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: production became more capital intensive while export did not; firms' export participation increased in the labor intensive industries but declined in the capital intensive industries from 1999 to 2007. To explain these seemingly puzzling 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 and find that capital deepening more than doubled the capital labor ratio of China, technology improved significantly but favored the labor intensive industries and trade liberalization reduced variable trade costs by about a quarter. Counterfactual simulations show that capital deepening made Chinese production capital intensive, but technology change that bias towards the labor intensive industries provided a counterbalancing force. We also find that the Melitzian export selection mechanism shapes Ricardian comparative advantage extensively and contributes to about 2.1% of productivity growth during this period.

Key Words: Structural Adjustments, Comparative Advantage, Heterogeneous Firm

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 introducing firm's heterogeneity into the HO and Ricardian framework. Using this unified model, we analyse 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. Although capital deepening were driving production to be more capital intensive, technology change and trade liberalization favored the labor intensive sectors. And due to intenser selection into export in the labor intensive sectors, the Ricardian comparative advantage of China in the labor intensive sector is further amplified. As a result, Chinese export didn't become more capital intensive as output and export participation rose in labor intensive sector but fell in the capital intensive ones.

We first compare the production and export in China's manufacturing 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.

We then construct a unified framework to explore the driving forces behind these structural adjustments. We introduce firm heterogeneity (Melitz, 2003) into a 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. In each country, there is 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 production and trade pattern. Countries specialize in industries which they have strong comparative advantage and deter entry of foreign firms. Thus trade is only one-way in such industries. These could either be the most labor or capital intensive industries, depending on the relative endowments and productivity. For industries with intermediate factor intensities, both countries produce. Thus trade is two-way in such industries. So with endogenous entry, we don't need truncated productivity distribution to generate zeros in trade flow (Helpman, Melitz and Rubinstein, 2008). We also show that export participation, measured by the conditional probability of export or export intensity, is higher in industries with larger comparative advantage.

Using the framework, we numerically solve the model and structurally estimate the parameters of the model for both years by Method of Moments. The estimation result indicates the following main findings: capital labor ratio more than doubled, technology improved significantly and favored 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.[1] Changes in parameters governing trade costs and technology contributed much less to the adjustments in production pattern. While changes of all the parameters affect the export participation, sector-biased technology improvement was the main driving force behind the adjustment of export participation. Overtime, China gained more Ricardian comparative advantage in the labor industries due to faster productivity growth in such industries. Such changes induced more firms select into export and endogenously amplified the Ricardian comparative in these sectors which induced further export. Our estimation allows us to quantify such a Ricardian comparative advantage which arises endogenously due to cross sector differences in firm selection (Bernard, Redding and Schott, 2007) and decompose the productivity growth overtime. The results show that the endogenous firm selection shapes the Ricardian comparative advantage extensively and contributes 12% of the productivity growth. Finally, we also evaluate the welfare gain change overtime. We find both China and the Rest of World (RoW) benefit from the adjustments in endowments, technology and trade liberalization. But China benefits relatively more. And the welfare gain mostly come from changes in endowment, less in technology change and least from trade liberalization.

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

[1] We use industry and sector interchangibly in this paper.

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 a long history of testing the classic Heckscher-Ohlin theory since the work by Leontief (1953). We embrace the key insight from the recent contributions by Trefler (1993, 1995), Harrigan (1995, 1997), Davis and Weinstein (2001) and Morrow (2010) in the last two decades to incorporate cross country and sector productivity differences. The closest papers to us would be Schott (2003, 2004) and Romalis (2004). They both study specialization pattern motivated by a multi-sector Heckscher-Ohlin model but without taking into account of Ricardian comparative advantage. [2] Our contribution is to incorporate heterogeneous firm and structurally estimate the model primitives. This approach allows us to generate all possible model moments and carry out counterfactuals that provide more powerful test of the theory.

There is a growing literature which incorporates the heterogeneous firm into a multi-sector models, most notably by Bernard, Redding and Schott (2007) in which they embed heterogeneous firm into a two-country two-sector Heckscher-Ohlin model. Okubo (2009), Lu (2010), Fan *et al* (2011), Burstein and Vogel (2011, 2016) are among the recent contributions. [3] With the exception of Burstein and Vogel (2011, 2016), these paper include only HO or Ricardian comparative advantage. While the focus of Burstein and Vogel (2011, 2016) is on the effect of trade liberalization on skill premium, we consider more general shocks including changes in endowment and technology. Finally, as far as we know, we are the first paper to quantify the endogenous Ricaridan comparative discovered by Bernard, Redding and Schott (2007).

Thirdly, our paper is related to the literature studying the effect of evolving comparative advantages. Redding(2002) studies the evolution of specialization pattern and finds technology matters more in shorter run while endowments for longer run. Similar to his study, we also analyse how distribution of economic activities across sector changes overtime. Romalis (2004) focuses on how factor endowments affect production and trade patterns. He uses longer run data and finds evidences supporting the Rybczynski effect. While Costinot *et al* (forthcoming), 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 firm heterogeneity and changes in trade costs.

Lastly, our paper is related to the literature that study the growth of China and its implication for the Rest of World. Rodrik (2006), Schott (2008) and Wang and Wei (2010) find that Chinese export are getting more and more sophisticated and overlapping more and more with rich countries' export. Such

[2] Morrow (2010) extends the work by Romalis (2004) to bring in Ricardian comparative advantage. But he does not consider firm heterogeneity.

[3] Okubo (2009) and Fan et. al (2011) combine DFS of Ricardian with Melitz-type heterogeneous firm. Lu (2010) embeds heterogeneous firm model into a multiple sector Heckscher-Ohlin model without endogenous entry. Unlike our model, there is no specialization in her model. And our empirical focus is totally different from her paper.

a finding however is not inconsistent with our finding that Chinese export is not getting more capital intensive. Indeed China exports the Iphone. But the Iphone is assembled in China to take advantage of the cheap labor. Hsieh and Ossa (2011), di Giovanni *et al* (2014) both study the welfare effect of productivity growth in China. Other than the welfare effect of productivity growth, we also look at the welfare effect of changes in endowment and trade liberalization. While Song *et al* (2011) and Chang *et al* (2015) study the growth of China in the lens of different macro models. Without considering the institutional features highlighted in these papers, our counterfactual simulations find that the relative rise of China to RoW mostly come from technology growth, less from change in endowment and least from reduction in trade costs, a conclusion consistent with the growth accounting exercise in a survey paper by Zhu (2011).

2 Motivating Evidences

We present stylized facts about the adjustments in production and trade structure over time in this section. The data we use is the Chinese Annual Industrial Survey. It covers all State Owned Enterprise (SOE) and non-SOEs with annual 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 etc.. We focus on manufacturing firms and exclude utility and mining firms. To clean the data, we follow Brandt *et al* (2012) to drop firms with missing, zero, or negative capital stock, export and value added, and only include firms with employment larger than 8. We define capital share defined as $1 - \frac{wage}{value\ added}$.[4] We drop firms with capital intensity larger than one or less than zero. Since the focus of this paper is on changes over time, we look at both the data of year 1999 and 2007.[5] The summary statistics of the basic variables after cleaning is shown in the Appendix Table A.1.

Table 1 presents the basic empirical features of Chinese manufacturing firms on the factor allocation and export participation. The average capital share of the manufacturing firms increased by 4 percentage points.[6] So the overall manufacture production is more capital intensive in 2007 than in 1999. Despite that, the average capital share of exporters decreased slightly from 0.623 to 0.619. Although the average export across firms almost tripled as shown in A.1, the fraction of firms which export remained around 25%. The share of goods exported increased by about 3 percentage points from 18% to 21%.

[4]Wage is defined as the sum of payable wage, labor and employment insurance fee, and total employee benefits payable. The 2007 data also reports information about housing fund and housing subsidy, endowment insurance and medical insurance, and employee educational expenses provided by the employers. Adding these three variables would increase the average labor share but only slightly. To be consistent across years, we do not include them.

[5]We do not use year 2008 and years after due to the lack of data. The aftermath of the financial crisis is also of great concern.

[6]Hsieh and Klenow (2009) point out that labor share generated out of the firm level survey is significantly less than the numbers reported in the Chinese input-output tables and the national accounts (roughly 50%). They argue that it could be explained by non-wage compensation. But even in the aggregate numbers, capital share is increasing overtime, as documented by Karabarbounis and Neiman (2014) and Chang, Chen, Waggoner and Zha (2015).

Table 1: Capital Share and Export Participation

Variables	mean in 1999	mean in 2007
capital share of all manufacturers	0.667	0.707
capital share of exporters	0.623	0.619
proportion of exporters	0.253	0.249
exports/gross sales	0.181	0.208

2.1 Definition of Industry

Our definition of Industry is non-conventional. Table A.2 in the appendix shows that there are large variations of capital share within the 2-digit Chinese Industry Classification (CIC) of industry in year 2007. The standard deviation of capital intensity across firms within each is around 0.22. Moreover, the capital intensity between exporters and non-exporters differs significantly. Except for Manufacture of Tobacco (industry 16), the capital share of exporters is significantly lower than non-exporters. These persist even if we use 4-digit CIC industry classification which includes more than 400 industries. [7]

As Schott (2003, page 687) argues, "*testing the key insight of Heckscher-Olin theory ... requires grouping together products that are both close substitutes and manufactured with identical techniques. Traditional aggregates can fail on both counts.*" Given the large variation of capital intensity within each industry and the systematic differences between exporters and non-exporters, such an insight should not only apply to the industry level data which Schott used but also the firm level data that we have. Thus we follow his idea to define industry as "HO aggregate" and regroup firms according to their capital intensity. 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.[8]

2.2 Production

We first examine how the Chinese production pattern changes overtime. Figure 1 plots the distribution of firms across industries. Each dot on the figure represents the fraction of firms operating in each industry. The share of firms producing in capital intensive industries increased overtime as the whole distribution shifts to the right in 2007. Thus there is significant reallocation of resources towards capital intensive industries. Figure 2 plots the distribution of outputs in terms of industry real value added. Firms in capital intensive industries accounted for larger fractions in 2007 than in 1999.[9] The message from Figure 1 and 2 could also be summarized by Table 2. It focuses on the capital intensive firms which are firms with capital intensity higher than 0.5. As the first column indicates, the share of capital intensive firms

[7] For brevity, we do not report it here but the results are available upon request. Alvarez and López (2005) and Bernard *et al*'s (2007b) found that exporters are more capital intensive than non-exporters for Chilean and American firms respectively. Bernard *et al's* (2007b) speculated that exporters in developing countries should be more labor intensive than non-exporters given their comparative advantage in labor intensive goods. For the same data, Ma *et al* (2014) use capital labor ratio (capital divided by wage payment) as the indicator of factor intensity. They also find Chinese exporters are less capital intensive than non-exporters.

[8] Such an industry definition has also been used by Ju, Lin and Wang (2015) to study industry dynamics.

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

increased by about 5.3% from 76.5% in 1999 to 81.8% in 2007. Their employment and output shares also increased as the second and third column show. These findings could be summarized as:

Stylized fact 1: *The Chinese manufacturing production became more capital intensive overtime.*

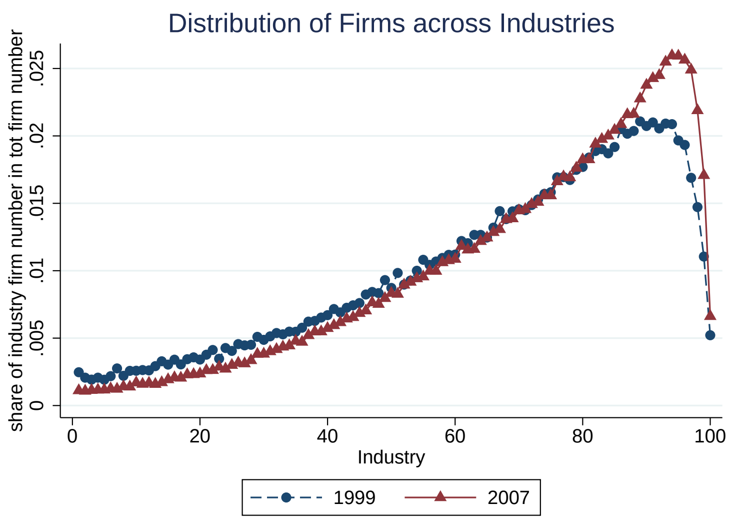

Figure 1: Distribution of Firms

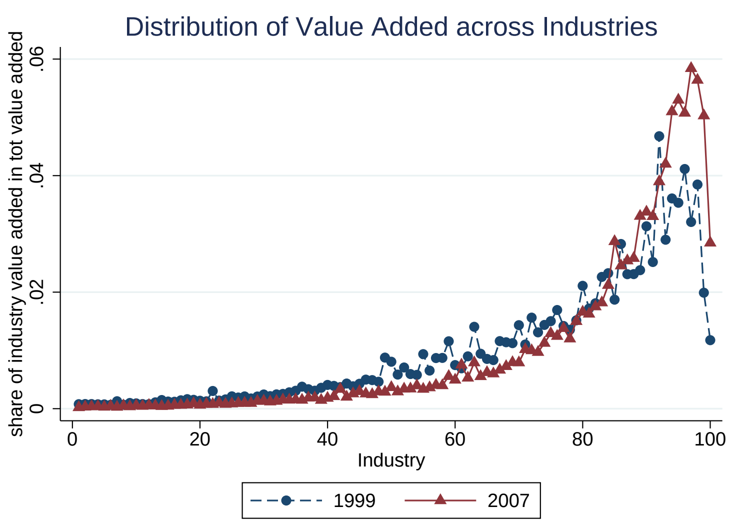

Figure 2: Distribution of Value Added

2.3 Trade Patterns

Now we examine the trade pattern. Figure 3 plots the distribution of export across industries. The left panel plots the distribution of exporters and it stays almost unchanged. If anything, it shifts towards the labor intensive industries. The right panel plots the distribution of export sales. The distributions of the

Table 2: Structural Adjustment of Production

	fraction of firms in capital intensive industries	share of employment in capital intensive industries	share of value added by capital intensive industries
2007	0.818	0.762	0.938
1999	0.765	0.672	0.879
Difference	0.053	0.090	0.059

Notes: The numbers in the 1st and 2nd row are the corresponding share for firms with capital share higher than 0.50. The 3rd row is the difference of the first two rows.

two years are almost indistinguishable. Figure 4 plots export participation for *within* each industry. The left panel plots the share of exporter for each industry. Overtime, it increases in labor intensive industries and drops in capital intensive industries. The right panel plots the export intensity which is the value of export divided by total sales for each industry. It increases for most of industries, especially the labor intensive industries. However, it also drops for the most capital intensive industries.

