frac{\widehat{\varphi}'_z}{\widehat{\varphi}_z} = \frac{A(z)'}{A(z)}[\frac{(1+f'\chi'_z)}{1+f\chi_z}]^{\frac{1}{a}}$$

Since $\frac{E(A(z)\varphi|\varphi\geq\bar{\varphi}_z)'}{E(A(z)\varphi|\varphi\geq\bar{\varphi}_z)}$ and $[\frac{(1+f'\chi'_z)}{1+f\chi_z}]^{\frac{1}{a}}$ can both be estimated, we can infer $\frac{A(z)'}{A(z)}$ using the equation above and determine how much productivity growth is due to endogenous export selection. The left panel of Figure 14 plots $\frac{E(A(z)\varphi|\varphi\geq\bar{\varphi}_z)'}{E(A(z)\varphi|\varphi\geq\bar{\varphi}_z)}$ as estimated TFP by LP method, while the right panel plots $[\frac{(1+f'\chi'_z)}{1+f\chi_z}]^{\frac{1}{a}}$. We find the average estimated productivity growth across sectors is 181% while the growth of the exogenous sectoral component $\frac{A(z)'}{A(z)}$ is 159.8%. Hence export selection contributes about 11.7% $(1-\frac{159.8\%}{181\%})$ of the total productivity growth.

5.4 Counterfactual

In this session, we conduct several counterfactual experiments to investigate the driving forces behind the structural adjustments of Chinese production and export. The experiment is to replace the estimated parameters of 1999 by those of 2007, one subset of parameters at one time. The first experiment is to replace the technology parameters $\{A,\lambda\}$ in 1999 to the ones estimated for 2007. The second one replaces the trade cost parameter τ. The last one is the use the endowment parameters $\frac{K^*}{K}$ and K/L,. Figure 15 and 16 compare the implied firm distribution and exporter share in the counterfactuals to those in the baseline for 1999 and 2007. As we can see from the figures. Only the increase of $\frac{K}{L}$ significantly shifts the firm mass distribution towards the capital intensive industries. 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. We also compute the aggregate statistics in the counterfactuals as reported in Table 10. One interesting statistics to examine is the relative size of China to RoW. In the data, $R*/R$ reduces from 17 to 7, which shows the fast growth of the Chinese economy. The counterfactual experiments indicates that besides the change in endowment, the productivity growth plays an important role in the growth of output. This result is consistent with Zhu (2012) and Tombe and Zhu (2015).

