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The Graduate School
Department of Economics

TWO ESSAYS ON INTERNATIONAL TRADE

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Abstract

This dissertation includes two chapters on international trade. My research focuses on understanding the welfare implication of processing trade policy–an export promotion policy commonly adopted by developing countries, and quantifying these effects. In chapter 1, I build and structurally estimate a multi-country general equilibrium model, and quantify the impact of processing trade policy on welfare. In chapter 2, I extend the model in chapter 1 into a multi-country growth model with idea diffusion through trade, and the calibrated growth model shows that the welfare implication of processing trade policy is reversed in the presence of global idea diffusion.

Chapter 1: Processing Trade and International Trade: Evidence from Chinese Firms

Processing trade policy is often used by developing countries, and export value-added tax rebate is common for countries at different stages of economic development. I build a multi-country general equilibrium model to investigate these policies. I structurally estimate the model using China's firm-level data, and utilize the additional information from processing trade to identify the elasticity of substitution. In the counterfactual exercise that China eliminates the duty drawback for processing trade, its exports are reduced by about 20%, but welfare is increased by about 4%.

Chapter 2: Processing Trade and Global Idea Diffusion

Processing trade allows firms to claim an import duty exemption for imported intermediates used to produce exports. I study the welfare implication of this policy in a multi-country growth model in which ideas diffuse through trade. New potential producers continuously arrive in each country, and learn from all the sellers operating in the country (including foreign sellers). If a country is far from world technology frontier, processing trade affects the welfare in the country through a trade-off between the loss of varieties (static losses) and the increase in aggregate productivity (dynamic gains). The calibrated model shows that Chinas welfare decreases by 7.6% if China eliminates the duty drawback for processing trade, and the magnitude of the dynamic gains is about three times larger than that of the static losses.

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Dedication

To my parents.

Chapter 1

Processing Trade and International Trade: Evidence from Chinese Firms

1.1 Introduction

Processing trade allows firms to claim an import duty exemption for imported inputs used to produce exports. For example, Foxconn China can claim a duty exemption for imported inputs used to assemble iPhones sold to the rest of the World, such as cameras imported from Japan, memory chips from South Korea and processors from the United States etc. This policy is also called a duty drawback scheme in some countries. Many developing countries have adopted this policy,[1] and processing exports account for 18% of world total exports from 2000 to 2008 (Maurer and Degain (2012)). Among these countries, China and Mexico are the two largest users of this policy, with China accounting for about 67% and Mexico another 18%(Maurer and Degain (2012)). Moreover, processing exports make up more than half of their total manufacturing exports during this period (Koopman et al. (2012), Bergin et al. (2009)).

How do these policies affect aggregate bilateral trade and production? What are

[1] Processing trade is usually adopted in developing countries in terms of Export Processing Zones (EPZ), and processing trade is restricted to certain geographic area. Amirahmadi and Wu (1995) is a good review of the history and development of EPZ.

the welfare implications? In this paper, I build a multi-country general equilibrium model based on Eaton et al. (2011), including processing trade policy and export VAT rebate. I structurally estimate the model with Chinese firm-level data, and use the estimated model to answer these questions.

I examine entry behavior and sales at the firm-level in different export markets for both processing and ordinary trade by using China's custom data.[2] These data reveal that Chinese manufacturing firms' entry patterns and sales distribution are almost identical for both processing and ordinary trade:[3] (i) the number of Chinese firms selling to a market tends to increase with size of the market for both processing and ordinary trade; (ii) the shapes of sales distributions are almost identical for both processing and ordinary trade across destination markets.[4]

To conform with these features in Chinese data, I extend the structure of Melitz (2003), as augmented by Helpman et al. (2004) and Chaney (2008) by introducing trade mode and market-specific fixed cost of entry. To connect more formally to the Chinese firm-level data,[5] I also introduce trade mode, market and firm-specific heterogeneity in entry costs and demand, and Arkolakis (2010) formulation of market access costs similarly as Eaton et al. (2011).

I use the simulated method of moments to estimate all parameters in the model except the elasticity of substitution, as do Eaton et al. (2011), but with two more moments related to processing trade. By utilizing the additional information of

[2]Eaton et al. (2011) found striking regularities associated with French manufacturing firms' entry patterns and sales distributions across 113 destination markets, and they argues that any successful model of trade and market structure must confront with these key features of the data.

[3]China's custom data separately records processing and ordinary trade at the firm-level, where ordinary trade refers to transactions that firms sell their products in a foreign markets without tariff exemption for imported material used to produce these products, and processing trade refers to transactions that firms sell their products in a foreign market with tariff exemption on imported material used to produce these products.