These adjustments could also be read from Table 3. As the first column indicates, the fraction of capital intensive exporters dropped by 0.5% during 1999-2007. These exporters contributed to 81.4% of total export in 1999. It dropped by 0.3% to 81.1% in 2007 as shown in the second column. Finally, 23.4% of firms with capital intensity higher than 0.5 were exporters in 1999. It dropped to 21.4% in 2007. We summarize the main findings from this subsection as:

Stylized fact 2: *The average capital intensity of Chinese exporters stayed almost unchanged overtime. Export participation increased in labor intensive industries, vice versa in capital intensive industries.* [10]

Putting Stylized fact 1 and 2 together, we have a seemingly puzzling observation. The production clearly became more capital intensive in 2007 than 1999 while export did not. According to the standard Heckscher-Ohlin theory, one should expect export to become more capital intensive when the production becomes more capital intensive. However, the Heckscher-Ohlin theory assumes away the role of productivity. This leads us to the next stylized fact.

Table 3: Structural Adjustment of Export

	fraction of exporters from capital intensive industries	share of export sales by capital intensive industries	share of exporters in capital intensive industries
2007	0.703	0.811	0.214
1999	0.708	0.814	0.234
Difference	-0.005	-0.003	-0.020

Notes: The numbers in the 1st and 2nd row are the corresponding share for firms with capital share higher than 0.50. The 3rd row is the difference of the first two columns.

[10] Our finding that Chinese export did not become more capital intensive seems to contradict earlier work on the rising sophistication of Chinese export (Rodrik 2006, Schott 2008, Wang and Wei 2010). Though China might expand its export on the extensive margin towards capital intensive industries, there is no guarantee that the overall share of exporters or export value in capital intensive industries would also increases. If more firms become exporters in the labor intensive industries and their export sales increase by 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.

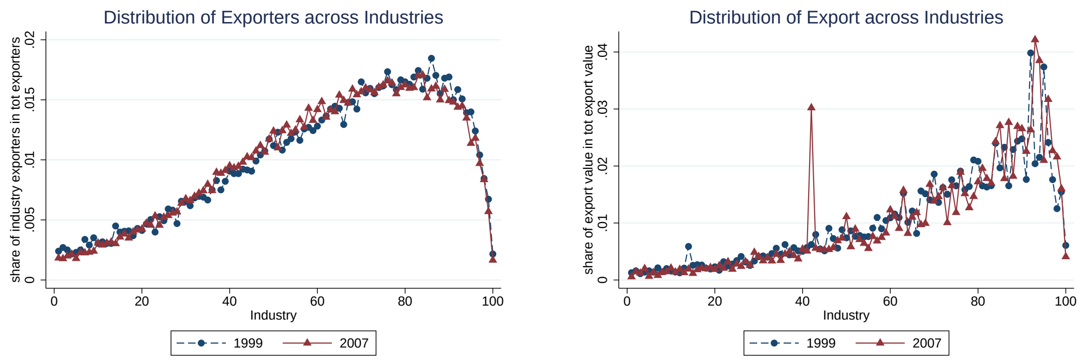

Figure 3: Distribution of Export

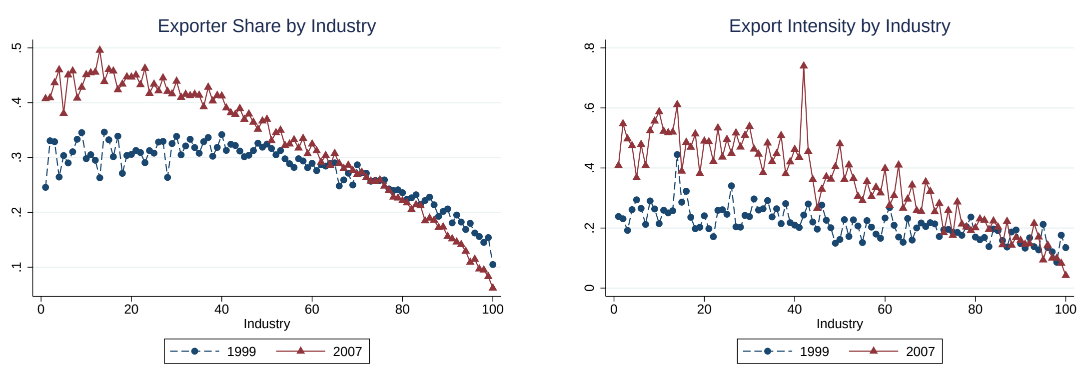

Figure 4: Export Participation within each Industry

2.4 Productivity

This subsection looks at the productivity growth between year 1999 and 2007 across industries. Firstly, a 9-year long firm level panel data is constructed to estimate the firm level TFP using the Levinsohn and Petrin (2003) method.[11] Then we compute the average TFP for each industry weighted by real value added, trimming the top and bottom one percent to remove outliers. Figure 5 shows the estimated average TFP for each industry. There are two basic observations. First, TFP tends to be higher for capital intensive industries and rises from 1999 to 2007 for all industries. Second, TFP grows faster in labor intensive industries. In other words, productivity growth is biased towards labor intensive industries. We summarize the finding as:

Stylized fact 3: *Productivity growth is faster in labor intensive industries than in capital intensive industries.*

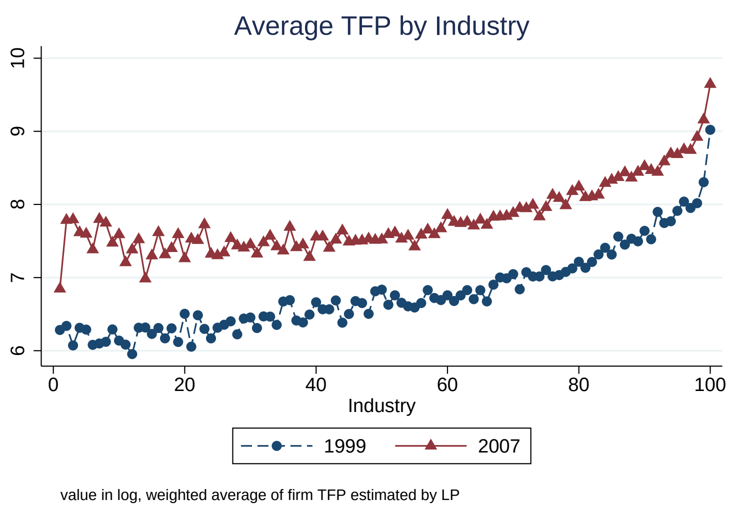

Figure 5: Total Factor Productivity

2.5 Robustness of the Facts

We explore the robustness of the stylized facts in this subsection. The first concern is whether the findings are purely driven by the industry definition of "HO aggregate". In the Appendix 7.10, we show that this is not the case. There we use the 4-digit CIC industry classification to regenerate all facts. As evident from the figures, our findings that Chinese production became more capital intensive but export did not, export participation increased in labor intensive sector but declined in capital intensive sectors, and

[11]The panel is constructed using the method by Brandt *et al* (2012). Their price indexes and program to construct the panel are available at `http://feb.kuleuven.be/public/N07057/China/`. Real output as measured by real value added, real input are all constructed using the input and output price indexes provided by them. Capital stock is constructed using the perpetual inventory method. Labor is measured as employment. We estimate the TFP by 2-digit CIC industries. For brevity, the estimate results are not reported here but available upon request. Our results are robust to the Olley and Pakes (1996) method or labor productivity measured as real value added per worker. This is shown in the Appendix 7.10.

productivity growth is faster in labor intensive sectors all hold under CIC industry classification. But patterns contain much more noise than the results above.

The other concern is whether our results are driven by any peculiar Chinese institution. To address such concern, we regenerate the facts using various sub-samples. To address the concern of the expiration of the Multi Fiber Agreement in 2005 and rising export in the labor intensive textile industries, we exclude the 2-digit CIC industries of 17 and 18 in the light of Khandelwal, Schott and Wei (2013). To address the concern on the Chinese reform of the SOEs since late 1990s which might favor certain industries more than others, we exclude all the SOEs in our sample. Finally, to address the concern on processing trade and export subsidy, we exclude all the pure exporters which are predominantly processing exporters and benefit from export subsidy[12]. In these various sub-samples, our basic findings are qualitatively preserved as shown in the Appendix 7.10.

3 Model Setup

Motivated by the empirical features of the data, we now build a model that incorporate Ricardian comparative advantage, Heckscher-Ohline comparative advantage and firm heterogeneity. The model incorporates heterogeneous 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: home and foreign. 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 the labor intensive industries.[13] There is a continuum of industries z on the interval of $[0, 1]$. z indexes 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

There is 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 given by the following 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

[12]Pure exporters are defined as exporters with export intensity greater than 70% following Defever and Riaño (2016).
[13]Variables with "*" are for the foreign.

the consumption of individual varieties $q_z(\omega)$ given by the following CES aggregator:[14]

$$Q(z) = (\int_{\omega \in \Omega_z} q_z(\omega)^\rho d\omega)^{1/\rho}$$

where 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:

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

where $P(z) = (\int_{\omega \in \Omega_z} p_z(\omega)^{1-\sigma} d\omega)^{\frac{1}{1-\sigma}}$ is the dual price index defined over price of different varieties $p_z(\omega)$.

3.2 Production

Following 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 $A(z)\varphi$ has two components: $A(z)$ is a common component for all firms from the same industry z; φ is an idiosyncratic component drawn from a common continuous and increasing distribution $G(\varphi)$, with probability density function $g(\varphi)$. Following Romalis (2004) and Bernard *et al* (2007a), we assume that fixed costs are paid using capital and labor with factor intensity the same as production in that industry. Specifically, we assume that the total cost function is:

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

where r and w are rents for capital and labor respectively. The relative industry specific productivity for home and foreign $\varepsilon(z)$ is assumed to be:

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

Under this assumption, λ captures the absolute advantage and A captures comparative advantage. Higher λ leads home country to be relatively more productive in all industries. If $A > 1$, home country is relatively more productive in the capital intensive industries and has Ricardian comparative advantages in these industries. If $A = 1$, $\varepsilon(z)$ does not vary with z and there is no role for Ricardian comparative advantage. To simplify the exposition, we assume that home has Ricardian comparative advantage in labor intensive industries,that is $0 < A < 1$.[15]

Trade is costly. For firms that export, they need to pay a per-period fixed cost $f_{zx} r^z w^{1-z}$ which

[14] Such a preference structure is also used in the survey paper to quantify gains from trade by Costinot and Rodriguez-Clare (2014). In the Appendix 7.8, we generalize our theoretical results to a nested-CES preferences structure.

[15] The case that home country has Ricardian comparative advantage in the capital intensive industries is discussed in the section of equilibrium analysis.

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. Profit maximization implies that the equilibrium price is a constant mark-up over the marginal cost. 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 $p_{zd}(\varphi)$ are the exporting and domestic price respectively. Given the pricing rule, a firm's revenue from domestic and foreign market are:

$$\begin{aligned} r_{zd}(\varphi) &= b(z)R\left(\frac{\rho A(z)\varphi P(z)}{r^z w^{1-z}}\right)^{\sigma-1} && (3.5) \\ r_{zx}(\varphi) &= \tau^{1-\sigma}\left(\frac{P(z)^*}{P(z)}\right)^{\sigma-1}\frac{R^*}{R} r_{zd}(\varphi) && (3.6) \end{aligned}$$

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:

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

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 $\pi_{zd}(\varphi) \geq 0$. Similarly, it exports if $\pi_{zx}(\varphi) \geq 0$. These define the zero-profit productivity cut-off $\bar{\varphi}_z$ and costly trade zero profit productivity cut-off $\bar{\varphi}_{zx}$ which satisfy:

$$\begin{aligned} r_{zd}(\bar{\varphi}_z) &= \sigma f_z r^z w^{1-z} && (3.9) \\ r_{zx}(\bar{\varphi}_{zx}) &= \sigma f_{zx} r^z w^{1-z} && (3.10) \end{aligned}$$

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 export. So we focus on parameters where exporters are always more productive following Melitz (2003) and Bernard *et al* (2007a).[16] 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 export conditional on successful entry is

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

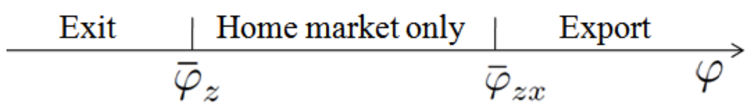

Figure 6: Productivity Cutoffs and Firm Decision

3.3 Free entry

If a firm does produce, it faces a constant probability δ of bad shock every period that forces it to exit. The steady-state equilibrium is characterized by a constant mass of firms entering an industry M_{ez} and a constant mass of firms producing M_z. The mass of firms entering equals the mass of firms exiting:

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

The entry cost is given by $f_{ez}r^z w^{1-z}$. 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 the *ex ante* probability of export times the expected profit from the export market until death. Free entry implies

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

where $\pi_{zd}(\widehat{\varphi}_z)$ and $\chi_z \pi_{zd}(\widehat{\varphi}_{zx})$ are the expected profit from serving the domestic and foreign markets respectively. $\widehat{\varphi}_z$ is the average productivity of all producing firms and $\widehat{\varphi}_{zx}$ is the average productivity of

[16] Lu(2010) explores the possibility that $\Lambda_z < 1$ and documents that in the labor intensive sectors of China, exporters are less productive. Dai *et al* (2011) find that this is driven by processing exporters. And using TFP as the productivity measure instead of value added per worker, even including processing exporters still support that exporters are more productive.

all exporting firms. They are defined as:

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

Combining the free entry condition (3.14) with the zero profit conditions (3.9), (3.10), the productivity cut-offs satisfy:

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

3.4 Market Clearing

In equilibrium, the sum of domestic and foreign spending on domestic varieties equals the value total industry revenue:

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

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

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

The factor market clearing conditions are:

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

3.5 Equilibrium

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

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

(b) Free entry condition (3.14) and the 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 7.1.*

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. Thus two assumptions are made to simplify the algebra. First, we assume that the idiosyncratic productivity is Pareto distributed with the following the density function:

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

where θ is a lower bound of productivity: $\varphi \geq \theta$. [17] Second, we assume that the coefficients of fixed costs are the same for all industries:[18]

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

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 home country specializes in the production within* $[0, \underline{z}]$ *while 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 ($\tau = 1$) *and fixed cost of export equals fixed cost of production for each industry* ($f_{zx} = f_z, \forall z$)*, then we have* $\underline{z} = \overline{z}$ *and complete specialization.*

Proof. *See Appendix 7.2.*

Given our assumption that $\frac{L}{K} > \frac{L^*}{K^*}$ and $A < 1$, home country has comparative advantage in the labor intensive industries. Proposition 2 and Figure 7 illustrate the production and trade pattern under this scenario. 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 theory)

[17] We will point it out when the results do not depend on this assumption.
[18] f_z , f_{ez}, f_{zx} could still differ from each other.