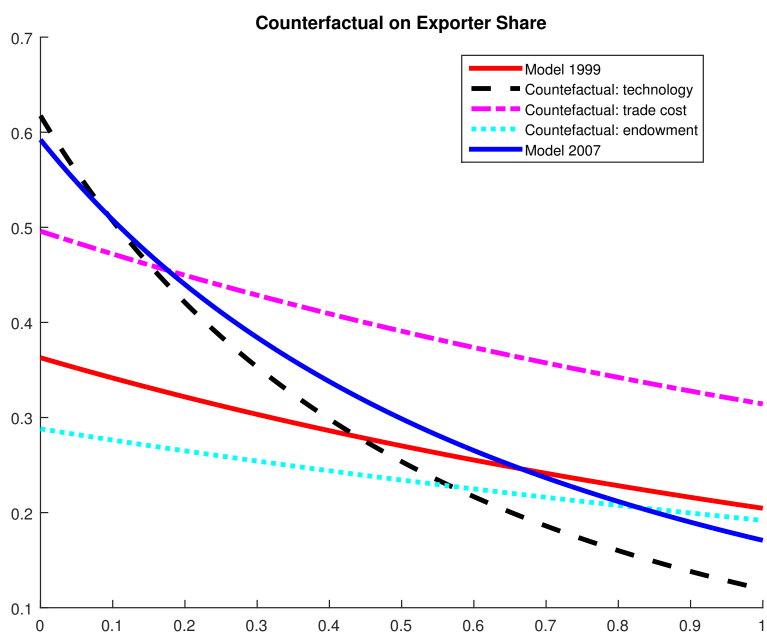


Figure 15: Exporter Participation in the Counterfactuals and Baseline

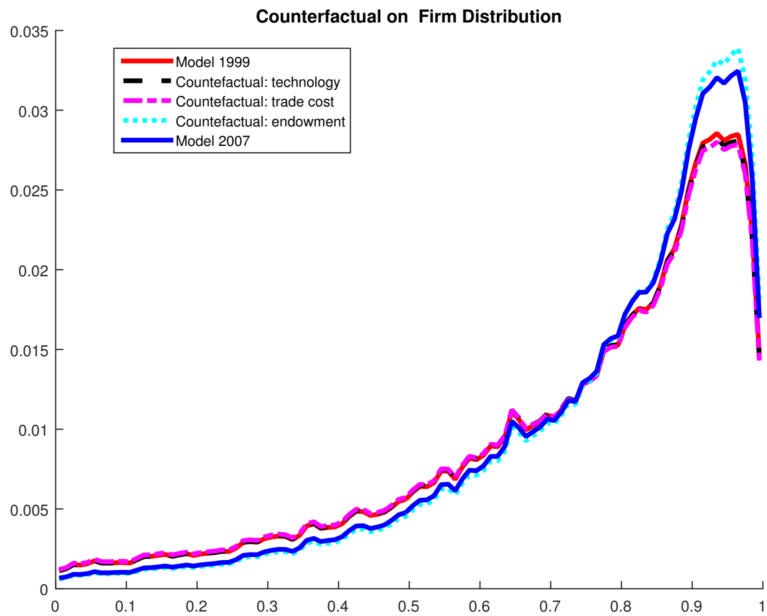


Figure 16: Firm Distribution in the Counterfactuals and Baseline

	model	A and λ	f and τ	endm't
year	1999	2007	2007	2007
R^*/R	16.74	9.17	16.09	13.98
exporter share: $z \leq 0.5$	0.314	0.402	0.440	0.261
exporter share: $z \geq 0.5$	0.236	0.177	0.350	0.212
capital intensity for all firms	0.659	0.658	0.655	0.694
capital intensity for exporters	0.631	0.567	0.633	0.678
aggregate exporter share	0.240	0.193	0.355	0.211
aggregate export intensity	0.189	0.147	0.379	0.173

Table 10: Aggregate Moments in the Counterfactuals and Baseline

5.5 Welfare Analysis

Lastly, we conduct the welfare analysis in the model. We compute welfare for China and RoW using the estimated $A(z)$ and $A(z)^*$. The Appendix contains the details about how we estimate the relative welfare as well as the change in welfare for China and RoW. First, we find that both China and RoW benefit from China's structural adjustment. The numbers below compute the increase in the level of welfare from 1999 to 2009.

$$\frac{\exp(U_{2007})}{\exp(U_{1999})} = 4.78$$
$$\frac{\exp(U^*_{2007})}{\exp(U^*_{1999})} = 1.98$$

This result implies that real consumption grows at 21.6% for China and 8.93% for RoW. To put that into perspective, the Real GDP per capita grows at 12.5% for China and 4.9% for RoW.

We can also compute the relative welfare of China to RoW for the two years as below.

$$\frac{\exp(U_{1999})}{\exp(U^*_{1999})} = 0.082$$
$$\frac{\exp(U_{2007})}{\exp(U^*_{2007})} = 0.199$$

In the data, the Real GDP per capita of China is 30.5% of RoW in 1999 and 53.1% in 2007 using data from the World Bank.

Lastly, we can conduct the welfare analysis in the counterfactual experiments and calculate the welfare changes from the baseline case for 1999 and the counterfactuals. Table 11 below reports $\frac{\exp(U^{CF}_{1999})}{\exp(U_{1999})}$ for China and RoW. The results show that the welfare gain are contributed by all the three sources of structural changes. The productivity growth and China's capital deepening account for most of the welfare improvement.

	A and λ	f and τ	endm't
China	2.29	1.026	2.386
RoW	1.119	1.008	2.156

Table 11: Change in Welfare in Counterfactuals from Baseline

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.[18] 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(**??**) , 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 (**??**), 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(**??**),(**??**) and $\frac{r(\widehat{\varphi}_z)}{r(\bar{\varphi}_z)} =$

[18] 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.

$(\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1}$,[19] 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 Λ_z is the productivity cut-off ratio given by (**??**). 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 (**??**) and (**??**), 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 $\widetilde{\tau} = \tau f^{\frac{1}{\sigma-1}}$.[20] From (**??**), we see that χ_z is a function of the factor price. From equation (**??**) 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 $\frac{P(z)}{P(z)^*} = \frac{\chi_z^{-1/a}}{\tau}(\frac{R^*}{fR})^{1/(\sigma-1)}$.So we can find that for those industries that both country produce:

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

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:

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

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 (**??**), 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.[21] So there are 4 equations for 4 unknowns, given reasonable parameters the equilibrium factor prices could be uniquely pinned down.■

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

[20]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.