[4]Details can be found in section 2.

[5]The structure of Melitz (2003), as augmented by Helpman et al. (2004) and Chaney (2008),which is characterized by Pareto distribution of firms' efficiency, Dixit-Stigliz demand, iceberg trade cost and fixed cost of entry, fails to term with some features in French manufacturing firms' entry patterns and sales distributions: (i) Firms do not enter markets according to an exact hierarchy. (ii) Their sales in these penetrated markets deviate from the exact correlation that the basic model predicts. (iii) Exporting firms sell too much in their domestic market. (iv) Too many firms sell small amounts in a destination. Eaton et al. (2011) introduces market and firm-specific heterogeneity in entry costs and demand, and incorporates Arkolakis (2010) formulation of market access costs to reconcile these features in data. These features are also shown in Chinese data.

processing trade, I can identify and estimate the elasticity of substitution.

With all estimated parameters, I compute the counterfactual equilibrium in which China shuts down the processing trade policy. China's export are reduced by 20%, and welfare is improved by around 4%. The most popular exporting destinations of Chinese firms, such as U.S. , Japan and U.K. etc, have welfare loss of less 1%, while China's competitors like Vietnam, Thailand have welfare gain, but also less than 1%. The intuition behind these results is quite straightforward. With shutdown of processing trade policy in China, Chinese firms sell more varieties in domestic market and export less varieties to foreign markets, and the price index declines much more than the wage rate in China; price indices in countries, such as U.S., Japan and U.K. etc, increases more than the wage rate since less varieties imported from China; countries, such as Vietnam and Thailand etc, start to produce and export more varieties, driving up the real wages.

This paper contributes to the literature looking into processing trade in developing countries. This paper models processing trade by incorporating trade mode and market-specific fixed costs of entry into the stand model in trade literature, and the model is very tractable to quantify the welfare implication of processing trade. The model is consistent with the fact found in Koopman et al. (2012) and Kee and Tang (2016) that domestic value added is lower in China's processing exports than ordinary exports because firms in the model use more imported inputs to produce processing exports compared with ordinary exports. Moreover, the model in this paper implies that the share of processing exports in total exports decreases as the import tariffs fall (Brandt and Morrow (2017)).

Section 2 explores three empirical regularities as Eaton et al. (2011), separating ordinary exports and processing exports. Section 3 presents the extended model which captures the empirical regularities described in section 2. Section 4 explains how I estimate the model. Section 5 defines the general equilibrium and calculates counterfactual.

1.2 Empirical Regularities

Eaton et al. (2011) found striking regularities associated with French manufacturing firms' entry patterns and sales distributions across 113 destinations. In this

