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

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Abstract

We document the patterns of structural adjustments in Chinese manufacturing production and exports: the production structures 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 (1977, 1980) where both Ricardian and Heckscher-Ohlin forces are at play. We structurally estimate the model by GMM. The estimation and counterfactual simulations show that the adjustment in production structures is mainly driven by capital deepening while the adjustment in export participation is driven by technology biased to labor intensive sectors and the trade liberalization.

Key Words: Structural Adjustments, Heterogeneous Firm, Comparative Advantage

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1 Introduction

In this paper we study interactions between changes in firm's distribution within a sector and resource reallocations across sectors. Using the firm level data in China from 1999 to 2007, we document seemingly puzzling data patterns: comparing the data in 2007 with that in 1999, productions became more capital intensive. On the other hand, however, exports became more labor intensive.

Following Schott (2003), we define industries as "HO aggregate" and regroup firms into 100 industries according to their capital share. Comparing the data in 2007 with that in 1999, the share of firm numbers (the number of firms in an industry/total number of firms), the share of employment (industrial employment/total employment) and the share of output (industrial output/total output, output measured by value added or sales), all increase in capital intensive industries but decline in labor intensive industries. However, across industries, the share of exporting firm numbers (the number of exporting firms in an industry/total number of exporting firms) increases in labor intensive industries but decreases in capital intensive industries. Within an industry, the share of exporting firms (number of exporting firms/number of total firms in the industry) increases in labor intensive industries but decreases in capital intensive industries; firms in labor intensive industries export a larger fraction of their total output while firms in capital intensive industries export a smaller fraction of their total output.

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

In the baseline model, we assume the Ricardian comparative advantage are in line with the Heckscher-Ohlin comparative advantage. We show that in equilibrium, there are two cut-off industries: the most capital intensive industries and labor intensive industries are specialized by the capital abundant country and labor abundant country respectively; for industries with intermediate factor intensities, both country produce. In industries that a country specialize, we show that the export participation (measured by export probability or export intensity) remain constant and does not vary with industrial factor intensity. In industries that both countries produce, the export participation decreases with capital intensity in the labor abundant country while it increases with capital intensity in the capital abundant country. The Chinese data supports the theoretical predictions on labor abundant country.

Using the framework, we find the numerical solution and perform comparative statics on capital deepening, trade liberalization and technology changes. We find that capital deepening and technology changes make productions and exports become more capital intensive in a labor abundant country: it produces and exports more in capital intensive industries and *vice versa* in labor intensive industries. However, trade liberalization makes productions and exports more labor intensive since its comparative advantage is strengthened. Finally, reduction in home bias increases export participation of all industries. Given that we

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

observe Chinese production became more capital intensive while export participation of labor intensive and capital intensive moves in different directions, none of these forces alone could explain what we observe in the Chinese data.

To find out the driving forces behind the structural adjusments, we structurally estimate the parameters of the model for both years by GMM. Using the structural relationships between export participation, firm mass distribution, relative size of economy and the deep parameters of the model, we estimate the key parameters of interests: endowment, trade cost, technology and the extent of home bias preference. The estimation result indicates the following main findings: capital labor ratio almost trippled, technology improved sinificantly and favored more labor intensive industries, trade libralization mostly came from reduction in fixed cost of export for China, and reduction in preference for home goods between 1999 and 2007. By running counterfactual simulations that replace year 1999 parameters with year 2007 parameters, we find changes in endowments is the main driving force that shift production towards more capital intensive sectors. Changes in parameters governing trade costs, technology and home bias preference contribute a little to the adjustments in production pattern. While changes of all the parameters affect the export participation, changes in technology is the main driving force behind the adjustment of export participation.