[21]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:

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

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:

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

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 χ_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 χ_z increases such that χ_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 χ_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 χ_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 $[\underline{z}, \overline{z}]$,[22] 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 (**??**) with $\chi_{\underline{z}}$ and $\chi_{\overline{z}}$ at $\underline{z}$ and $\overline{z}$.

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

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

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

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

$\chi_{\underline{z}} = \frac{R^*}{R} > \chi_{\overline{z}} = \frac{R^*}{R}\frac{1}{\tau^{2a}}$.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 Λ_z (**??**) 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 (**??**) we have $P(z) = M_z^{\frac{1}{1-\sigma}} p_{zd}(\widehat{\varphi}_z)$.Firm mass for each industry is $M_z = \frac{b(z)R}{r(\widehat{\varphi}_z)} = \frac{b(z)R}{r(\bar{\varphi}_z)}(\frac{\bar{\varphi}_z}{\widehat{\varphi}_z})^{\sigma-1}$.So $\frac{P(z)}{P(z')} = (\frac{w}{r})^{(z'-z)/\rho}(\frac{b(z)}{b(z')})^{\frac{1}{1-\sigma}}\frac{A(z')\bar{\varphi}_{z'}}{A(z)\bar{\varphi}_z}$. Using (**??**) we have homogeneous cut-offs for all industries under autarky:$\bar{\varphi}_{z'} = \bar{\varphi}_z$.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 Λ_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 (**??**) which determines the two cut-offs, we see that the first term of left hand side is a decreasing function of $\bar{\varphi}_z$. Since Λ_z increases with z, it can be easily shown that $\bar{\varphi}_z' > 0$ or $\bar{\varphi}_z' = 0$ cannot maintain the equation, so it must be the case that $\bar{\varphi}_z' < 0$. Then the first term will increase as z increases. To maintain the equation the second term must decrease with z. So $\bar{\varphi}_{zx} = \Lambda_z \bar{\varphi}_z$ 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 γ_z is a monotonic increasing function of χ_z and should follow the same pattern.■

7.5 Proof of Proposition 5

Again from equation (**??**), 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 χ_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 χ_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 (**??**). 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 (**??**) we find that the factor demand within the intra-industry trade region are:

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

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.

7.7 Algorithm to conduct welfare analysis

Given the CES preference for each sector, the real consumption for each sector would be:

$$
Q(z) = \frac{R(z)}{P(z)}
$$

where R(z)=b(z)R is the sectoral revenue and P(z) is the price index of sector z. Hence the welfare of the representative household would be given by

$$
\begin{aligned}
U &= \int_0^1 b(z) \ln Q(z) dz \\
&= \int_0^1 b(z) \ln \frac{b(z)R}{P(z)} dz \\
&= \int_0^1 b(z) \ln b(z) dz + \ln R - \int_0^1 b(z) \ln P(z) dz
\end{aligned}
$$

where the first term is a constant intrinsic to the Cobb-Douglas preferences. The sectoral price index $P(z)$ is given by:

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

$P_z(\widehat{\varphi}_z)$ and $P_z(\widehat{\varphi}_{zx}^*)$ are the average price of domestic varieties and F.O.B price of foreign varieties respectively:

$$
\begin{aligned}
P_z(\widehat{\varphi}_z) &= \frac{\sigma}{\sigma - 1} \frac{r^z w^{1-z}}{A(z)\widehat{\varphi}_z} \\
P_z(\widehat{\varphi}_{zx}^*) &= \frac{\sigma}{\sigma - 1} \frac{r^{*z} w^{*1-z}}{A(z)^* \widehat{\varphi}_{zx}^*}
\end{aligned}
$$

thus:

$$
P(z) = \frac{\sigma}{\sigma - 1} \frac{1}{A(z)} [M_z (\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma} + \chi_z^* M_z^* (\tau \frac{r^{*z} w^{*1-z}}{\frac{A(z)^*}{A(z)} \widehat{\varphi}_{zx}^*})^{1-\sigma}]^{\frac{1}{1-\sigma}}.
$$

where $\frac{A(z)^*}{A(z)}$ is estimated from by the Ricardian Comparative Advantage as λA^z. If we only care about relative welfare, then for the case of no specialization (which is the case of the estimated results):