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, the strength of comparative advantage would be relative weak. Then there would be no specialization and only intra-industry trade between the two countries. That is to say, $\underline{z} = 0$ and $\overline{z} = 1$. On the other hand, if trade is totally free, the classical trade force dominates and full specialization arises as $\underline{z} = \overline{z}$, this is the specialization pattern in the classical DFS model(1977,1980). Finally, if $A >= 1$, it is possible that the Ricardian comparative advantage is strong enough to overturn the Heckscher-Ohlin comparative advantage. Then the pattern of production and trade will be reversed. Home country will specialize in $[\overline{z}, 1]$ and foreign country will specialize in $[0, \underline{z}]$.

The other insight from this proposition is that we do not necessarily need bounded productivity distribution to generate zeros in trade flow as Helpman, Melitz and Rubinstein (2008, hence HMR) suggest. In our setting, zeros in trade flow exist if there is specialization. Trade would only be one-way if production is zero in certain industries in either one of the countries. In the case of full specialization, half of the trade flow matrix are zeros. This result arises since we allow for endogenous entry while entry is exogenous in HMR. In HMR, trade flow would be zero if all firms are not productive enough to export. In our setting, zeros arise if no firms ever enter at all since the expected profit is less than the entry cost in certain industries. [19]

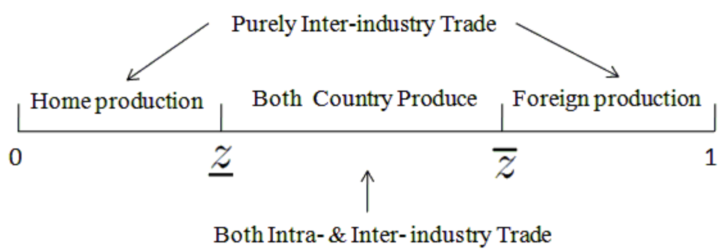

Figure 7: Production and Trade Pattern

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. Our model thus inherit all the property of Romalis (2004). However, his assumption of homogeneous firm leads to the stark feature that all firms export in all industries. With the assumption of firm heterogeneity, export participation varies across industries as shown in the following two propositions.

Proposition 3 *(a) Under general productivity distribution $g(\varphi) > 0$, the zero profit productivity cut-off*

[19] We think this channel is empirically relevant. Not every country is producing every product. And given such selection into production, we probably need to provide correction in estimating the gravity equation as HMR suggest for selection into export.

decreases with capital intensity while the export cut-off increases with capital intensity within $(\underline{z}, \overline{z})$ *in home country. The converse holds in foreign country.*

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

Proof. *See Appendix 7.3.*

The proposition does not rely on the assumption of Pareto distribution and is an extension of Bernard *et al* (2007a). They prove that under the two-industry case, the zero profit productivity cut-offs for production and export will be closer in the comparative advantage industry. Their discussion is constrained to that countries produce within the diversification cone and there is no specialization. Conclusion (b) characterizes the cut-offs if there is specialization. Figure 8 illustrates these results for both home and foreign country.

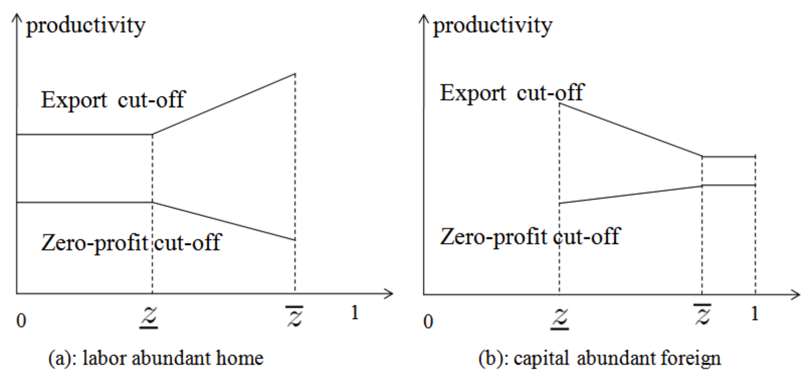

Figure 8: Productivity Cut-offs across Industries in Home and Foreign Countries

Proposition 4 *(a) Under general productivity distribution* $g(\varphi) > 0$*, the probability of export* χ_z *is constant for industries that either country specializes and decreases with capital intensity in home country within* $(\underline{z}, \overline{z})$*, vice versa in the foreign. If the productivity distribution is Pareto, we have*

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

where $h(z) \equiv \left(\frac{w}{w^*}(\frac{r/w}{r^*/w^*})^z\right)^{\frac{a\sigma}{1-\sigma}}$, $\widetilde{\tau} \equiv \tau(f)^{\frac{1}{\sigma-1}}$ *and for* $z \in (\underline{z}, \overline{z})$

$$\frac{\partial \chi_z}{\partial z} = B(z)\left[\ln(A) - \frac{\sigma}{\sigma-1}\ln\left(\frac{r/w}{r^*/w^*}\right)\right], \ B(z) > 0.$$

(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 7.4.*

Proposition 4 is a straightforward implication of proposition 3. It tells that the stronger the comparative advantage is, the larger the share of firms that participate in international trade. For industries that countries specialize, goods are supplied by only one country and export participation is a constant. This is illustrated in Figure 9. In the left panel, the probability of export(or export intensity) decreases with the capital intensity in home country. The right panel shows an opposite pattern for the foreign country.

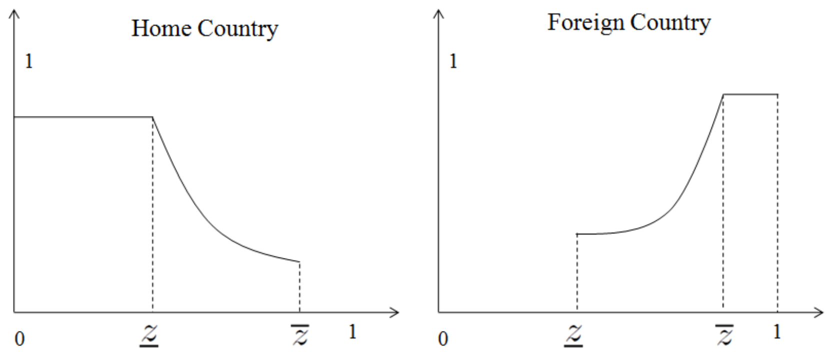

Figure 9: Probability of Export or Export Intensity in Home Country and Foreign Country

The Pareto distribution assumption leads to explicit expressions and allows us to examine the sign of $\frac{\partial \chi_z}{\partial z}$ within $(\underline{z}, \overline{z})$: it depends on 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 $\frac{K}{L} < \frac{K^*}{L^*}$, home country has both Ricardian comparative advantage and Heckscher-Ohlin comparative advantage in labor intensive industries. Thus we expect $\frac{\partial \chi_z}{\partial z} < 0$ and the probability of export decreases with capital intensities in home country. However, if $A > 1$ and home country has Ricaridan Comparative Advantage in 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 capital intensive industries.

The key insight from the Melitz model is that selection into export lead to within-sector resource reallocation and productivity gain. Bernard et al (2007a) find that the strength of reallocation is stronger in the industry one has comparative advantage. Such differential reallocations will generate productivity differences across sectors and countries. They coin such a mechanism "the endogenous Ricardian comparative advantage". In the following proposition, we show how to quantify such a mechanism.

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

$$\widehat{\varphi}_z = C(1 + f\chi_z)^{1/a}$$

where C is a constant. Within $(\underline{z},\overline{z})$, it increases with the strength of comparative advantage as reflected by χ_z. Within the specialization zone $[0,\underline{z}]$, it is a constant.

(b) For sectors within $(\underline{z},\overline{z})$, that both countries produce, the Ricardian comparative advantage could be decomposed into two components as:

$$\frac{\widehat{A(z)}}{\widehat{A^*(z)}} = \underbrace{\lambda A^z}_{exogenous} \underbrace{(\frac{1+f\chi_z}{1+f\chi_z^*})^{1/a}}_{endogenous}$$

Proof. *See Appendix 7.5.*

According to conclusion (a), opening up to trade brings productivity gain since χ_z would increase from zero to some positive number. The productivity gain would be larger if the share of exporter is higher. In conclusion (b), the relative average industry productivity between home and foreign country is decomposed into an exogenous component and an endogenous component which varies with the relative extent of export selection. Home country could be relative more productive either because the industry-wide productivity is higher or relative more firms are selected to export.

Moreover, the endogenous Ricardian comparative advantage could amplify or dampen the exogenous component, depending on how the relative share of exporter varies across industries. If the Heckscher-Ohlin comparative advantage is so strong that the share of exporter is relatively lower in industries with strong exogenous Ricardian comparative advantage, then the exogenous Ricardian comparative advantage would be dampened. For example, suppose $A > 1$ and λA^z increases with z. So home country has exogenous Ricardian comparative advantage in the capital intensive industries. However, if $\frac{L}{K}/\frac{L^*}{K^*}$ is so high that home country has strong Heckscher-Ohlin comparative advantage in the labor intensive industries and $\ln(A) < \frac{\sigma}{\sigma-1}\ln(\frac{r}{w}/\frac{r^*}{w^*})$. Then according to Proposition 4, $\frac{\partial \chi_z}{\partial z}$ is negative and χ_z is lower in the capital intensive industries. On the other hand, χ_z^* is higher in the capital intensive industries. Thus the endogenous component $(\frac{1+f\chi_z}{1+f\chi_z^*})^{1/a}$ declines with z. We will show that this is empirically possible in the next section.

5 Quantitative Analysis

In this section, we conduct a quantitative analysis of the model economy. We treat China as Home and RoW as Foreign. We first calibrate and structurally estimate the model parameters by fitting the model to the Chinese data. To disentangle the driving forces behind the pattern of structural adjustment that we observe in section 2, we run counterfactual experiments by turning on different channels in the estimated model. The estimated model also allows us to decompose the Ricardian comparative advantage and productivity growth. Finally, we analyze the model's implications on the source of welfare gains and the robustness of the estimation result.

5.1 Parametrization and Estimation

A subset of the parameters are based on the data statistics or estimates from the literature. Firstly, as first proved by Chaney (2008) and also in Arkolakis *et al* (2012), the trade elasticity in the Melitz model with Pareto distribution assumption is governed by the Pareto shape parameter. Thus we set the Pareto shape parameter $a = 3.43$, the median trade elasticity estimated by Broda *et al* (2006) for China. We will later test the robustness of our estimates by varying the trade elasticity from the lower end to the higher end of the estimates in the literature. Next, to infer the elasticity of substitution σ, we first regress of the logarithm of an individual firm's rank in sales on the logarithm of firm sales.[20] The estimated coefficient is 0.774, with a standard error of 0.001. According to Helpman, Melitz and Yeaple (2004), this coefficient would be $a - (\sigma - 1)$. Thus the elasticity of substitution is $\sigma = 3.43 + 1 - 0.7735 = 3.66$.

We normalize the labor supply for China to be 1. The relative labor endowment $\frac{L^*}{L}$ is calculated for both 1999 and 2007 using the data from the World Bank as ratio of industrial employment. [21] Next, from Proposition 7.4, the export intensity and probability of export for each industry are related to each other as $\gamma_z = \frac{f\chi_z}{1+f\chi_z}$. Thus we could infer the relative fixed cost of export as $f = \frac{\gamma_z}{\chi_z(1-\gamma_z)}$ for each industry. Our estimation for f is the average across all industries. The estimated result is 1.00 and 1.77 respectively for 1999 and 2007. [22] Lastly, the expenditure share function b(z) is estimated as the consumption share for each industry where consumption is accounted as output plus net import. However, we only observe output and export from the firm survey. To infer import, we match the firm survey data with the custom data from 2000 to 2006. [23] For each of the 100 industries, we compute the ratio of aggregate import to aggregate export of the matched firms. Then the import of each industry is estimated as the aggregate export of all firms multiplied by the ratio. Once we know import, consumption is simply output plus import minus export. We then compute the expenditure function b(z) as the average of consumption share during 2000-2006 for which we have the custom data. The estimated b(z) is shown in the Appendix (7.11). These are all the parameters calibrated before the main estimation which is also summarized in Table (4).

Turning to the remaining parameters, we estimate $\{\frac{K^*}{K}, K/L, A, \lambda, \tau\}$ by method of moments. The first target moment is the relative size of China and RoW, measured by the aggregation revenue ratio R^*/R. It is calculated using the ratio of manufacturing output for RoW and China using the data from the World Bank. [24] Secondly, we target on the empirical feature on industry-level exporter share and

[20] The coefficient is estimated by polling the data from two years together using OLS, controlling year-industry fixed effects.

[21] Industrial employment is computed by multiplying the total labor force with the share industrial employment and employment rate. World Bank Database doesn't provide industrial employment share for the whole world in year 1999 and 2007. We take data from the closest available year: year 2000 and 2005 respectively.

[22] This does not mean the fixed cost of export was increasing from 1999 to 2007. It could be the case both the fixed costs of sales at home and export were declining but the fixed cost of export was falling slower. Appendix 7.11 plots the estimated f by industry.

[23] There is no custom data available for year 1999 or 2007 to us. The custom data uses different firm identifier from the firm survey. We match them by firm name, address, post code and phone number. About 30%-40% of the exporters in the firm data are matched. The distribution of export across industries is almost identical for the matched exporters and all exporters from the firm data. Thus the matched firms are unlikely to be selected.