Our paper makes several contributions to the literature. Firstly, we contribute to the booming literature of structural approach in interntional trade (Eaton and Kortum 2002, Anderson and van Wincoop 2003 and among many others). The closest paper to ours is Eaton, Kortum and Kramarz (2011, hence EKK) in which they extend the standard trade model of heterogeneous firm with multiple countries and industries.[2] They find the standard trade model fail to explain the facts from the French data, i.e., exporters sell too much in home market and there are too many exporters selling small amounts in a typical destination. We find another fact that standard trade model fail to explain: the estimated model implies China is much larger than Rest of World (RoW) in terms of GDP, which is on the contrary to the data. EKK incorporate market access cost (Arkolakis 2010) to standard trade model to explain the previous facts. Instead we generalize the standard trade model with home bias preference. The model remains as simple as the standard trade model to solve and is able to reconcile the model with data.[3] Secondly, similar to Morrow (2010), we also structrually the estimate Ricardian and Heckscher-Ohlin comparative advantage at the same time. The main difference is that we fully estimate the deep parameters of the model and could discuss the counterfactual implication. Thirdly, our paper is related to the recent literature studying the effect of evolving comparative advantages. While Costinot et. al (forthcoming) and Levchenko and Zhang (2013) focus on the welfare implication of evolving comparative advantages across countries, this paper studies how evolving comparative advantage could shape the production and trade structure of one country, taking into account changes in trade costs and preference. Finally on the theory side, there are several papers that incorporate the heterogeneous firm with the DFS model. Lu (2010) incorporates heterogeneous firm into a Heckscher-Ohlin model with multiple industries based on EKK. Okubo (2009) and Fan et. al (2011) combine DFS of Ricardian with Melitz typed heterogeneous firm. This paper is different in that we consider Ricardian and Heckscher-Ohlin model jointly with home bias preference.

The following parts of the paper are organized as follows. Section 2 presents the data patterns we observed

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

[3] The estimated standard trade model implies that the size of RoW is less than half of China while the estimated model with home bias preference implies that RoW is more than 5 times as big as China. In the data, RoW is about 7-13 times as big as China between 1999 and 2007.

from the Chinese firm level data. Section 3 develops the model and section 4 is equilibrium analysis. Section 5 structurally estimates the model and runs counterfactual simulation. Section 6 concludes.

2 Motivating Evidences

In this section we present several stylized facts about the adjustments in production and trade structure over time. The data we use is the Chinese Annual Industrial Survey. It covers all State Own Enterprise (SOE) and non-SOEs with sales higher than 5 million RMB Yuan. The dataset provides information on balance sheet, profit and loss, cash flow statements of firms, and firm's identification, ownership, export, employment, capital stock, etc. Our focus is on manufacturing firms (thus exclude utility and mining firms) which contribute more than 90% of the total Chinese manufacturing exports in aggregate trade data. To clean the data, we follow Brandt *et al* (2011) and drop firms with missing, zero, or negative capital stock, export and value added, and only include firms with employment larger than 8. And we also drop firms with capital intensity larger than one or less than zero where capital share is defined as: $1 - \frac{wage}{value_added}$.[4] Since the focus of this paper are changes overtime, we look at data of year 1999 and 2007.[5] The Statistics Summary of the data after cleaning is shown in Table 1.

Table 1: 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.

As we mentioned earlier, industries are defined as "HO aggregate" following Schott (2003). That is, we put all firms in the same year together and then regroup them according to their capital share. 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.

Schott (2003) looks at product level variations, while we investigate variations at the firm level. From Table 2, we find there are indeed large variations of capital share within the 2 digit Chinese Industry

[4] 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.

[5] 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.

Figure 1: *Firm Number Share and Employment Share*

Figure 2: *Value Added Share and Sales Share*

Classification (CIC) of industry and significant difference in capital intensity between exporters and non-exporters. Interestingly, we find that except for Tobacco (industry 16) and Recycling (industry 43), capital share is significantly lower for exporters.[6] This is different from Alvarez and López (2005)'s finding that Chilean exporters are more capital intensive than non-exporters. It is in line with Bernard *et al's* (2007b) speculation that exporters in developing countries should be more labor intensive than non-exporters given their comparative advantage in labor intensive goods.[7]

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

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

[7] 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.

2.1 Production Structures

This subsection describes how the overall production structures change between 1999 and 2007. In the figures below, industries are defined according to capital intensities of firms and we regroup firms into 100 industries. The horizontal axis of the graphs is industry index and higher numbers correspond to higher capital share.