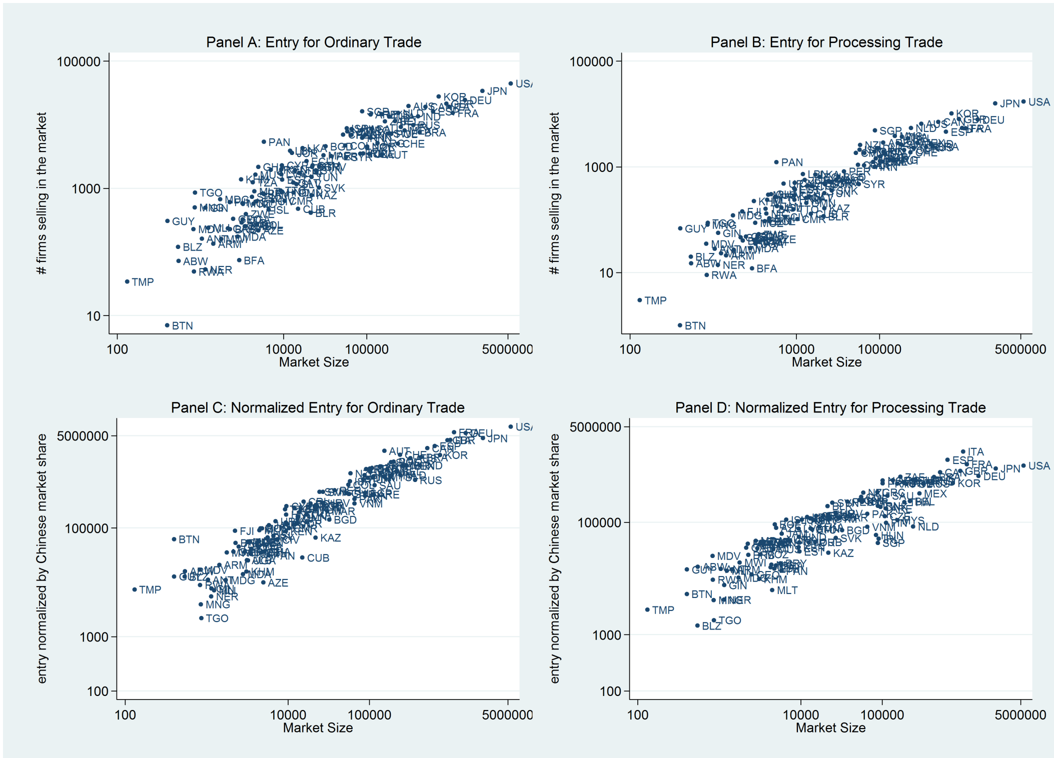

Figure 1.1: Entry and Sales by Market Size

section, I establish the similar empirical work as Eaton et al. (2011) by using Chinese firm-level data for both processing and ordinary trade, and these empirical patterns motivates how to include processing trade in the model.

1.2.1 Market Entry

Panel A and B in Figure 1.1 plot the number of Chinese manufacturing firm selling to a market against total manufacturing absorption in that market via ordinary trade and processing trade, respectively. The number of firms selling to a market tends to increase with size of the market regardless of trade mode.

I normalize the number of firms by the share of China in the market for both ordinary trade and processing trade, and plot the normalized entry against the total manufacturing absorption in that market, which are shown in panel C and D of Figure 1.1. Now the relationship is not only very tight, but linear in log especially for ordinary trade.

Table 1.1 lists each of the strings of top-seven destinations that obey a hierar-

Table 1.1: Chinese Firms Selling to Strings of Top 7 Countries

	Number of Chinese Exporters	
Export String	**Ordinary**	**Processing**
US	2657	1630
US-JP	815	471
US-JP-KR	484	207
US-JP-KR-DE	215	63
US-JP-KR-DE-UK	154	80
US-JP-KR-DE-UK-CA	218	116
US-JP-KR-DE-UK-CA-AU	942	586

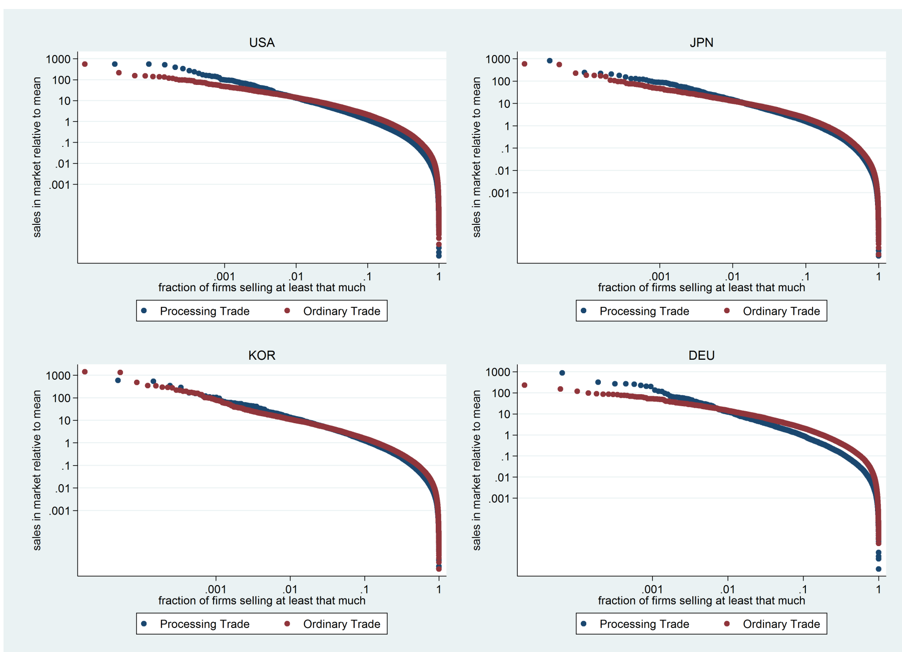

Figure 1.2: Ordinary and Processing Sales Distribution by Country

chical structure with ordinary trade and processing trade.

1.2.2 Sales Distribution

I plot the sales of each firm in a particular market (relative to mean sales there) against the fraction of firms selling in the market who sell at least that much.

Figure 1.2 plots results of ordinary trade and processing trade for U.S., Japan, Korea and Germany. Graphs for ordinary export and processing export of all four countries almost identical, which implies that I can introduce a different fixed cost for processing export to match this fact.