[24] Manufacturing output is estimated as nominal GDP multiplied by the share of manufacturing in aggregate GDP.

Table 4: Calibrated Parameters

parameters pre-chosen	value	source
Pareto shape a	3.43	Broda *et al* (2006)
Elasticity of substitution σ	3.66	Estimated using method by Helpman *et al* (2004)
relative labor size L^*/L	$year_{1999}$: 2.49 $year_{2007}$: 2.22	Ratio of industrial labor force (World Bank).
Relative fixed cost of export f	$year_{1999}$: 1.00 $year_{2007}$: 1.77	Inferred from $\gamma_z = \frac{f\chi_z}{1+f\chi_z}$
Expenditure share $b(z)$		Consumption share while C(z)=Y(z)-EXP(z)+IMP(z) and import is inferred from matched firm and custom data

Notes: The estimated f is the average across industries for each year. b(z) is averaged over 2000 and 2006. They are plotted in the Appendix 7.11.

capital intensity. The average share of exporters for the capital intensive industries ($z \geq 0.5$) and labor intensive industries ($z \leq 0.5$) are chose as the estimation target moments. Lastly, average capital intensity and capital intensity for exporters are included as the target moments. Thus there are five moments and five parameters to estimate.[25]

We estimate the model parameters separately for year 1999 and 2007 by matching the corresponding moments. The baseline results are reported in Table (5). Table (5) reports the estimated parameters, from which we have the following findings. Firstly, China became more capital abundant in 2007. The relative capital stock of RoW dropped and the capital labor ratio of China was more than doubled its level in 1999. Secondly, China became more productive compared with RoW, especially in labor intensive industries. As we can see, the parameter capturing absolutely advantage λ increased. Thus the gap in sectoral TFP shrank in every industries between China and RoW.[26] More importantly, the parameter capturing exogenous Ricardian comparative advantage A switched from greater than 1 to less than 1. This implies that the productivity growth in China must have been relatively faster in the labor intensive industries during this period. Although we cannot observe the TFP of RoW for each industries or measure directly the Ricardian comparative advantage. We do observe that TFP growth is relatively faster in the labor intensive industries in China as shown in Figure 5. And this is also consistent with the finding by Levchenko and Zhang (2016) that productivity tends to grow faster in industries with greater initial comparative disadvantage. Finally, the variable iceberg trade cost τ decreased by about 25% from 2.38 to 1.76. This is not surprising given the trade liberalization that China experienced after joining the WTO in 2001.

We then examine the fitting of our model. Table (6) shows the fitting of the targeted moments. As can be seen, we match the target moments reasonably well. Table (7) shows the fitting some non-targeted aggregate moments. The model match the aggregate exporter share and aggregate export intensity

[25] In the on-line appendix 8.1, we prove that the lower bound θ of the Pareto distribution, the exogenous death probability of firms δ, the fixed entry cost f_{ez} and fixed cost production f_z are all irrelevant for the these moments.

[26] Our estimate of the relative productivity between China and RoW is close to the estimate by di Giovanni *et al*(2014). They estimate that average relative productivity of China to RoW is about 0.34 in the 2000s. According to our estimate, the weighted average of relative productivity of China to RoW is 0.16 in 1999 and 0.30 in 2007.

Table 5: Estimation Results

parameters	$\frac{K^*}{K}$	K/L	A	λ	τ
1999	3.50	0.907	1.31	0.125	2.38
	(0.004)	(0.02)	(0.001)	(0.0002)	(0.001)
2007	2.54	2.03	0.739	0.355	1.76
	(0.02)	(0.015)	(0.009)	(0.0002)	(0.001)

Notes: This table presents the estimation results. $\frac{K^*}{K}$ is the relative endowment of home and RoW. K/L is the capital labor ratio at home. A captures the Ricardian comparative advantage. λ captures the absolute comparative advantage. τ measures the iceberg trade cost. The numbers in the parentheses are bootstrapped standard errors. In each boostrap, we use a sample with replacement from the data to generate the target moments and redo the estimation. We perform 25 boostraps for each year.

relatively well. The aggregate export intensity in the model has a slightly higher level and shows a bigger increase compared to the data. The model also predicts a significant wage growth in China relative to RoW. In 1999, the wage of RoW was about 6.5 times of China. It declined to around 3 times in 2007. Such relative wage growth is close to what we observe. [27] As we will show in the counterfactual, such wage growth is mostly driven by the technology change that favors the labor intensive industries, less by the increasing scarcity of labor to capital, least by trade liberalization. The model also generates distribution of firm and exporter share across industries. The fitting is illustrated in Figure 10. The model not only matches the static shape closely but also the change overtime.

Not all aggregate moments are well matched. 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 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.

5.2 Decompose the Ricardian Comparative Advantage and Productivity Growth

With the estimated parameters, we can decompose Ricardian comparative advantage into an exogenous and endogenous components using results from Proposition 5. This channel is first discovered in Bernard,

[27] According to ILO (2013, 2014), the world real wage growth between 1999 and 2007 is 20.3%. The world CPI grew by 33.5% during 1999-2007 according to World Bank data. Thus the nominal wage grew by 60.6% ((1+20.3%)(1+33.5%)-1). For the same period, the nominal wage of China grew by 168%. So the relative wage growth of the World to China is $\frac{w^W_{2007}/w^C_{2007}}{w^W_{1999}/w^C_{1999}} = \frac{w^W_{2007}}{w^W_{1999}} / \frac{w^C_{2007}}{w^C_{1999}} = (1+60.6\%)/(1+168\%) = 59.9\%$. If we are willing to accept that the wage of RoW is very close to the whole world, the same calculation using our estimate is $\frac{w^*_{2007}/w_{2007}}{w^*_{1999}/w^C_{1999}} = \frac{2.89}{6.43} = 44.9\%$. Thus our estimate of the relative wage growth of China to RoW from our model accounts a significant proportions of wage growth in China.

Table 6: Model fit: target moments

year	data: 1999	data: 2007	model: 1999	model: 2007
R^*/R	16.74	7.47	16.74	7.47
exporter share: $z \leq 0.5$	0.312	0.42	0.315	0.423
exporter share: $z \geq 0.5$	0.241	0.234	0.238	0.228
capital intensity for all firms	0.667	0.707	0.659	0.688
capital intensity for all exporters	0.623	0.619	0.630	0.633

Notes: The current table demonstrates the fitting of the moments that are included in the estimation.

Table 7: Model fit: non-target moments

year	data: 1999	data: 2007	model: 1999	model: 2007
aggregate exporter share	0.253	0.249	0.241	0.230
aggregate export intensity	0.181	0.208	0.189	0.284
capital income share	0.761	0.830	0.790	0.768
relative wage: w*/w			6.43	2.89

Notes: The current table computes moments that are not included in the estimation using estimation results from Table 5 and compares them against data.

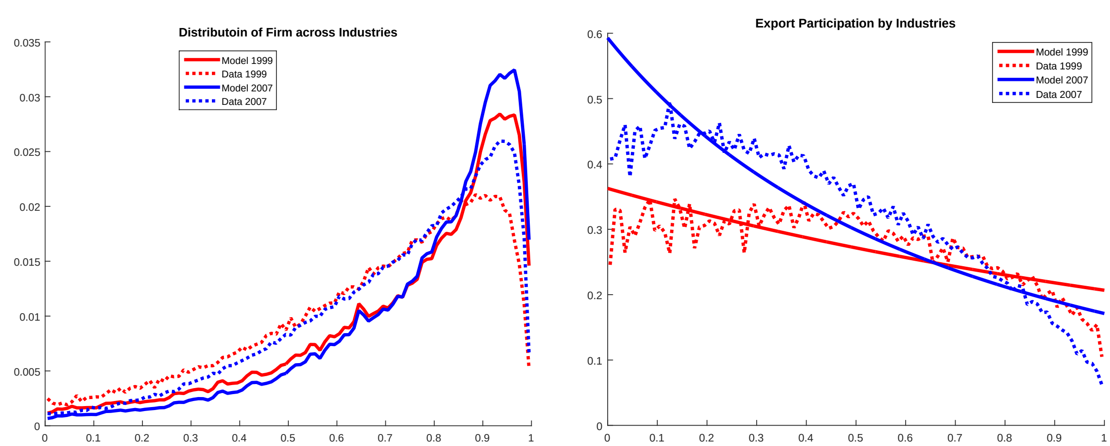

Figure 10: Model fitnon-targeted production and export

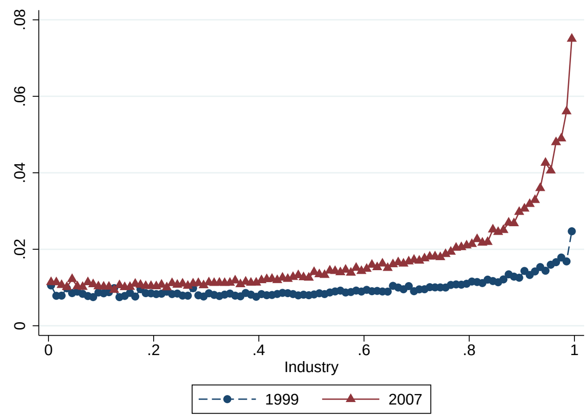

Figure 11: Inferred exporter share for RoW

Redding and Schott (2007). They demonstrate the theoretical possibility of such a channel. Proposition 5 allows us to evaluate its quantitative relevance. According to Proposition 5, the Ricardian comparative advantage could be decomposed as:

$$\frac{\widehat{A(z)}}{\widehat{A^*(z)}} = \underbrace{\lambda A^z}_{exogeneous} \underbrace{(\frac{1+f\chi_z}{1+f\chi_z^*})^{1/a}}_{endogenous}$$

The exogenous component could be readily estimated using the λ and A from Table (5). To compute endogenous component, we could measure the left hand side of the equation and then back out the endogenous component using the equality. We could estimate $\widehat{A(z)}$ for China using the firm data we have but there is no counterpart for RoW. So we need to measure the endogenous component directly. To do that, we need the share of exporter for each industry χ_z^* which is not available. Fortunately, from the proof of Proposition 2, we know that $\chi_z\chi_z^* = \widetilde{\tau}^{-2a}$ where $\widetilde{\tau} \equiv \tau(f)^{\frac{1}{\sigma-1}}$. So the share of exporters for RoW is

$$\chi_z^* = \chi_z^{-1}\left(\tau f^{\frac{1}{\sigma-1}}\right)^{-2a}$$

Then with the data on χ_z, the estimated τ and f, and the given a and σ, we could infer the share of exporters in RoW exporting to China. The result is plotted in Figure 11. We find that the share of exporters to China in RoW is significantly lower than the share of exporters in China to RoW. This is driven by the fact that RoW is much larger than China. But the share is increasing with capital intensity, consistent with RoW's comparative advantage in the capital intensive industries. It is also increasing overtime, especially for the capital intensive industries. This is due to trade liberalization and the increasing size of China.

Now we are ready to decompose the Ricardian comparative advantage. Figure 12 illustrates the decomposition for both 1999 and 2007. The red triangle lines capture the exogenous component λA^z

and the blue dotted lines captures both the exogenous and endogenous component. Thus the difference between the two lines is the endogenous component. The estimated exogenous Ricardian comparative advantage favored the labor intensive industries in 2007. Since the exporter share is relatively higher in the labor intensive industries, the endogenous Ricardian comparative advantage would also favor the labor intensive industries. Thus the exogenous Ricardian comparative advantage is amplified by the endogenous component. This is why the blue dotted line for 2007 is steeper than the red triangle line. The situation is exactly reversed in 1999. The estimated exogenous Ricardian comparative advantage favored the capital intensive sectors and got dampened by the endogenous component.

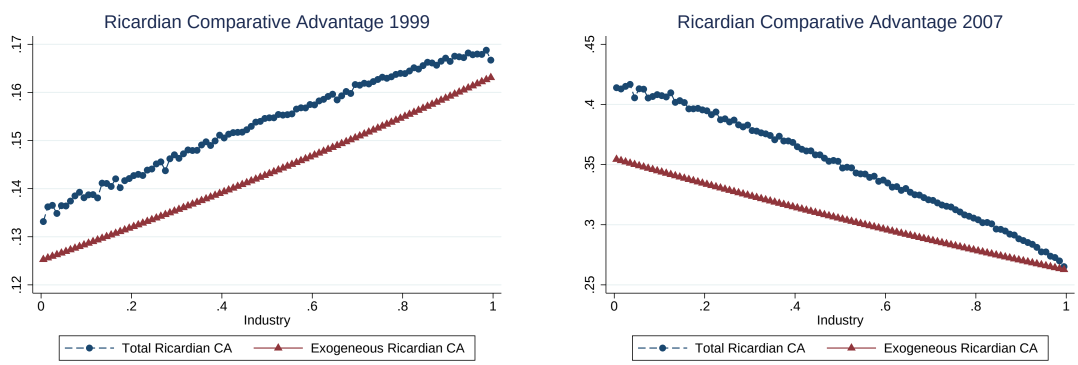

Figure 12: Decomposition of Ricardian comparative advantage

We can apply such decomposition not only for cross sectional productivity differences but also productivity growth overtime. Let x and x' denote variable x for current period and next period respectively. The sectoral productivity growth could be decomposed as: [28]

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

where $\frac{A(z)'}{A(z)}$ absorbs the industry wide productivity growth and $[\frac{(1+f'\chi_z')}{1+f\chi_z}]^{\frac{1}{a}}$ captures productivity growth due to change in export selection. The problem is that we don't observe $\frac{A(z)'}{A(z)}$. So we need to measure the left hand side of the equality in order to evaluate the contribution of endogenous selection given by $[\frac{(1+f'\chi_z')}{1+f\chi_z}]^{\frac{1}{a}}$. We estimate $\frac{E(A(z)\varphi|\varphi\geq\bar{\varphi}_z)'}{E(A(z)\varphi|\varphi\geq\bar{\varphi}_z)}$ as the growth of average sectoral productivity from 1999 to 2007. The sectoral productivity is computed as the weighted average of firm level TFP as estimated by the Levinsohn and Petrin (2003) method. The left panel of Figure 13 plots the estimated productivity growth by industries. As noted earlier, the productivity growth is higher in the labor intensive industries.