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

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

A direct evidence is from Table 1, the average of capital share is 0.669 in 1999 and 0.707 in 2007. Thus we do see the aggregate production became more capital intensive.[8] Other than this piece of evidence, there are several others using different measures. We firstly look at number of firms and labor employment for each industry. As can be seen from Figure 1, during 1999-2007, more firms are producing capital intensive industries while less firms are producing in labor intensive industries. At the same time, workers are moving

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

Figure 3: *Labor Productivity*

out of labor intensive industries into more capital intensive industries. Thus there is a significant reallocation of resources towards capital intensive industries. In terms of output, from Figure 2, we find that firms in capital intensive industries are accounting for larger and larger fraction of value added and sales. 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. Clearly, we find the production structures become more capital intensive in 2007.

Table 3: Structural Adjustment of Production

Variable	firm number share	employment share	value added share	sales share
2007	0.648	0.585	0.860	0.860
1999	0.588	0.459	0.744	0.706
Difference	0.061	0.126	0.116	0.154

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

We also compare the labor productivity between the two years in Figure 3. Labor productivity is in terms of real value added per worker so as to make it comparable over years. Real value added is calculated using the input and output pricing index constructed by Brandt *et al* (2011). From the left panel, the labor productivity is higher for capital intensive industries and it increases from 1999 to 2007 for all industries. From the right panel, we find that in general labor productivity increases more in labor intensive industries. We also try estimate firm productivity using TFP measure[9], similar result holds.

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

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

Figure 4: *Export Share in Terms of Firm Number and Value*

Figure 5: Export Participation

2.2 Trade Structure

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

Fact 4: *From 1999 to 2007, the exporting number share became more labor intensive.*

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

In Figure 4, we plot the export share in terms of firm number and value of export. From the left panel, we find the number share of exporters *decrease* in capital intensive industries and increase in labor intensive industries in general. From the right panel, we find the value of export share is more or less the same for both years. In Figure 5, we focus on how export changes *within* each industries. From the left panel, we find the proportion of exporters in 2007 is higher than 1999 in labor intensive industries while the opposite is true for capital intensive industries. In terms of sales exported, we find it increases in general over time but more significantly for labor intensive industries. In fact, for the most capital intensive ones, it even decreases.

The messages from Figure 4 and Figure 5 could also be summarized by Table 4. By comparing with it with Table 3, we find a puzzling observation here**.** The production clearly became more capital intensive in 2007 than 1999 (if measured by export value share, the difference is +0.013 between 2007 and 1999 while

the difference of total sales share +0.154 in Table 3). However, export did not become as capital intensive as production does. In fact there is evidence that it become more labor intensive (if measure by export number share difference, it is -0.018 in Table 4 versus firm number share difference +0.061 in Table 3). As we have said in the introduction, it is puzzling in the sense that from standard trade theory, we would expect the export also become more capital intensive when the production becomes more capital intensive.

Our finding that Chinese export didn't become more capital intensive seems to contradict 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 export value share or exporter number share in capital intensive industries also increase. If more firms became exporters in labor intensive and their export value increased more, the overall Chinese export could indeed became more labor intensive. In fact, Schott (2008) finds that though Chinese export overlaps more and more with OECD countries, it also becomes cheaper in terms of unit value.

Table 4: Structural Adjustment of Export

Variable	exporter number share	export value share	average fraction of exporter
2007	0.487	0.667	0.194
1999	0.505	0.654	0.217
Difference	-0.018	0.013	-0.023

Notes: The numbers in the 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).

3 Model Set Up

Our model incorporates heterogenous firm (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 lost of generality, we assume that home country is labor abundant, that is: $L/K > L^*/K^*$, and has Ricardian comparative advantage in more labor intensive industries. [10] There is a continuum of industries z on the interval of $[0, 1]$. The index z is also industry capital intensity and higher z stands for higher capital intensity. Each industry is inhabited by heterogeneous firms which produce different varieties of goods and sell in a market with monopolistic competition.