1.3 Model

The quantitative general equilibrium model builds on Eaton et al. (2011). There are N countries. and countries are denoted by i or n. Country i is endowed with a measure of labor L_i, and labor is the primary factor of production. Labor is mobile within country, but immobile across countries.

1.3.1 Technology

A continuum of intermediate goods is produced. The production technology of intermediate good ω from country i with efficiency $z_i(\omega)$ is given by

$$q_i(\omega) = z_i(\omega)\left[l_i(\omega)\right]^{\beta}\left[m_i(\omega)\right]^{1-\beta},$$

where $l_i(\omega)$ is labor and $m_i(\omega)$ is the composite intermediate good used for production of intermediate good ω. The parameter $\beta \geq 0$ is the output elasticity of labor.[6]

1.3.2 Policies

Two policies are exogenously given in each country. The first is processing trade policy: a firm can claim import duty exemption for imported inputs used for producing exported goods, but no import duty exemption for imported inputs for domestic sales. In the model, firms can claim import duty exemption for imported intermediate goods aggregated in the composite intermediate goods used as inputs for producing exports. To simplify the notation, let O and P denote ordinary trade and processing trade, respectively, and let TM denote trade mode that can

[6]Composite intermediate goods are put into the production function above only describing input usage of an average firm in a country, hence, no heterogeneity on the share of input usage across firms, but it is necessary to include input usage to model processing trade policy.

be either O or P. Let $\mathbb{I}_i^P$ denote the choice of processing trade policy in country i, where $\mathbb{I}_i^P$ equals to 1 if country i chose processing trade policy, and 0 otherwise. Let $\mathbb{I}_i^O$ denote ordinary trade in country i, and the value is equal to 1. Let τ_{ni} denote 1 plus the ad-valorem flat-rate tariff of intermediate goods imported by country n from country i.

The second policy is export value-added tax (VAT) rebate policy: a firm can claim a full or partial refund of VAT applied to exported goods. Value-added Tax (VAT) is a key component of the tax system in over 140 countries at different stages of economic development, raising about 25% of world tax revenue (Harrison and Krelove (2005)). Export VAT rebates are common in these countries having VAT, such as the European Union, Canada, China, etc.[7] Let t_{ni} denote the applied VAT rate for the sales generated by firms from country i selling products to market n, particularly,

$$t_{ni} = \begin{cases} \text{VAT rate in country } i, & \text{if } n = i; \\ \text{VAT rate minus export VAT rebate rate in country } i, & \text{if } n \neq i. \end{cases}$$

1.3.3 Unit Costs and Firm Heterogeneity

A firm from country i can potentially sell its products in market n through ordinary trade, processing trade or both. Suppose a firm from country i selling its products in market n through both ordinary and processing trade. I consider products sold through ordinary and processing trade to be two different intermediate goods, labeled as ω^O and ω^P, respectively, because the composite intermediate goods used for producing ω^O is different from that for ω^P. To be more specific, the compositions of intermediate goods in these two composite intermediate goods are different since the prices of the imported intermediate goods are different between ordinary and processing trade. Moreover, assume that $z_i\left(\omega^O\right) = z_i\left(\omega^P\right) = z_i\left(\omega\right)$, which simply means that a firm has identical efficiency level to produce intermediate goods sold through ordinary and processing trade.

[7] I don't have the data about export VAT rebate share of total VAT revenue across countries, but Harrison and Krelove (2005) provided the VAT refund share of total VAT revenue for some countries, and export VAT rebates dominate the VAT refund.

Since production of intermediate goods is at constant return to scale, the cost of a bundle of inputs used for trade mode TM in country i is given by

$$c_i^{TM} = \Upsilon (w_i)^\beta \left(P_i^{TM}\right)^{1-\beta}, \ TM = O \text{ or } P, \tag{1.1}$$

where w_i is wage, P_i^{TM} is the price of the composite intermediate good used for producing intermediate goods sold through trade mode TM, and Υ is a constant. If country i did not choose processing trade policy, there is no processing exports.