[28]The results is immediately from conclusion (a) of proposition 5 by assuming that the constant C is the same overtime. C depends on δ the exogenous death shock for firms, θ the lower bound of the support of Pareto Distribution, and $\widetilde{f}$ the relative fixed entry cost. Any changes in these 3 parameters will be absorbed by the industry-wise productivity change in our accounting setting. If we could identify these 3 parameters, we could further decompose the productivity growth.

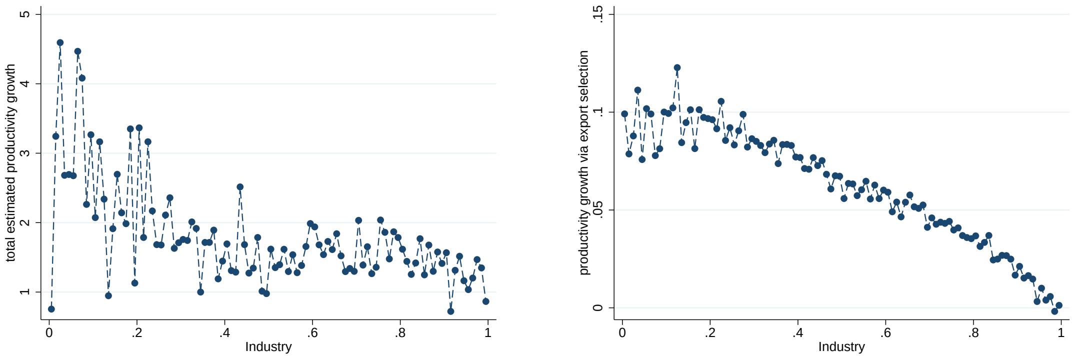

Figure 13: Total productivity growth and productivity growth due to export selection

The right panel plots $[\frac{(1+f'\chi'_z)}{1+f\chi_z}]^{\frac{1}{a}}$. Since χ_z increased in the labor intensive industries, selection to export would lead to a disproportionally higher productivity growth. Although exporter share declined for the capital intensive industries, the relative higher fixed cost of export f in 2007 still implied a tougher selection. So export selection leads to productivity growth almost in every industry. We find the average productivity growth rate weighted by value added across all industries is about 144%. On the other hand, the weighted average of productivity growth rate driven by export selection is about 3.1%. Hence export selection contributes about 2.1% of the overall productivity growth.[29]

5.3 Counterfactual

In this subsection, we conduct counterfactual experiments to investigate the driving forces behind the structural adjustments of Chinese production and export discussed in Section 2. Each experiment replaces the estimated parameters of 1999 by those of 2007, one subset of parameters at one time. The first experiment replaces the technology parameters $\{A,\lambda\}$. The second one replaces the trade cost parameter $\{\tau,\, f\}$. The last one replaces the endowment parameters $\{\frac{L^*}{L},\frac{K^*}{K},\, K/L\}$. Results are presented in Table (8) and Figure 15.

Our first finding is that the rise of China is mostly driven by productivity growth, less by changes in endowment, least by trade liberalization. The relative size of China to RoW $\frac{R^*}{R}$ drops more than half from 16.74 to 10.29 when we change $\{A,\lambda\}$. This is consistent with the findings by Zhu (2012), Tombe and Zhu (2015). [30] They also find that the growth of China is mostly driven by productivity growth. Similar to us, Tombe and Zhu (2015) also find that trade liberalization with RoW only contributes a small fraction to the growth of China. Similar conclusion holds for relative wage $\frac{w^*}{w}$. It drops by about

[29] The small contribution of export selection to overall productivity growth not unique to this study. For example, Baldwin and Gu (2003) also find that Canadian plants that make transition to export market contribute very little overall growth.

[30] Zhu (2012) uses a growth accounting approach. Tombe and Zhu(2015) calibrate a general equilibrium model of trade and migration.

a half when we replace $\{A,\lambda\}$.

Secondly, the fact that production became more capital intensive is mostly driven by changes in endowments. The capital intensity of all firms barely change when we replace $\{A,\lambda\}$ or $\{\tau,\ f\}$ but increases from 0.659 to 0.694 when we replace the endowment parameters. By becoming more capital abundant in 2007, China's comparative disadvantage in the capital intensive industries got weakened. Hence, expected profit would rise for the capital intensive industries. Furthermore, as capital became relative cheaper, fixed entry cost for the capital intensive industries also decreased. In the end, more firms entered the capital intensive industries. On the other hand, China gained Ricardian comparative advantage in the labor intensive industries in 2007 according to our estimate. Given the changes in $\{A,\lambda\}$, the expected profit of operating in the labor intensive industries would increase. But wage also increased. This would drive up the fixed entry cost for the labor intensive industries. It happened that the rising expected profit and rising fixed entry cost balance out and the firm mass distribution stays almost unchanged. Trade liberalization would benefit the comparative advantage industries more. Thus we would expect an expansion of the labor intensive industries. But the effect turned out to be quite small. These results are also demonstrated in the left panel of Figure 15. Only in the counterfactual experiment with endowments, we see the firm mass distribution shifting to the capital intensive industries.

Finally, the fact that exporters did not become more capital intensive and export participation increased in labor intensive industries but dropped in capital intensive ones is mostly driven by technology change. As evident from Table (8), only when $\{A,\lambda\}$ is replaced would the average capital intensity of exporters fall. This is due to a significant rise of exporter in the labor intensive industries and a fall in the capital intensive ones. Export participation increases universally at similar magnitude when we replace $\{\tau,\ f\}$. When replacing the endowment parameters, exporter share declines everywhere, more in the labor intensives, making exporters more intensive on average.

Table 8: Counterfactual

	Baseline Model		Counterfactual		
	(1)	(2)	(3)	(4)	(5)
year	1999	2007	A and λ	τ and f	endowments
R^*/R	16.74	7.47	10.31	16.22	12.31
exporter share: $z \leq 0.5$	0.315	0.423	0.559	0.435	0.196
exporter share: $z \geq 0.5$	0.238	0.228	0.193	0.352	0.196
capital intensity for all firms	0.659	0.688	0.659	0.655	0.694
capital intensity for all exporters	0.630	0.633	0.538	0.634	0.694
aggregate exporter share	0.241	0.230	0.221	0.357	0.196
aggregate export intensity	0.189	0.284	0.161	0.381	0.164
relative wage: w*/w	6.43	2.89	3.44	6.04	5.81

Notes: Column (1) and (2) are model results using the parameters estimated in Table (5). Column (3) replace the estimated technology parameters $\{A,\lambda\}$ of 1999 by the estimates of 2007 and keep other parameters unchanged. Column (4) replaces $\{\tau,f\}$ of 1999 by the estimates of 2007 and keeps other parameters unchanged. Column (5) replaces $\{\frac{L^*}{L},\frac{K^*}{K},\frac{K}{L}\}$ of 1999 by the estimates of 2007 and keeps other parameters unchanged.

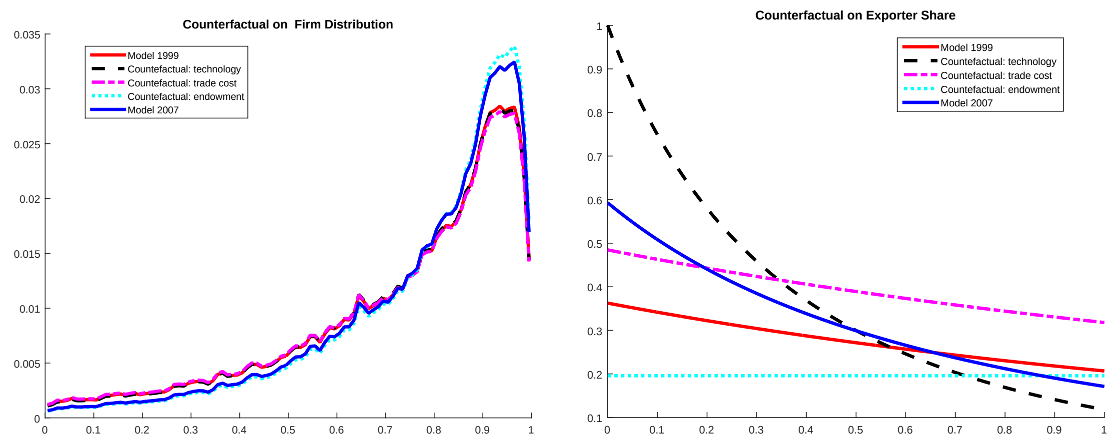

Figure 15: Counterfactuals

5.4 Welfare Analysis

An estimated model also allows us to provide welfare analysis for China and RoW. Given the logarithm utility we use, welfare measured in real consumption is given $W \equiv \exp(U)$. The exact welfare formula is specified in the Appendix 7.7. Armed with estimated parameters and the welfare formula, we first compare the welfare level of China with RoW, and we find

$$\begin{aligned} \frac{W_{1999}}{W^*_{1999}} &= 8.2\% \\ \frac{W_{2007}}{W^*_{2007}} &= 20\% \end{aligned}$$

Though the welfare of China is much lower than RoW, it is catching up quickly. To gauge speed of welfare growth in China and RoW, we estimate the changes in real consumption overtime. [31] The result is presented in column (1) of Table (9) and we have $\frac{W_{2007}}{W_{1999}} = 5.84$ and $\frac{W^*_{2007}}{W^*_{1999}} = 2.43$. It implies that the real consumption grows at 24.7% for China and 11.7% for RoW. [32] To understand the source of these welfare gains, we compute the corresponding welfare number in the counterfactual experiment discussed in previous subsection. The results are reported from column (2) to (4) in Table (9). [33] As can be seen, the welfare gain of China mostly comes from changes in endowment and productivity growth, not much from trade liberalization. For RoW, the welfare gain mostly comes from changes in endowment, less from

[31] As explained in Appendix 7.7, we assume the relative fixed entry cost $\widetilde{f}$, death probability δ and the lower bound of the Pareto distribution θ are constants overtime.

[32] To put these numbers into perspective, the real GDP per capita grows at 12.5% for China and 4.9% for RoW. But since we only capture the manufacturing sector, these numbers are not directly comparable.

[33] In column (2), instead of replacing A, λ, we replace the estimated year 1999 sectoral productivity for China $A(z)$ and RoW $A(z)^*$ by those estimated for 2007. If we only replace A, λ, only changes the relative productivity between China and RoW would be captured. And we would miss out the productivity growth overtime in China and RoW.

productivity growth, and least from trade liberalization.

Table 9: Counterfactual Welfare

	(1) Baseline	(2) $A(z)$ and $A(z)^*$	(3) τ and f	(4) endowments
$\frac{W_{2007}}{W_{1999}}$	5.84	2.32	1.02	2.38
$\frac{W^*_{2007}}{W^*_{1999}}$	2.43	1.31	1.01	1.84

Notes: Column (1) correspond to the welfare growth rate computed using the estimated parameters from Table 5, assuming the death shock δ, lower bound of productivity θ and the relative fixed cost of entry $\widetilde{f}$ do not change between 1999 and 2007. Column (2) computes the hypothetical welfare growth if only $A(z)$ and $A(z)^*$ have changed between 1999 and 2007. It is similar for column (3) and (4) which change only the trade costs and endowments respectively from 1999 to 2007.

5.5 Robustness

In this subsection, we conduct various tests to check the robustness of our estimation results. We first test the robustness of our results with respect to the trade elasticity. In our baseline, we set the trade elasticity $a = 3.43$. In Table (10), we vary the trade elasticity from 2.5 which is at the lower end of the estimate to 7.5 which is at the higher end. By the nature of our calibration, the elasticity of substitution σ also vary accordingly. It turns out that the point estimate of each parameter varies with trade elasticity. However, the direction of the changes in the estimated parameters are the same as our baseline estimation: across all cases, $\frac{K^*}{K}$, A and τ decrease from 1999 to 2007, *vice versa* for $\frac{K}{L}$ and λ.

Table 10: Robustness check with various trade elasticity

Given Parameters			Estimated Parameters				
a	σ	year	K*/K	K/L	A	λ	τ
2.5	2.73	1999	3.88	0.91	1.56	0.10	3.28
		2007	2.88	2.03	0.82	0.33	2.10
5	5.23	1999	4.09	0.91	1.59	0.14	1.81
		2007	2.76	2.03	0.89	0.36	1.49
7.5	7.73	1999	4.21	0.91	1.63	0.15	1.49
		2007	2.34	2.03	0.77	0.36	1.31

Notes: Our baseline estimation result in Table 5 is obtained by setting the Pareto shape $a = 3.43$. This table provides estimation results with a varying from 2.5 to 7.5.

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 did not between 1999-2007; export participation increased in labor intensive industries but dropped in capital intensive ones. 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.

We structurally estimate the model and find that China became relatively more capital abundant overtime, technology improved significantly and favored labor intensive industries between 1999 and 2007. Trade liberalization reduces the variable trade costs by about a quarter. By running counterfactual simulations, we find the adjustment in production pattern is mainly driven by changes in endowment while the changes in export participation is mostly driven by changes in technology. Using the estimated model, we find that export selection shapes the Ricardian comparative advantage extensively but only contributes to about 2.1% of productivity growth overtime. Finally, growth of output and welfare in China is mostly driven by technology change, less by endowment and trade liberalization.

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7 Appendix

7.1 Proof of Proposition 1

The proof follows a similar idea of the proof of Proposition 3 in Bernard, Redding and Schott (2007a). But complication arises once countries start to specialize in certain industries.[34] The idea of the proof is as follows. Suppose that factor prices $\{w, w^*, r, r^*\}$ are known, we would know the factor demand. Then

[34] We will show how to determine the specialization pattern in proposition 2.

factor market clearing condition will pin down the equilibrium. Once the factor prices are known, all the other equilibrium variables are determined.