$$
\begin{aligned}
U^* - U &= \ln \frac{R^*}{R} + \int_0^1 b(z) \ln \frac{P(z)}{P(z)^*} dz \\
&= \ln \frac{R^*}{R} + \int_0^1 b(z) [\ln \frac{A(z)^*}{A(z)} + \frac{1}{1-\sigma} \ln \frac{M_z (\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma} + \chi_z^* M_z^* (\tau \frac{r^{*z} w^{*1-z}}{\frac{A(z)^*}{A(z)} \widehat{\varphi}_{zx}^*})^{1-\sigma}}{M_z^* (\frac{r^{*z} w^{*1-z}}{\frac{A(z)}{A^*(z)} \widehat{\varphi}_z^*})^{1-\sigma} + \chi_z M_z (\tau \frac{r^z w^{1-z}}{\widehat{\varphi}_{zx}})^{1-\sigma}}] dz
\end{aligned}
$$

This can be computed given the estimated results. However, if we want to the know the absolute level of U or U*, we need to know $A(z)$, the exogenous sectoral level productivity which is not directly observed. However, we could estimate the average TFP of firms within each sector which is given by

$$E(A(z)\varphi|\varphi \geq \bar{\varphi}_z) = A(z)\widehat{\varphi}_z$$

The left hand side could estimated from the data while $\widehat{\varphi}_z$ could be computed from:

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

so

$$A(z) = \frac{E(A(z)\varphi|\varphi \geq \bar{\varphi}_z)}{\widehat{\varphi}_z}.$$

Let x and x' denote for variable x for current period and next period respectively. The sectoral productivity growth overtime could be decomposed as:

$$\frac{E(A(z)\varphi|\varphi \geq \bar{\varphi}_z)'}{E(A(z)\varphi|\varphi \geq \bar{\varphi}_z)} = \frac{A(z)'}{A(z)}\frac{\widehat{\varphi}_z'}{\widehat{\varphi}_z} = \frac{A(z)'}{A(z)}[\frac{(1+f'\chi_z')}{1+f\chi_z}]^{\frac{1}{a}}$$

Since $\frac{E(A(z)\varphi|\varphi \geq \bar{\varphi}_z)'}{E(A(z)\varphi|\varphi \geq \bar{\varphi}_z)}$ and $[\frac{(1+f'\chi_z')}{1+f\chi_z}]^{\frac{1}{a}}$ could both be estimated, we could infer $\frac{A(z)'}{A(z)}$ using the equation above and determine how much productivity growth is due to endogonous reallocation.

We note that

$$\exp(U) = \exp(\int_0^1 b(z)\ln b(z)dz)\frac{R}{\exp(\int_0^1 b(z)\ln P(z)dz)}$$

is the real consumption.[23] Then the welfare as measured by real consumption is given by:

[23]Since we normalize L=1, R would be income per capita in China. For Rest of World, we divide R* by L* to normalize the income to be a per capita measure as well.