3.1 Demand Side

The economy is inhabited by a continuum of identical and infinitely lived households that can be aggregated into a representative household. The representative household's preference over different goods is summarized

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

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 consumption of individual varieties $q_z(\omega)$ given by the following CES aggregation. $P(z)$ is the dual price index of $Q(z)$ defined over price of different varieties $p_z(\omega)$.

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

Ω_z and Ω_z^* are the varieties available for industry z from home and foreign and $0 < \rho \leq 1$ so that the elasticity of substitution $\sigma = \frac{1}{1-\rho} > 1$. Here $\gamma \in [0,1]$ captures the extent of home bias. If $\gamma = \frac{1}{2}$, there is no home bias. There is home bias if $\gamma > \frac{1}{2}$ and foreign bias if $\gamma < \frac{1}{2}$. This is standard assumption in the international macro literature, e.g., Coeurdacier and Rey (2013).[11] The aggregates can be used to derive the demand function for individual varieties.

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

3.2 Production

Following the standard assumptions of Melitz(2003), we assume that production incurs a fixed cost each period which is the same for all firms in the same industry and the variable cost varies with firm productivity. Firm productivity is denoted as $A(z)\varphi$ where $A(z)$ is a common component for all firms in industry z while φ, the heterogeneous productivity, is drawn randomly by firms from a distribution $G(\varphi)$. Following Romalis (2004) and Bernard *et al* (2007a), we assume that fixed cost are paid using capital and labor with factor intensity the same as production in that industry. To be specific, we assume that the total cost function looks like:

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

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

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

Here λ is a parameter capturing the absolute advantage of home country: higher λ means home has higher relative industry specific productivity for all industries. And A is parameter capturing the comparative advantage. If $A > 1$, home country is relatively more productive in more capital intensive industries and has Ricardian comparative advantages in these industries. If $A = 1$, then $\varepsilon(z)$ doesn't vary with z and there is

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

no role for Ricardian comparative advantage. Given our assumption that home has Ricardian comparative advantage in more labor intensive industries, we have $0 < A < 1$.

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

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

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

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

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

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

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

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

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

So the total profit is given by:

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

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

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

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

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

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

$\Lambda_z > 1$ implies selection into export market: only the most productive firms export. The empirical

Figure 6: Production and Trade Pattern

literature strongly supports selection into market and we focus on parameters where exporters are always more productive following Melitz (2003) and Bernard *et al* (2007a).[12] Then the decision of firms on production and export are shown in Figure 6**.** For all firms that enter each period, a fraction of $G(\overline{\varphi}_z)$ exit upon entry since they do not earn positive profit at all. And $1-G(\overline{\varphi}_{zx})$ 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 $\overline{\varphi}_{zx}$and $\overline{\varphi}_z$, they only sell in domestic market. So the *ex ante* probability of exporting conditional on successful entry is

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

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 steady state equilibrium, the mass of firms that enter must equal to the firms that die:

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

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

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

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

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

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

Combining with the zero profit condition (3.9), (3.10), we have (3.16) below which determines the two productivity cut-offs with the equation (3.11).

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

3.4 Market Clearing

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

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

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

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

The factor market clearing condition is:

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

Before we proceed, there assumptions are made here so as 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:[13]

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

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

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

3.5 Equilibrium

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

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

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

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

(c) Factor market clearing condition (3.19);

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

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

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

Proof. *See Appendix.*■

4 Equilibrium Analysis

The presence of trade cost, multiple factors, heterogeneous firm, 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 find the numerical solution and solve the equilibrium factor prices and other endogenous variables.

4.1 Analytical Properties

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

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

Proof. *See Appendix.*■

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

In the classical DFS model with zero transportation costs, factor price equalization (FPE) prevails and the geographic patterns of production and trade are not determined when the two countries are not too different. With costly trade and departure from FPE, we are able to determine the pattern of production. This is the property of Romalis model (2004) which we are able to inherit. However, his assumption of homogeneous firm leads to the stark feature that all firms export. With firm heterogeneity coming in, we have the following proposition 3 and 4 on the variation of export participation across industries.