Firstly, the national revenue for home country and foreign country are $R = wL + rK$ and $R^* = w^*L^* + r^*K^*$ respectively. For industries that home country specialize, the factor demands for these industries are $l(z) = (1-z)b(z)(R+R^*)/w$, $k(z) = zb(z)(R+R^*)/r$. Factor demands in foreign country have symmetric expressions. For industries that both country produce, the industry revenue function is given by equation(3.17) , thus we need to know the firm mass M_z, M_z^*, the pricing index $P(z)$ and $P(z)^*$ and industry average productivity $\widehat{\varphi}_z$ and $\widehat{\varphi}_z^*$ (average price p($\widehat{\varphi}_z$) and p($\widehat{\varphi}_z^*$)) in order to find its factor demand. Firstly, from equation (3.17), we find that:

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

Here $r(\widehat{\varphi}_z) = \frac{R_z}{M_z}$ is the average firm revenue and $\widetilde{p}_z \equiv \frac{p_{zd}(\widehat{\varphi}_z)}{p_{zd}(\widehat{\varphi}_z^*)} = \frac{\widehat{\varphi}_z^* w}{\varepsilon(z)\widehat{\varphi}_z w^*}(\frac{r/w}{r^*/w^*})^z$ is the relative average domestic price between the two countries. Using the zero profit condition(3.9),(3.10) and $\frac{r(\widehat{\varphi}_z)}{r(\bar{\varphi}_z)} = (\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1}$, we have $r(\widehat{\varphi}_z) = (f_z(\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1} + \chi_z f_{zx}(\frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}})^{\sigma-1})\sigma r^z w^{1-z}$. 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 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:

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

$h(z) = (\frac{w}{w^*}(\frac{r/w}{r^*/w^*})^z)^{\frac{a\sigma}{1-\sigma}}$ and $\widetilde{\tau} = \tau f^{\frac{1}{\sigma-1}}$. From (7.3), we see that χ_z is a function of the factor price. From equation (3.11) we have $\Lambda_z = \chi_z^{-1/a} = \frac{\tau P(z)}{P(z)^*}(\frac{fR}{R^*})^{1/(\sigma-1)}$, then $\frac{P(z)}{P(z)^*} = \frac{\chi_z^{-1/a}}{\tau}(\frac{R^*}{fR})^{1/(\sigma-1)}$. which is also function of the factor prices. Combining with equations (3.17) and (3.18), we find that for those industries that both country produce:

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

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

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:

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

Another 2 symmetric equations could be written for the case of foreign country. I(s) is set of the industries that home country specializes and while I(b) is the set of industries that both countries produce. It is determined where either domestic or foreign firm mass is zero. From the definition of price index (3.18), we have $\frac{M_z}{M_z^*} = \widetilde{p}_z^{\sigma-1}\frac{(\frac{P(z)}{P(z)^*})^{1-\sigma} - \chi_z^{-\frac{a+1-\sigma}{a}}\widetilde{\tau}^{-2(a+1-\sigma)}\tau^{1-\sigma}}{1-\chi_z^{\frac{a+1-\sigma}{a}}\tau^{1-\sigma}(\frac{P(z)}{P(z)^*})^{1-\sigma}}$. Thus it is also determined by factor prices.[35] So we have pin down all the factor demand functions to determine the factor prices.

Once the factor prices are known, we could determine the χ_z for all industries which in turn would determine the productivity cutoffs $\bar{\varphi}_z, \bar{\varphi}_{zx}$ for each industry. [36] Once the cutoffs are known, we could further determine the average revenue for each industry using $r(\widehat{\varphi}_z) = (f_z(\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1} + \chi_z f_{zx}(\frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}})^{\sigma-1})\sigma r^z w^{1-z}$. Then we could use the goods market clearing condition (3.17) to determine the firm mass for each industry. Once the firm mass is known, the price index (3.18) for each industry would also be known. ■

7.2 Proof of Proposition 2

Suppose $M_z^* \neq 0$, from the equation of price index (3.18), we could extract the relative firm mass between home and foreign country as:

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

where we have use the result that $\chi_z\chi_z^* = \widetilde{\tau}^{-2a}$ to replace χ_z^* by $\chi_z^{-1}\widetilde{\tau}^{-2a}$. Since $\frac{P(z)}{P(z)^*} = \frac{\chi_z^{-1/a}}{\tau}(\frac{R^*}{fR})^{1/(\sigma-1)}$ and $\widetilde{p}_z = \frac{\widehat{\varphi}_z^* w}{\varepsilon(z)\widehat{\varphi}_z w^*}(\frac{r/w}{r^*/w^*})^z$, as shown in the proof of Proposition 1, we have:

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

Then $\exists\ \chi_z = \frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2$ such that $\frac{M_z}{M_z^*} = 0$. Since $M_z^* > 0$, it must be that $M_z = 0$. And as χ_z decreases such that $\chi_z < \frac{R^*}{fR}(\frac{f}{\widetilde{\tau}^a})^2$, we have $\frac{M_z}{M_z^*} < 0$. Since M_z cannot be negative, we still have $M_z = 0$ and foreign will specialize in these industries. On the other hand, if χ_z increases such that χ_z approaches $\frac{R^*}{fR}$ and $\frac{M_z}{M_z^*} \to +\infty$, or say $\frac{M_z^*}{M_z} \to 0$, which implies $M_z^* = 0$. And if χ_z further increases such that $\chi_z > \frac{R^*}{fR}$, we again have $\frac{M_z^*}{M_z} < 0$. Since M_z^* cannot be negative, M_z^* stays at zero and home will specialize in these

[35] We provide the details in next proof.

[36] This result is proved in Proposition 5

industries. 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 and the other is positive. This is where specialization happens. For industries that both country produces, we have

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

which is a continuous and monotonic function between $[\underline{z}, \overline{z}]$. [37] 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 $\tau = f = 1$ we have $\chi_{\underline{z}} = \chi_{\overline{z}} = \frac{R^*}{R}$. So $\underline{z} = \overline{z}$ and there is no intra-industry trade other than $z = \underline{z} = \overline{z}$. ■

7.3 Proof of Proposition 3

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

[37] This is proved in proposition 4.

$\frac{P(z)}{P(z')} = (\frac{w}{r})^{(z'-z)/\rho}(\frac{b(z)}{b(z')})^{\frac{1}{1-\sigma}}\frac{A(z')\bar{\varphi}_{z'}}{A(z)\bar{\varphi}_z}$. 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 intra-industry trade industries, from equation (3.16) which determines the cut-offs, we find that the first term of left hand side is a decreasing function of $\bar{\varphi}_z$ and the second term is a decreasing function of $\bar{\varphi}_{zx}$ given that $g(\varphi) > 0$, $\bar{\varphi}_z <= \varphi$ and $\bar{\varphi}_{zx} <= \varphi$. Since Λ_z increases with z, it can be shown that $\frac{\partial\bar{\varphi}_z}{\partial z} > 0$ or $\frac{\partial\bar{\varphi}_z}{\partial z} = 0$ cannot maintain the equation. [38] So it must be the case that $\frac{\partial\bar{\varphi}_z}{\partial z} < 0$. Then the first term of equation (3.16) increases with z. To maintain the equation the second term must decrease with z. Thus $\bar{\varphi}_{zx}$ should be an increasing function of z. Similar logic applies for the foreign country: $\frac{\partial\bar{\varphi}^*_z}{\partial z} > 0$ and $\frac{\partial\bar{\varphi}^*_{zx}}{\partial z} < 0$.

For industries that home country specializes: $M^*_z = 0$ and $M_z > 0$. Thus the price indexes at home and foreign are: $P(z) = M_z^{\frac{1}{1-\sigma}} p_{zd}(\widehat{\varphi}_z)$ and $P(z)^* = \chi_z^{\frac{1}{1-\sigma}} M_z^{\frac{1}{1-\sigma}} p_{zx}(\widehat{\varphi}_{zx})$. So we have $\Lambda_z = \frac{\tau P(z)}{P(z)^*}(\frac{fR}{R^*})^{\frac{1}{\sigma-1}} = \chi_z^{\frac{1}{\sigma-1}}\frac{\widehat{\varphi}_{zx}}{\widehat{\varphi}_z}(\frac{fR}{R^*})^{\frac{1}{\sigma-1}}$. Using the definition of $\widehat{\varphi}_z$ and $\widehat{\varphi}_{zx}$, we have $\Lambda_z = (\chi_z \frac{\frac{1}{1-G(\bar{\varphi}_{zx})}\int_{\bar{\varphi}_{zx}}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi}{\frac{1}{1-G(\bar{\varphi}_z)}\int_{\bar{\varphi}_z}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi})^{\frac{1}{\sigma-1}}$ $(\frac{fR}{R^*})^{\frac{1}{\sigma-1}} = (\frac{\int_{\Lambda_z\bar{\varphi}_z}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi}{\int_{\bar{\varphi}_z}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi})^{\frac{1}{\sigma-1}} (\frac{fR}{R^*})^{\frac{1}{\sigma-1}}$ which is an implicit function of Λ_z and $\bar{\varphi}_z$. On the other hand, the free entry condition $\frac{f_z}{\delta}\int_{\bar{\varphi}_z}^{\infty}\left[(\frac{\varphi}{\bar{\varphi}_z})^{\sigma-1} - 1\right]g(\varphi)d\varphi + \frac{f_{zx}}{\delta}\int_{\Lambda_z\bar{\varphi}_z}^{\infty}\left[(\frac{\varphi}{\bar{\varphi}_{zx}})^{\sigma-1} - 1\right]g(\varphi)d\varphi = f_{ez}$ is also an implicit function of Λ_z and $\bar{\varphi}_z$. Solving these two equations together we would have Λ_z and $\bar{\varphi}_z$. Since these two functions hold for all the industries that home specializes, the solution would be the same for all these industries given our assumption that f_z, f_{zx} and f_{ez} are the same.■

[38] This is a proof by contradiction. Suppose $\frac{\partial\bar{\varphi}_z}{\partial z} > 0$, so will $\bar{\varphi}_{zx}$ given $\frac{\partial\Lambda_z}{\partial z} > 0$. Then the left hand side of equation (3.16) will decrease with z. But the right hand side is a constant. Contradiction. Similar argument applies if $\frac{\partial\bar{\varphi}_z}{\partial z} = 0$.

7.4 Proof of Proposition 4

The probability of export is given by $\chi_z = \frac{1-G(\bar{\varphi}_{zx})}{1-G(\bar{\varphi}_z)}$. From Proposition 3, we know that $\frac{\partial \bar{\varphi}_z}{\partial z} < 0$ and $\frac{\partial \bar{\varphi}_{zx}}{\partial z} > 0$ for $z \in (\underline{z}, \overline{z})$. Thus we have $\frac{\partial G(\bar{\varphi}_z)}{\partial z} < 0$ and $\frac{\partial G(\bar{\varphi}_{zx})}{\partial z} > 0$ as long as the cumulative distribution function $G(\varphi)$ is continuous and $G(\varphi)' > 0$. Then it is easy to see that $\frac{\partial \chi_z}{\partial z} < 0$ for $z \in (\underline{z}, \overline{z})$. For $z \in [0, \underline{z}]$, we know that $\frac{\partial \bar{\varphi}_z}{\partial z} = 0$ and $\frac{\partial \bar{\varphi}_{zx}}{\partial z} = 0$ from Proposition 3, so $\frac{\partial \chi_z}{\partial z} = 0$.

Under the assumption that $G(\varphi)$ is Pareto distributed, we have $\chi_z = \Lambda_z^{-a}$ and the $\Lambda_z = \frac{\bar{\varphi}_{zx}}{\bar{\varphi}_z} = \frac{\widehat{\varphi}_{zx}}{\widehat{\varphi}_z}$. Thus using the result that $\Lambda_z = \chi_z^{\frac{1}{\sigma-1}} \frac{\widehat{\varphi}_{zx}}{\widehat{\varphi}_z} (\frac{fR}{R^*})^{\frac{1}{\sigma-1}}$ from the proof of Proposition 3, we have $\chi_z = \frac{R^*}{fR}$ for industries that home specializes. For industries that both country produce, we know that $\chi_z = \frac{\widetilde{\tau}^{-a} f - \varepsilon^a h(z)}{\varepsilon^a f h(z) - \widetilde{\tau}^a}$ from the proof of Proposition 1. Using the chain rule, we have $\frac{\partial \chi_z}{\partial z} = \frac{(1-\widetilde{\tau}^{-2a} f^2)\varepsilon^a h(z) a}{(\varepsilon^a f h(z) - \widetilde{\tau}^a)^2} (\ln(A) - \frac{\sigma}{\sigma-1} \ln(\frac{r/w}{r^*/w^*}))$. Let $B(z) = \frac{(1-\widetilde{\tau}^{-2a} f^2)\varepsilon^a h(z) a}{(\varepsilon^a f h(z) - \widetilde{\tau}^a)^2}$ which is positive, immediately, we have

$$\frac{\partial \chi_z}{\partial z} = B(z)(\ln(A) - \frac{\sigma}{\sigma - 1} \ln(\frac{r/w}{r^*/w^*}))$$

whose sign only depends on $\ln(A)$ and $\frac{\sigma}{\sigma-1} \ln(\frac{r/w}{r^*/w^*})$. [39] For average export intensity for each sector is $\gamma_z \equiv \frac{\chi_z r(\widehat{\varphi}_{zx})}{r(\widehat{\varphi}_z) + \chi_z r(\widehat{\varphi}_{zx})} = \frac{\chi_z f_{zx} (\frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}})^{\sigma-1} \sigma r^z w^{1-z}}{(f_z (\frac{\widehat{\varphi}_z}{\bar{\varphi}_z})^{\sigma-1} + \chi_z f_{zx} (\frac{\widehat{\varphi}_{zx}}{\bar{\varphi}_{zx}})^{\sigma-1}) \sigma r^z w^{1-z}} = \frac{f_{zx}\chi_z}{f_z + f_{zx}\chi_z} = \frac{f\chi_z}{1+f\chi_z}$, 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 as χ_z.$\blacksquare$

7.5 Proof of Proposition 5

From the equation (3.16) for free entry equation, we could calculate that the average of idiosyncratic firm productivity as

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

where $\widetilde{f} = \frac{f_{ez}}{f_z}$. Let $C = (\frac{a}{a+1-\sigma})^{\frac{1}{\sigma-1}} [\frac{(\sigma-1)\theta^a}{(a+1-\sigma)\delta \widetilde{f}}]^{\frac{1}{a}}$, we immediately have

$$\widehat{\varphi}_z = C(1 + f\chi_z)^{1/a}$$

As obvious, $\widehat{\varphi}_z$ is monotonic increasing function of χ_z. As we have proved in Proposition 4, χ_z will be higher in industries with larger comparative advantage, so will $\widehat{\varphi}_z$. Then measured average productivity for each industry would be

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

Thus the measured Ricardian comparative advantage

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

[39] In the proof of Proposition 2, we have shown that $\widetilde{\tau}^{-a} f < 1$. Thus $B(z)$ is positive.