$$
\begin{aligned}
\widehat{U} &\equiv \exp(U'-U) = \exp(\ln \frac{R'}{R} - \int_0^1 b(z) \ln \frac{P(z)'}{P(z)} dz) \\
&= \frac{R'}{R} \exp(-\int_0^1 b(z) \ln \frac{P(z)'}{P(z)} dz) \\
&= \frac{R'}{R} \exp(\int_0^1 b(z)[\ln(\frac{A(z)'}{A(z)}) - \frac{1}{1-\sigma} \ln \frac{M_z'(\frac{r'^z w'^{1-z}}{\widehat{\varphi}_z'})^{1-\sigma} + \chi_z^{*'} M_z^{*\prime}(\tau' \frac{r^{*\prime z} w^{*\prime 1-z}}{\frac{A(z)^{*\prime}}{A(z)'} \widehat{\varphi}_{zx}^{*\prime}})^{1-\sigma}}{M_z(\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma} + \chi_z^* M_z^*(\tau \frac{r^{*z} w^{*1-z}}{\frac{A(z)^*}{A(z)} \widehat{\varphi}_{zx}^*})^{1-\sigma}}] dz) \\
&= \frac{R'}{R} \exp\{\int_0^1 b(z) \ln(\frac{A(z)'}{A(z)}) dz\} \exp(\int_0^1 b(z)[\frac{1}{\sigma-1} \ln \frac{M_z'(\frac{r'^z w'^{1-z}}{\widehat{\varphi}_z'})^{1-\sigma}}{M_z(\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma}} \frac{1 + \frac{\chi_z^{*'} M_z^{*\prime}(\tau' \frac{r^{*\prime z} w^{*\prime 1-z}}{\frac{A(z)^{*\prime}}{A(z)'} \widehat{\varphi}_{zx}^{*\prime}})^{1-\sigma}}{M_z'(\frac{r'^z w'^{1-z}}{\widehat{\varphi}_z'})^{1-\sigma}}}{1 + \frac{\chi_z^* M_z^*(\tau \frac{r^{*z} w^{*1-z}}{\frac{A(z)^*}{A(z)} \widehat{\varphi}_{zx}^*})^{1-\sigma}}{M_z(\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma}}}] dz) \\
&= \frac{R'}{R} \exp\{\int_0^1 b(z) \ln(\frac{A(z)'}{A(z)}) dz\} \exp(\int_0^1 \frac{b(z)}{\sigma-1} \ln \frac{M_z'(\frac{r'^z w'^{1-z}}{\widehat{\varphi}_z'})^{1-\sigma}}{M_z(\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma}} \frac{M_z^{*\prime}(\tau' \frac{r^{*\prime z} w^{*\prime 1-z}}{\widehat{\varphi}_{zx}^{*\prime}})^{1-\sigma}}{M_z^*(\tau \frac{r^{*z} w^{*1-z}}{\widehat{\varphi}_{zx}^*})^{1-\sigma}} \cdot \ldots \\
&\quad \ldots \cdot \frac{(\frac{A(z)^{*\prime}}{A(z)'})^{\sigma-1}}{(\frac{A(z)^*}{A(z)})^{\sigma-1}} (\frac{A(z)^{*\prime}}{A(z)^*})^{1-\sigma} \frac{\frac{A(z)'^{\sigma-1}}{M_z^{*\prime}(\tau' \frac{r^{*\prime z} w^{*\prime 1-z}}{\widehat{\varphi}_{zx}^{*\prime}})^{1-\sigma}} + \frac{\chi_z^{*'} A(z)^{*\prime \sigma-1}}{M_z'(\frac{r'^z w'^{1-z}}{\widehat{\varphi}_z'})^{1-\sigma}}}{\frac{A(z)^{\sigma-1}}{M_z^*(\tau \frac{r^{*z} w^{*1-z}}{\widehat{\varphi}_{zx}^*})^{1-\sigma}} + \frac{\chi_z^* A(z)^{*\sigma-1}}{M_z(\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma}}}] dz) \\
&= \underbrace{\frac{R'}{R} \exp\{\int_0^1 b(z)(\ln \frac{A(z)'}{A(z)} - \ln \frac{A(z)^{*\prime}}{A(z)^*}) dz\}}_{Sectoral\ productivity} \exp(\int_0^1 b(z)[\underbrace{\frac{\ln \frac{M_z'}{M_z} \frac{M_z^{*\prime}}{M_z^*}}{\sigma-1}}_{Krugman.love.of.varieties} - \underbrace{\ln \frac{r'^z w'^{1-z}}{r^z w^{1-z}} \frac{r^{*\prime z} w^{*\prime 1-z}}{r^{*z} w^{*1-z}}}_{HO} \\
&\quad + \underbrace{\ln \frac{\frac{A(z)^{*\prime}}{A(z)'}}{\frac{A(z)^*}{A(z)}}}_{Ricardian} + \underbrace{\ln \frac{\widehat{\varphi}_z' \widehat{\varphi}_{zx}^{*\prime}}{\widehat{\varphi}_z \widehat{\varphi}_{zx}^*}}_{Melitz} - \underbrace{\ln(\frac{\tau'}{\tau})}_{trade\ \mathrm{cost}} + \ldots \\
&\quad \ldots + \frac{\frac{A(z)'^{\sigma-1}}{M_z^{*\prime}(\tau' \frac{r^{*\prime z} w^{*\prime 1-z}}{\widehat{\varphi}_{zx}^{*\prime}})^{1-\sigma}} + \frac{\chi_z^{*'} A(z)^{*\prime \sigma-1}}{M_z'(\frac{r'^z w'^{1-z}}{\widehat{\varphi}_z'})^{1-\sigma}}}{\frac{A(z)^{\sigma-1}}{M_z^*(\tau \frac{r^{*z} w^{*1-z}}{\widehat{\varphi}_{zx}^*})^{1-\sigma}} + \frac{\chi_z^* A(z)^{*\sigma-1}}{M_z(\frac{r^z w^{1-z}}{\widehat{\varphi}_z})^{1-\sigma}}}] dz
\end{aligned}
$$

Computation results

We first estimate A(z)

$$A(z) = \frac{E(A(z)\varphi | \varphi \geq \bar{\varphi}_z)}{\widehat{\varphi}_z}$$

where $\widehat{\varphi}_z$ is approximated by $(1 + f\chi_z)^{\frac{1}{a}}$.