Figure 7: *Productivity Cutoffs and Firm Decision*

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

Proposition 3 *(a)Within* ($\underline{z}$, $\overline{z}$), *the zero profit productivity cut-off decreases with capital intensity while the costly trade zero profit cut-off increases with capital intensity in home country and vice versa 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 industries case, the productivity cut-offs will be closer in the comparative advantage industry. We generalize their result and an important extension is that the cut-offs do not vary with factor intensity in industries that countries specialize. And the nice property of this proposition is that home country and foreign country are symmetric.

Proposition 4 *(a)Within the specialization zone* $[0, \underline{z}]$ *and* $[z, 1]$,*the export probability* χ_z *is a constant. For the industries that both country 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. To be specific, we have*

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

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

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

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

(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. And 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* $\ln(\frac{r/w}{r^*/w^*})$. And the magnitude of the HO Comparative Advantage depends on σ, the elasticity of substitution between varieties, or say imperfect competition: the smaller σ is, the larger that different 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 more powerful. If Ricardian Comparative Advantage is so strong that it overturns the Heckscher-Ohlin Advantage, then home country will export more in more capital intensive industries.

Fan *et al* (2011) incorporate Melitz (2003) into the DFS model (1977) with Ricardian Comparative Advantage and get very similar prediction on export participation. The key insight from Melitz model is that within sector resource reallocation generates productivity gain. Bernard et al (2007) find that the strength of reallocation is stronger in the industry uses more of the country's abundant factor. Such heterogeneous reallocation will generate endogenous Ricardian Comparative Advantage. From the last paragraph, 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 of firm specific productivity in each industry is*

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

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 Recardian Comparative Advantage could be amplified by the endogenous technology difference generated by reallocation if the Heckscher-Ohlin Comparative Advantage is in line with it, or else

it is dampened.

Proof. *See Appendix.*■

Conclusion (a) of Proposition 5 enables us to decompose industrial average productivity. A(z) is industrial specific producibility 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 with the result of Proposition 4, conclusion (b) is very straight forward: 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 z, then the overall average industry productivity ratio $\frac{A(z)\widehat{\varphi}_z}{A^*(z)\widehat{\varphi}_z^*}$ could become a decreasing function of z if the reallocation effect is very strong. If this is the case then the Ricardian comparative advantage is dampened. Otherwise, it is amplified.

4.2 Numerical Solution

In this subsection, we find the numerical solution to the model and discuss other equilibrium properties of the model. The algorithm is in Appendix 6 and the parameters chosen are in Table 5. The equilibrium factor prices and cut-off industries are in table 6. It is easy to see that $\frac{r/w}{r^*/w^*} = 1.165 > 1$. Also $A < 1$, thus we would expect $\frac{\partial \chi_z}{\partial z} < 0$ between ($\underline{z}$,$\overline{z}$). From Figure 10, we find this is exactly the case: export probability and intensity first stays constant and then decreases with capital intensity, the opposite is true for foreign country. We also find that industrial output and industrial export follow the same pattern: countries tend to produce and export more in its comparative advantage industries. Firm mass follows similar patterns but it doesn't stay constant in industries that countries specialize. We should point out that firm mass, industrial output and export also depend on household's expenditure share b(z): for industries with higher demand, firm mass industrial output and export will also be higher. Since we normalize b(z) to be 1 for all industries, this channel is shut down.

Table 5: Parameters used in simulation

Variables	meaning	value
K	home capital stock	100
L	home labor stock	300
K^*	foreign capital stock	300
L^*	foreign labor stock	100
f	relative fixed cost of export $\frac{f_{zx}}{f_z}$	6.5
$\widetilde{f}$	relative fixed cost of entry $\frac{f_{ez}}{f_z}$	20*f
τ	icebery cost	1.05
a	shapre parameter of Pareto Distribution	3.8
θ	lower bound of Pareto Distribution	0.2
δ	exogeneous death probability of firms	0.025
σ	elasticity of substitution	3.4
A	strength of comparative advantage	0.5
λ	strength of absolute advantage	1
γ	home bias	$\frac{1}{2}$