Given our assumptions that $\frac{A(z)}{A^*(z)} = \lambda A^z$ and the expression for $\widehat{\varphi}_z$ above, we have

$$\frac{\widehat{A(z)}}{\widehat{A^*(z)}} = \lambda A^z (\frac{1 + f\chi_z}{1 + f\chi_z^*})^{1/a}$$

which the second results of the proposition. ■

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:

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

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 Welfare

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

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

where the first term is a constant intrinsic to the Cobb-Douglas preferences. The sectoral price index $P(z)$ is given by equation (3.18). Plugging in the average price of domestic varieties and average F.O.B price of foreign varieties respectively: $P_z(\widehat{\varphi}_z) = \frac{\sigma}{\sigma-1} \frac{r^z w^{1-z}}{A(z)\widehat{\varphi}_z}$ and $P_z(\widehat{\varphi}^*_{zx}) = \frac{\sigma}{\sigma-1} \frac{r^{*z} w^{*1-z}}{A(z)^* \widehat{\varphi}^*_{zx}}$, we have

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

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 our 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 our baseline estimation result. However, if we want to know the welfare change at Home and Foreign overtime, we need to know $A(z)$ and $A(z)^*$, the exogenous sectoral level productivities which are not directly observed. However, we could estimate the average TFP for each sector defined as

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

while $\widehat{\varphi}_z$ could be computed from Proposition 5 as $\widehat{\varphi}_z = C(1+f\chi_z)^{1/a}$.[40] Then we could have an estimate of A(z) as:

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

[40]The limitation that we face here is that we cannot identify C. We have to assume that it is constant overtime. Thus we cannot capture the welfare effect due to change in δ, θ or $\tilde{f}$.

and A(z)* is inferred by $A(z)^* = \frac{A(z)}{\lambda A^z}$.

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

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

7.8 CES preferences

Instead of assuming an aggregate Cobb-Douglas utility function, we could assume that

$$\begin{aligned} U &= (\int_0^1 Q(z)^\mu dz)^{1/\mu} \\ Q(z) &= [\int_{\varpi \in \Omega_z} q_z(\varpi)^\rho d\varpi]^{1/\rho} \end{aligned}$$

where U is the upper-tier utility function and $Q(z)$ is the lower-tier utility function and $\mu \in (0, 1], \rho \in (0, 1]$. Then the elasticity of substitution between different industry and within each industry $\eta = \frac{1}{1-\mu} > 1$ and $\sigma = \frac{1}{1-\rho} > 1$. Then the demand for each industry and each variety are given by

$$\begin{aligned} Q(z) &= Q(\frac{P(z)}{P})^{-\eta} \\ q_z(\varpi) &= Q(z)(\frac{p_z(\varpi)}{P(z)})^{-\sigma} \end{aligned} \tag{7.11}$$

where P and $P(z)$ are pricing indexes. Given the equation above, the revenue from domestic and foreign market would be:

[41] Since we normalize $L = 1$, R would be income per capita in China. We divide R^* by L^* to normalize the income to be a per capita measure as well whenever we compute the welfare for RoW.

$$\begin{aligned} r_{zd}(\varphi) &= R(\frac{P(z)}{P})^{1-\eta}(\frac{p_z(\varphi)}{P(z)})^{1-\sigma} = RP^{\eta-1}P(z)^{\sigma-\eta}p_z(\varphi)^{1-\sigma} \\ r_{zx}(\varphi) &= R^*P^{*\eta-1}P^*(z)^{\sigma-\eta}p_{zx}(\varphi)^{1-\sigma} \end{aligned}$$

The profit from domestic and foreign sales are

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

Using the zero-profit condition, we find $\Lambda_z \equiv \frac{\overline{\varphi}_{zx}}{\overline{\varphi}_z}$, the ratio between the cutoff productivity of export and survival is

$$\Lambda_z = \tau(\frac{f_{zx}R}{f_z R^*})^{\frac{1}{\sigma-1}}(\frac{P^*}{P})^{\frac{1-\eta}{\sigma-1}}(\frac{P(z)}{P(z)^*})^{\frac{\sigma-\eta}{\sigma-1}}$$

where $P = [\int_0^1 P(z)^{1-\eta}dz]^{\frac{1}{1-\eta}}$ is the aggregate pricing index (P* for foreign). If $\eta = 1,$ we are back to the Cobb-Douglas world. Using the equation above, we can prove that our propositions in the main text still hold. Especially, under the assumption of Pareto Distribution, the conditional probability of export is given by

$$\chi_z = \begin{cases} \left[\tau^{\eta-1}\frac{fR}{R^*}(\frac{P}{P^*})^{\eta-1}\right]^{\frac{a(\sigma-1)}{(1-\eta)(\sigma-1)-a(\sigma-\eta)}} & z \in [0, \underline{z}] \\ \frac{\widetilde{\tau}^{-a}f-\varepsilon^a g(z)}{\varepsilon^a f g(z)-\widetilde{\tau}^a} & z \in (\underline{z}, \overline{z}) \end{cases}$$

7.9 Additional Tables

Table A.1: Statistical Summary of Main Variables

Variables	mean in 1999	mean in 2007
revenue(¥*1,000*)	50,932	117,888
value added(¥*1,000*)	14,130	31,983
sales(¥*1,000*)	49,306	115,413
export(¥*1,000*)	8,932	24,052
employee	329	219
total profit(¥*1,000*)	1,867	6,814
wage(¥*1,000*)	3,383	5,429

Notes: We followed Brandt et al (2012) to clean the sample and only include manufacturing firms with more than 8 employees, positive output and fixed assets and drop firms with capital intensity less than zero or greater than one. We are left with 116,905 and 290,382 firms in 1999 and 2007 which represent about 80% and 93% of the original sample of manufacturing firms respectively.

Table A.2: 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
	All Industries	0.74	0.21	0.62	0.23

Notes: The table computes the average and standard deviation of the capital intensity for exporters and non-exporters for each two digit CIC manufacturing industry in 2007.

7.10 Robustness of the motivating evidences

In this subsection, we examine the robustness of our motivating evidences that productivity growth is faster in labor intensity industries, production becomes more capital intensive and export participation increases for labor intensive industries but falls for capital intensive industries.

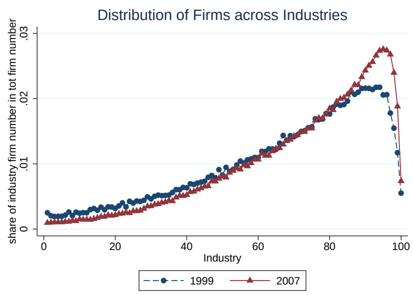
First, we use two alternative measures of productivity labor productivity and TFP as estimated by the Olley and Pakes (1996) method rather than using Levinsohn and Petrin (2003) as in the main text. The results are presented in Figure A1. Again, we find productivity growth is relative faster in labor intensive industries.

We then check whether our motivating evidences are driven by any institutional particular to China. We examine the role of Multi Fibre Agreement (MFA), State Owned Enterprise (SOE) and processing trade. Each time, we exclude firms subject to these institutions respectively and regenerate our basic motivating graphs. The results are shown in Figure A2. They are qualitatively consistent with the evidences in the main text.

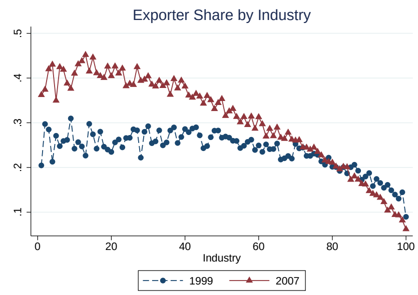
Finally, we check whether our findings are driven by definition for industries. Instead of using the industry classification of "HO aggregate", we use the 4-digit Chinese Industry Classification (CIC) to see whether our evidences still hold. The results are presented Figure A3. The results are consistent with our evidences using HO aggregate as industries classification.

Figure A1: robustness by TFP growth

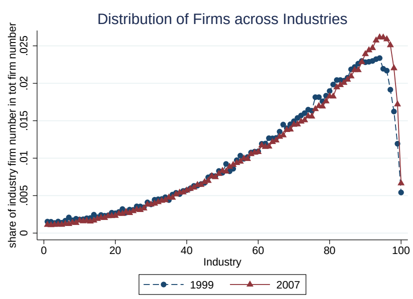
Notes: (a) Labor productivity is measured as real valued added per worker. (b)TFP is estimated as in Olley-Pakes (1996).



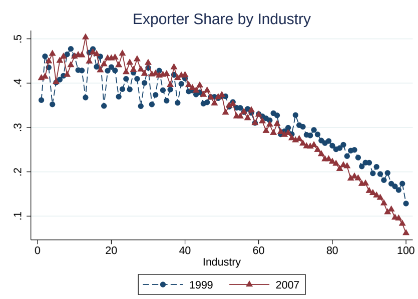
MFA: firm mass



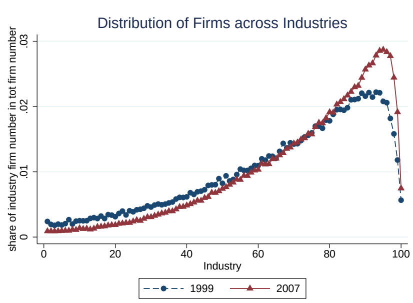
MFA: exporter share



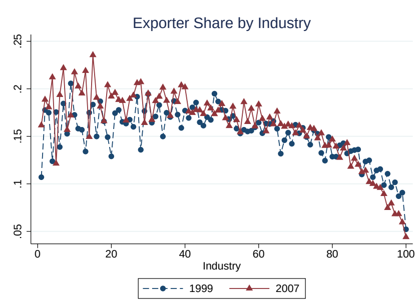
SOE: firm mass



SOE: exporter share



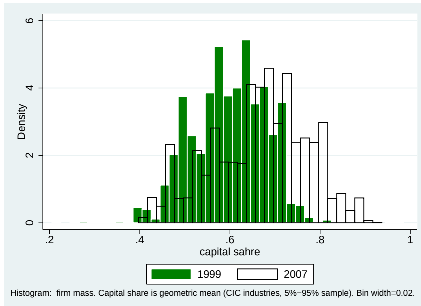
Processing Trade: firm mass



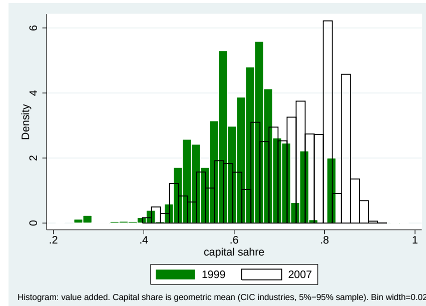
Processing Trade: exporter share

Figure A2: robustness by excluding subsamples

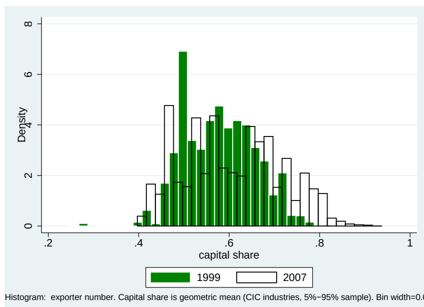
Notes: (a) Industry classification is "HO aggregate" as in the main text. (b) The MFA charts are produced by excluding the textile industries: 2-digit CIC industries of 17 and 18. (b) The SOE charts are by excluding state owned firms. (c) The Processing Trade charts are by excluding pure exporters, i.e., firms which export more than 70% of the outputs.



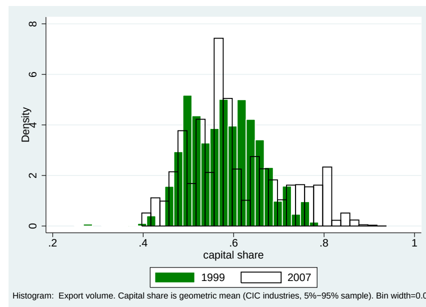
firm mass



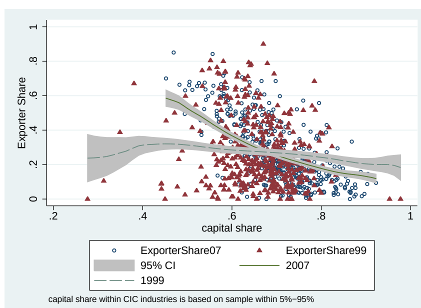
value added



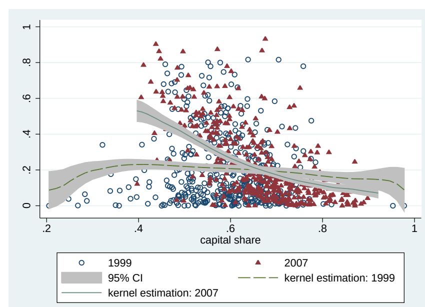
exporter distribution



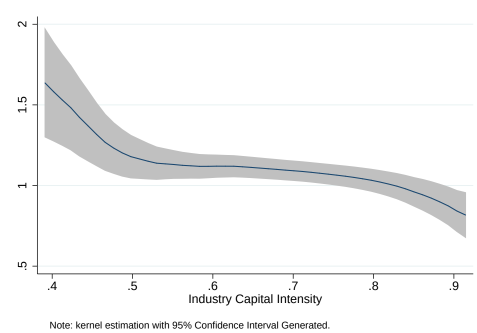
export volume



exporter share



export intensity



Sectoral TFP growth

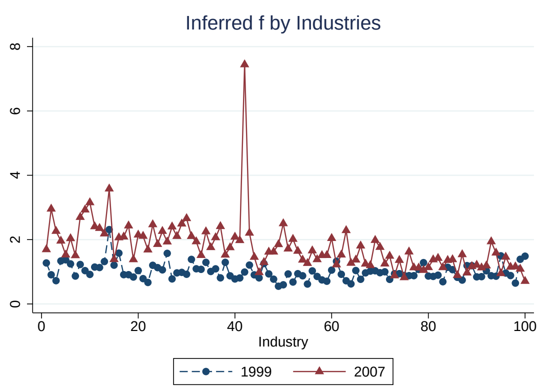
Figure A3: Motivating evidences in CIC industry classfication

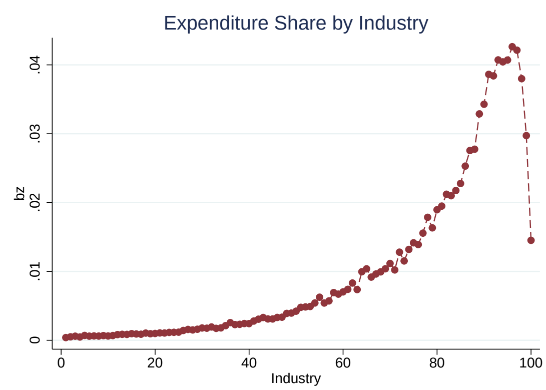
Notes: (a) Industry classification is 4-digit CIC manufacturing industries. (b)Capital intensity is measured as the geometric mean across firms for each industry. (c) Non-parametric local polynomial is used to capture the trend in the data. (d) For the chart of TFP growth, capital intensity is measured as the average of 1999 and 2007 for each industry. Industry TFP is measured as the weighted average of firm level TFP, dropping the top and bottom 1% within each industry.