Then we infer A(z)* by

$$A(z)^* = \frac{A(z)}{\lambda A^z}$$

With the estimated A(z) and A(z)*, we could compute the welfare for China and RoW.

7.8 Tables and Figures

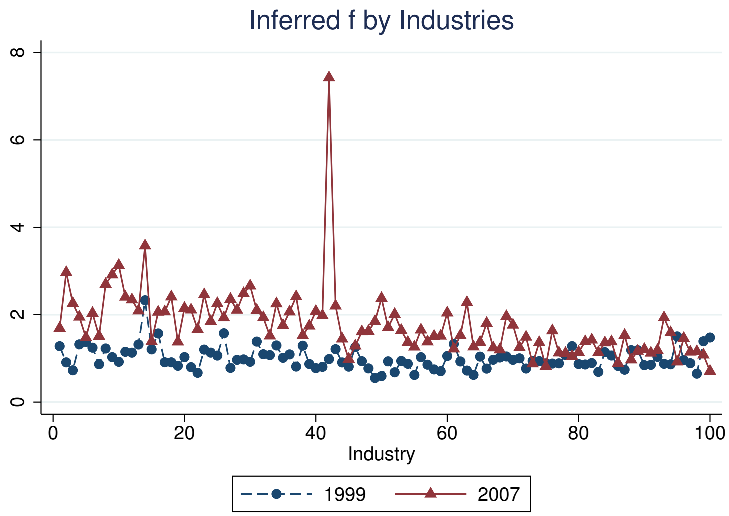

Figure 15: Structural Adjustment of Production and Exports in the Model

Table 1: Capital Share of Exporters and Non-Exporters in 2007

2-digit industry code	description	capital share of non-exporters		capital share of exporters	
		mean	std	mean	std
13	Processing of Foods	0.83	0.18	0.76	0.21
14	Manufacturing of Foods	0.76	0.20	0.71	0.22
15	Manufacture of Beverages	0.80	0.18	0.78	0.17
16	Manufacture of Tobacco	0.74	0.19	0.90	0.11
17	Manufacture of Textile	0.72	0.20	0.63	0.22
18	Manufacture of Apparel, Footwear & Caps	0.60	0.24	0.51	0.24
19	Manufacture of Leather, Fur, & Feather	0.64	0.25	0.53	0.23
20	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm & Straw Products	0.74	0.20	0.69	0.21
21	Manufacture of Furniture	0.69	0.23	0.56	0.23
22	Manufacture of Paper & Paper Products	0.73	0.19	0.65	0.22
23	Printing, Reproduction of Recording Media	0.67	0.21	0.59	0.22
24	Manufacture of Articles For Culture, Education & Sport Activities	0.64	0.23	0.54	0.23
25	Processing of Petroleum, Coking, &Fuel	0.85	0.16	0.78	0.20
26	Manufacture of Raw Chemical Materials	0.79	0.19	0.75	0.19
27	Manufacture of Medicines	0.78	0.19	0.74	0.19
28	Manufacture of Chemical Fibers	0.80	0.17	0.77	0.20
29	Manufacture of Rubber	0.73	0.21	0.61	0.23
30	Manufacture of Plastics	0.72	0.21	0.60	0.23
31	Manufacture of Non-metallic Mineral goods	0.74	0.20	0.63	0.22
32	Smelting & Pressing of Ferrous Metals	0.82	0.17	0.82	0.15
33	Smelting & Pressing of Non-ferrous Metals	0.82	0.18	0.78	0.19
34	Manufacture of Metal Products	0.71	0.21	0.61	0.21
35	Manufacture of General Purpose Machinery	0.72	0.20	0.65	0.20
36	Manufacture of Special Purpose Machinery	0.72	0.21	0.63	0.21
37	Manufacture of Transport Equipment	0.70	0.21	0.65	0.21
39	Electrical Machinery & Equipment	0.73	0.21	0.61	0.23
40	Computers & Other Electronic Equipment	0.65	0.23	0.58	0.25
41	Manufacture of Measuring Instruments & Machinery for Cultural Activity & Office Work	0.69	0.22	0.56	0.23
42	Manufacture of Artwork	0.66	0.23	0.57	0.24
43	Recycling and Disposal of Waste	0.79	0.21	0.81	0.18
	All Industries	0.74	0.21	0.62	0.23