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

Table 6: Equilibrium Factor Prices and Cut-off Industry

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

Figure 10: Baseline Simulation

4.3 Comparative Statics

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

4.3.1 Capital Deepening

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

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

Figure 11: Capital Deepening

4.3.2 Technology Changes

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

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

Figure 12: Comparative Advantage: A

For brevity, we do not put the comparative statics on trade costs and home bias preference. For trade liberalization, if we decrease the fixed cost, export increases in all sectors and production moves towards more labor intensive sectors in home country. And we get similar results if we decrease the variable trade costs. For the home bias preference, if we decrease the extent of home bias, export increases in all industries and production also moves towards more labor intensive industries. In summary, none of these forces alone could explain the data pattern that we observe. Thus we need to estimate the model and understand the

movement of each force overtime. Then we could do counterfactual simulation to distangle the effect of each forces. This is what we do in next section.

5 Estimation

5.1 Strategy

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

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

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

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

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

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

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

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

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

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

5.2 Results

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

Table 7: Estimated Parameters

Year	$\frac{L^*}{L}$	$\frac{K^*}{K}$	$\frac{K}{L}$	A	λ	a	τ	f	f_z	γ
1999	2.28	2.18	0.749	0.614	0.491	2.02	1.64	0.686	0.771	0.856
	(0.0281)	(0.0256)	(0.007)	(0.012)	(0.019)	(0.011)	(0.013)	(0.018)	(0.137)	(0.001)
2007	2.21	2.28	2.21	0.534	0.665	2.33	1.84	0.539	0.497	0.812
	(0.018)	(0.013)	(0.013)	(0.004)	(0.041)	(0.014)	(0.013)	(0.005)	(0.178)	(0.001)

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

Figure 13: Fitted Curve and Data used in GMM

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

Table 8: Factor Prices and Cut-off Industries

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

5.3 Counterfactual

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

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

Figure 14: Counterfactual on Technology

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

Figure 15: Counterfactual on Endowment

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

Figure 16: Counterfactual on Trade Costs

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

Figure 16: Counterfactual on home bias

6 Conclusion

In this paper, we firstly document 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 counter our understanding from Rybczynski Theorem of HO theory. To explain these findings, we embed Melitz-type heterogeneous firm into the Ricardian and Heckscher-Ohlin trade theory with *continuous* industries with home bias preference. The theory predicts that export probability and export intensity decrease with comparative advantages. And they remain *constant* for inter-industry trade industries where countries specialize. Such predictions are supported by data.

By estimate the model structurally, we find that capital labor ratio almost trippled, technology improved sinificantly and favored more labor intensive industries, trade libralization mostly came from reduction in fixed cost of export for China, and reduction in preference for home goods between 1999 and 2007. 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, trade liberalization and reduction of home bias preference, but mostly driven by changes in technology.

The results are still preliminary, we also need to do sensitivity test on σ and make the estimation more robust.

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7 Appendix

7.1 Proof of Proposition 1

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

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

Here $r(\widehat{\varphi}_z) = \frac{R_z}{M_z}$ is the average firm revenue and $\widetilde{p}_z \equiv \frac{p_{zd}(\widehat{\varphi}_z)}{p_{zd}(\widehat{\varphi}_z^*)} = \frac{\widehat{\varphi}_z^* w}{\varepsilon(z)\widehat{\varphi}_z w^*}(\frac{r/w}{r^*/w^*})^z$ is the relative average domestic price between the two countries. Using the zero profit condition(3.9),(3.10) and $\frac{r(\widehat{\varphi}_z)}{r(\widehat{\varphi}_z)} = (\frac{\widehat{\varphi}_z}{\widehat{\varphi}_z})^{\sigma-1}$,[20]

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

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

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 (3.11). Then we have:

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

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

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

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

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

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

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 (3.18), we have $\frac{M_z}{M^*_z} = \widetilde{p}_z^{\sigma-1}\frac{(\frac{P(z)}{P(z)^*})^{1-\sigma} - \chi_z^{-\frac{a+1-\sigma}{a}}\widetilde{\tau}^{-2(a+1-\sigma)}\tau^{1-\sigma}}{1-\chi_z^{\frac{a+1-\sigma}{a}}\tau^{1-\sigma}(\frac{P(z)}{P(z)^*})^{1-\sigma}}$. Thus it is also determined by factor prices.[22] So there are 4 equations for 4 unknowns, given reasonable parameters the equilibrium factor prices could be uniquely pinned down.■

7.2 Proof of Proposition 2

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

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

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

[22] We provide more details in next proof.