7.11 Additional Figures on Parameterization

To estimated the relative fixed costs of export $f \equiv \frac{f_{zx}}{f_z}$, we use the structural relationship that export intensity $\gamma_z = \frac{f\chi_z}{1+f\chi_z}$. Given that we observe both γ_z and χ_z, f is estimated by sector using $f = \frac{\gamma_z}{\chi_z(1-\gamma_z)}$. The result is presented in the left figure below.

The expenditure share b(z) is computed as the average of consumption share during 2000-2006. For each industries, the ratio of aggregate import to aggregate export is estimated for all the matched firms between the Chinese Annual Industry Survey and the Chinese Custom Data. Then the import of each industry is estimated as the aggregate export of all the firms in the survey multiplied by the ratio. Once import is estimated, consumption for is simply output plus import minus export. Up till this point, we only estimate a discrete distribution. To infer the expenditure function b(z) across the whole support on [0,1] as a continuous functions, we interpolate the expenditure function by linear interpolation. The result is shown in the right figure below.





8 Online Appendix(not for publication)

8.1 Identification

We first prove that given b(z), χ_z and $\frac{R^*}{R}$ only depend on $\{\frac{K^*}{K}, \frac{L^*}{L}, A, \lambda, a, f, \tau, \gamma, \sigma\}$. Then we prove that firm mass distribution m_z depends on $\{\frac{K^*}{K}, \frac{L^*}{L}, \Psi, \lambda, a, f, \tau, \gamma, \sigma\}$ and $\frac{K}{L}$

- Starting from factor market clearing condition
  - For sectors that are specialized by either country, we have

$$L_s = \int_0^{\underline{z}} l(z)dz = \frac{R+R^*}{w}\int_0^{\underline{z}}(1-z)b(z)dz = \frac{R+R^*}{w}N$$
$$K_s = \int_0^{\underline{z}} k(z)dz = \frac{R+R^*}{r}\int_0^{\underline{z}} zb(z)dz = \frac{R+R^*}{r}B$$
$$L_s^* = \int_{\overline{z}}^1 l^*(z)dz = \frac{R+R^*}{w^*}\int_{\overline{z}}^1(1-z)b(z)dz = \frac{R+R^*}{w^*}C$$
$$K_s^* = \int_{\overline{z}}^1 k^*(z)dz = \frac{R+R^*}{r^*}\int_{\overline{z}}^1 zb(z)dz = \frac{R+R^*}{r^*}D$$

where $N \equiv \int_0^{\underline{z}}(1-z)b(z)dz, B \equiv \int_0^{\underline{z}} zb(z)dz, C \equiv \int_{\overline{z}}^1(1-z)b(z)dz$ and $D \equiv \int_{\overline{z}}^1 zb(z)dz.$

  - For sectors that are produced by both countries, we have

$$L_{int} = \frac{1}{w}\int_{\underline{z}}^{\overline{z}} b(z)(1-z)[\frac{R}{1-\widetilde{\tau}^{-a}\varepsilon^a fh(z)} - \frac{fR^*}{\widetilde{\tau}^a\varepsilon^a h(z)-f}]dz = \frac{R}{w}E - \frac{R^*}{w}F$$
$$K_{int} = \frac{1}{r}\int_{\underline{z}}^{\overline{z}} b(z)z[\frac{R}{1-\widetilde{\tau}^{-a}\varepsilon^a fh(z)} - \frac{fR^*}{\widetilde{\tau}^a\varepsilon^a h(z)-f}]dz = \frac{R}{r}G - \frac{R^*}{r}H$$
$$L_{int}^* = \frac{1}{w^*}\int_{\underline{z}}^{\overline{z}} b(z)(1-z)\varepsilon^a h(z)[\frac{R^*}{\varepsilon^a h(z)-f\widetilde{\tau}^{-a}} - \frac{fR}{\widetilde{\tau}^a-\varepsilon^a fh(z)}]dz = \frac{R^*}{w^*}I - \frac{R}{w^*}J$$
$$K_{int}^* = \frac{1}{r^*}\int_{\underline{z}}^{\overline{z}} b(z)z\varepsilon^a h(z)[\frac{R^*}{\varepsilon^a h(z)-f\widetilde{\tau}^{-a}} - \frac{fR}{\widetilde{\tau}^a-\varepsilon^a fh(z)}]dz = \frac{R^*}{r^*}X - \frac{R}{r^*}Y$$

where $E \equiv \int_{\underline{z}}^{\overline{z}} \frac{b(z)(1-z)}{1-\widetilde{\tau}^{-a}\varepsilon^a fh(z)}dz$, $F \equiv \int_{\underline{z}}^{\overline{z}} \frac{fb(z)(1-z)}{\widetilde{\tau}^a\varepsilon^a h(z)-f}dz, G \equiv \int_{\underline{z}}^{\overline{z}} \frac{b(z)z}{1-\widetilde{\tau}^{-a}\varepsilon^a fh(z)}dz, H \equiv \int_{\underline{z}}^{\overline{z}} \frac{fb(z)z}{\widetilde{\tau}^a\varepsilon^a h(z)-f}dz, I \equiv$

$$\int_{\underline{z}}^{\overline{z}} \frac{b(z)(1-z)\varepsilon^a h(z)}{\varepsilon^a h(z)-f\widetilde{\tau}^{-a}}dz,\ J \equiv \int_{\underline{z}}^{\overline{z}} \frac{fb(z)(1-z)\varepsilon^a h(z)}{\widetilde{\tau}^a-\varepsilon^a fh(z)}dz,\ X \equiv \int_{\underline{z}}^{\overline{z}} \frac{b(z)z\varepsilon^a h(z)}{\varepsilon^a h(z)-f\widetilde{\tau}^{-a}}dz \text{ and } Y \equiv \int_{\underline{z}}^{\overline{z}} \frac{fb(z)z\varepsilon^a h(z)}{\widetilde{\tau}^a-\varepsilon^a fh(z)}dz.$$

Using factor market clearing condition,

$$\begin{aligned} L_s + L_{int} &= L \\ K_s + K_{int} &= K \\ L_s^* + L_{int}^* &= L^* \\ K_s^* + K_{int}^* &= K^* \end{aligned}$$

We have

$$\begin{aligned} L &= \frac{R}{w}(N+E) + \frac{R^*}{w}(N-F) \\ K &= \frac{R}{r}(B+G) + \frac{R^*}{r}(B-H) \\ L^* &= \frac{R}{w^*}(C-J) + \frac{R^*}{w^*}(C+I) \\ K^* &= \frac{R}{r^*}(D-Y) + \frac{R^*}{r^*}(D+X) \end{aligned}$$

Moreover, given $R = wL + rK$ and $R^* = w^*L^* + r^*K^*$,we have

$$\frac{R^*}{R} = \frac{1-N-E-B-G}{N-F+B-H} = \frac{C+D-J-Y}{1-C-D-X-I}$$

Since N, B, C,..., I, J, X and Y only depend on $\{\frac{r^*}{r}, \frac{w^*}{w}, A, \lambda, a, f, \tau, \gamma, \sigma\}$[42], according to the equation above, $\frac{R^*}{R}$ also depends on $\{\frac{r^*}{r}, \frac{w^*}{w}, A, \lambda, a, f, \tau, \gamma, \sigma\}$ only.

- On the other hand,

$$\begin{aligned} \frac{L^*}{L} &= \frac{w}{w^*}\frac{C-J+(C+I)\frac{R^*}{R}}{N+E+(N-F)\frac{R^*}{R}} \\ \frac{K^*}{K} &= \frac{r}{r^*}\frac{(D-Y)+(D+X)\frac{R^*}{R}}{B+G+(B-H)\frac{R^*}{R}} \end{aligned}$$

Then given $\{A, \lambda, a, f, \tau, \gamma, \sigma\}$, there is an one to one mapping between $\{\frac{K^*}{K}, \frac{L^*}{L}\}$ and $\{\frac{r^*}{r}, \frac{w^*}{w}\}$.

- So $\chi_z = \begin{cases} \frac{R^*}{fR} & z \in [0, \underline{z}] \\ \frac{\widetilde{\tau}^{-a}f-\varepsilon^a h(z)}{\varepsilon^a fh(z)-\widetilde{\tau}^a} & z \in (\underline{z}, \overline{z}) \end{cases}$ depends on $\{\frac{K^*}{K}, \frac{L^*}{L}, A, \lambda, a, f, \tau, \gamma, \sigma\}$ only.

[42] Given b(z), N, B, C, ..., I, J, X and Y are integrals of function of $\varepsilon^a h(z)$ defined over a intersection given by 0, $\underline{z}$, $\overline{z}$ and 1. $\varepsilon^a h(z)$, $\underline{z}$ and $\overline{z}$ are functions of $\{\frac{r^*}{r}, \frac{w^*}{w}\Psi,\lambda,a,f,\tau,\gamma,\sigma\}$ only.

- Next, we prove that firm mass distribution m_z depends on $\{\frac{K^*}{K}, \frac{L^*}{L}, A, \lambda, a, f, \tau, \gamma, \sigma\}$ and $\frac{K}{L}$.

  We define the firm mass distribution as

$$m_z = \frac{M_z}{\int_0^{\overline{z}} M_z dz}$$

  For industris that home country specializes

$$\begin{aligned} b(z)(R+R^*) &= M_z r(\widetilde{\varphi}_z) \\ &= M_z \frac{a\sigma f_z r^z w^{1-z}(1+f\chi_z)}{a+1-\sigma} \end{aligned}$$

  Thus

$$\begin{aligned} M_z (\frac{r}{w})^z &= \frac{b(z)(R+R^*)}{\frac{a\sigma f_z w}{a+1-\sigma}(1+f\chi_z)} \\ &= b(z)L\frac{(1+\frac{rK}{wL})(1+\frac{R^*}{R})}{\frac{a\sigma f_z}{a+1-\sigma}(1+f\chi_z)} \end{aligned}$$

  Similarly, for industries that both countries produces:

$$M_z = \frac{b(z)L(1+\frac{rK}{wL})(1+\frac{R^*}{R})}{\frac{a\sigma f_z}{a+1-\sigma}(1+f\chi_z)(1+\frac{M_z^* r(\widetilde{\varphi}_z^*)}{M_z r(\widetilde{\varphi}_z)})(\frac{r}{w})^z}$$

  Then, according to the definition of m(z), we have

$$\begin{aligned} m_z &= \frac{M_z}{\int_0^{\overline{z}} M_z dz} \\ &= \frac{b(z)L\frac{(1+\frac{rK}{wL})(1+\frac{R^*}{R})}{\frac{a\sigma f_z}{a+1-\sigma}(\frac{r}{w})^z(1+f\chi_z)}}{\int_0^{\underline{z}} b(z)L\frac{(1+\frac{rK}{wL})(1+\frac{R^*}{R})}{\frac{a\sigma f_z}{a+1-\sigma}(1+f\chi_z)(\frac{r}{w})^z}dz + \int_{\underline{z}}^{\overline{z}} \frac{b(z)L(1+\frac{rK}{wL})(1+\frac{R^*}{R})}{\frac{a\sigma f_z}{a+1-\sigma}(1+f\chi_z)(1+\frac{M_z^* r(\widetilde{\varphi}_z^*)}{M_z r(\widetilde{\varphi}_z)})(\frac{r}{w})^z}dz} \\ &= b(z)\frac{(\frac{r}{w})^{-z}(1+f\chi_z)^{-1}}{\int_0^{\underline{z}} b(z)(\frac{r}{w})^{-z}(1+f\chi_z)^{-1}dz + \int_{\underline{z}}^{\overline{z}} \frac{b(z)(\frac{r}{w})^{-z}}{(1+\frac{M_z^* r(\widetilde{\varphi}_z^*)}{M_z r(\widetilde{\varphi}_z)})(1+f\chi_z)}dz} \end{aligned}$$

  for the industries that home specializes. As for industries that both countries produce:

$$
\begin{aligned}
m_z &= \frac{M_z}{\int_0^{\overline{z}} M_z dz} \\
&= b(z)\frac{\frac{(\frac{r}{w})^{-z}}{(1+\frac{M_z^* r(\tilde{\varphi}_z^*)}{M_z r(\tilde{\varphi}_z)})(1+f\chi_z)}}{\int_0^{\underline{z}} b(z)(\frac{r}{w})^{-z}(1+f\chi_z)^{-1}dz + \int_{\underline{z}}^{\overline{z}} \frac{b(z)(\frac{r}{w})^{-z}}{(1+\frac{M_z^* r(\tilde{\varphi}_z^*)}{M_z r(\tilde{\varphi}_z)})(1+f\chi_z)}dz}
\end{aligned}
$$

It is obvious that m$_z$ depends on $\frac{r}{w}$ which is determined by

$$
\begin{aligned}
\frac{r}{w} &= \frac{L}{K}\frac{R(B+G)+R^*(B-H)}{R(N+E)+R^*(N-F)} \\
&= \frac{L}{K}\frac{(B+G)+\frac{R^*}{R}(B-H)}{(N+E)+\frac{R^*}{R}(N-F)}
\end{aligned}
$$

Thus $\frac{r}{w}$ not only depends on $\{\frac{K^*}{K}, \frac{L^*}{L}, A, \lambda, a, f, \tau, \gamma, \sigma\}$ but also $\frac{K}{L}$. So is m_z.