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

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

Then $\exists\ \chi_z = \frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2$ such that $\frac{M_z}{M_z^*} = 0$.Since $M_z^* > 0$ ($M_z^* \neq 0$), it must be that $M_z = 0$. And as 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 $[\underline{z}, \overline{z}]$,[23] Then we have

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

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

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

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

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 (3.11) and using the assumption that trade costs and fixed costs are the same all industries, we have:

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

Thus if $\frac{P(z)}{P(z')} < \frac{P(z)^*}{P(z')^*}$, or say labor intensive products are relatively cheaper in home country, then we have $\Lambda_z < \Lambda_{z'}$. This is exactly what we are going to prove. If $\frac{P(z)}{P(z')} < \frac{P(z)^*}{P(z')^*}$ under autarky and $\frac{P(z)}{P(z')} = \frac{P(z)^*}{P(z')^*}$ un-

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

der free trade, then the costly trade case will fall between and establishes our proof. When there is free trade (no variable costs or fixed costs of trade), all firms will export, the price of each variety and number of varieties will be the same for both countries. Thus the pricing index P(z)=P(z)* for all industries and $\frac{P(z)}{P(z')} = \frac{P(z)^*}{P(z')^*}$. On the other extreme of close economy, no firms export and from (3.18) we have $P(z) = M_z^{\frac{1}{1-\sigma}} p_{zd}(\widehat{\varphi}_z)$.Firm mass for each industry is $M_z = \frac{b(z)R}{r(\widehat{\varphi}_z)} = \frac{b(z)R}{r(\bar{\varphi}_z)}(\frac{\bar{\varphi}_z}{\widehat{\varphi}_z})^{\sigma-1}$.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 (3.16) 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$\frac{w}{r} < \frac{w^*}{r^*} \Longleftrightarrow \frac{P(z)}{P(z')} < \frac{P(z)^*}{P(z')^*}$. 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 $\frac{K}{L} < \frac{K^*}{L^*} \Longleftrightarrow \frac{w}{r} < \frac{w^*}{r^*}$ 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 (3.16) 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 (3.16), we could calculate that:

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

where $\widetilde{f} = \frac{f_{ez}}{f_z}$.Again it is monotonic function of 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 (7.6). Then the factor demand within the specialization region are:

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

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

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

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:

$$L_s + L_{int} = L \tag{7.7}$$

$$K_s + K_{int} = K \tag{7.8}$$

$$L_s^* + L_{int}^* = L^* \tag{7.9}$$

$$K_s^* + K_{int}^* = K^* \tag{7.10}$$

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

7.7 Constructing the Expenditure Share b(z)

First, we compute the average output share for year 1999 and 2007 for each industry using sales as measurement. Then we use a 4th-order polynomials to approximate b(z), i.e., we assume that:

$$b(z) = a_0 + a_1 z + a_2 z^2 + a_3 z^3 + a_4 z^4 + \mathrm{o}(z^5)$$

Since $\int_0^1 b(z)dz = 1$, there is a constraint on the polynomial coefficients which is:

$$a_0 = 1 - \frac{a_1}{2} - \frac{a_2}{3} - \frac{a_3}{4} - \frac{a_4}{5}$$

Then for each pair of $\{a_1, a_2, a_3, a_4\}$, we could generate the corresponding CDF of b(z) and then the corresponding histogram with bandwidth of 0.01 from 0 to 1. By minimizing the distance between the hypothetical histogram with what we observe from the data[24] , we could get an estimation of $\{a_1, a_2, a_3, a_4\}$. In the figure below, we plot the data we use and the result we get for the 4th order polynomial.

[24] With the constraint that b(z) is always non-negative.