The unit cost to a potential firm producing good ω from country i with efficiency $z_i(\omega)$ delivering 1 unit to country n through trade mode TM is given by

$$c_{ni}^{TM}(\omega) = \frac{c_i^{TM} d_{ni}}{z_i(\omega)}, \ TM = O \text{ or } P,$$

where d_{ni} describes the iceberg cost of delivering intermediate goods from country i to country n. The measure of potential firms in country i with efficiency higher than z is

$$\mu_i^z(z) = T_i z^{-\theta}, z > 0,$$

where θ and T_i are parameters. Hence the measure of intermediate goods that can be delivered from country i to country n through trade mode TM at unit cost below c is

$$\mu_{ni}^{TM}(c) = \Phi_{ni}^{TM} c^\theta, \ TM = O \text{ or } P,$$

where

$$\Phi_{ni}^{TM} = T_i \left(c_i^{TM} d_{ni}\right)^{-\theta}, \ TM = O \text{ or } P.$$

1.3.4 Demand, Market Structure and Entry

A market n contains a measure of potential buyers. To sell to a fraction f of them, a firm from country i selling good ω in country n through trade mode TM must incur a fixed cost

$$E_{ni}^{TM}(\omega) = \varepsilon_n(\omega) E_{ni}^{TM} M(f), \ TM = O \text{ or } P,$$

where E_{ni}^{TM} is the constant component of the cost faced by all sellers from country i in destination n through trade mode TM; $\varepsilon_n(\omega)$ is the fixed cost shock specific to good ω in market n. The function $M(f) = \frac{1-(1-f)^{1-1/\lambda}}{1-1/\lambda}$, the same across destinations, relates a seller's cost of entering a market to the share of consumers it reaches there.

The demand of good ω from country i in market n is given by

$$X_{ni}(\omega) = \alpha_n(\omega) f p^{1-\sigma} A_{ni},$$

where

$$A_{ni} = X_n^O \left(P_n^O/\tau_{ni}\right)^{(\sigma-1)} + \mathbb{I}_n^P X_n^P \left(P_n^P\right)^{(\sigma-1)},$$

which is an index of market demand of country n that proportionally scales the residual demand of every firm from country i; X_n^O is the spending on goods consumed by households in country n or absorbed by firms in country n to produce domestic sales or ordinary exports; X_n^P is the spending on goods absorbed by firms in country n to produce processing exports, thus, $X_n = X_n^O + \mathbb{I}_n^P X_n^P$ is the total absorption in country n. $\alpha_n(\omega)$ is the demand shock specific to good ω in market n.[8] The demand of good ω from country i in market n is composed of two parts: the first part is for domestic use and producing ordinary exports, and the second for producing processing exports if country n chose processing trade policy, otherwise the second part is zero. Since the tariff rates are country-specific, the index of market demand in country n is different for firms from different countries.

A firm producing good ω in country i selling in market n via trade mode TM with a unit cost of $c_n(\omega)$ chooses price p and a fraction of f buyers to maximize its profit in the market

$$\max_{p,f} \left(\frac{p - c_n(\omega)}{p} - \frac{p - (1-\beta) c_n(\omega)}{p} t_{ni} \right) \times \alpha_n(\omega) f p^{1-\sigma} A_{ni} - \varepsilon_n(\omega) E_{ni}^{TM} M(f), \ TM = O \text{ or } P.$$

I now describe a firm's behavior in market n in terms of its unit cost $c_n(\omega) = c$, demand shock $\alpha_n(\omega) = \alpha$, and entry shock $\eta_n(\omega) = \frac{\alpha_n(\omega)}{\varepsilon_n(\omega)} = \eta$. By solving the

[8]The demand shock or fixed cost shock are only specific to the good variety, so I don't need the superscripts to label these shocks.

maximization problem, I have

$$\begin{aligned} p_n(\omega) &= \overline{m}\zeta_{ni}c, \text{ where } \overline{m} = \frac{\sigma}{\sigma-1} \text{ and } \zeta_{ni} = \frac{1-(1-\beta)\,t_{ni}}{1-t_{ni}} \\ f_{ni}^{TM}(\eta,c) &= \begin{cases} 0, & \text{if } c > \overline{c}_{ni}^{TM}(\eta)\,; \\ 1-\left(\frac{c}{\overline{c}_{ni}^{TM}(\eta)}\right)^{\lambda(\sigma-1)}, & \text{if } c \leq \overline{c}_{ni}^{TM}(\eta)\,, \end{cases} \end{aligned}$$

where

$$\overline{c}_{ni}^{TM}(\eta) = \frac{1}{\overline{m}\zeta_{ni}}\left(\eta\frac{1-t_{ni}}{\sigma E_{ni}^{TM}}A_{ni}\right)^{1/(\sigma-1)}.$$

Firms charge a higher markup with VAT than without, if not, then the marginal revenue is smaller compared to the case of no VAT since some of it is taxed away, so firms have to raise the price to increase the marginal revenue in order to maximize profits.[9] At the moment, I can take a glance at how these two policies to affect the cutoff in domestic market.

$$\begin{aligned} \overline{c}_{nn}^{O}(\eta) &= \frac{1}{\overline{m}\zeta_{nn}}\left(\eta\frac{1-t_{nn}}{\sigma E_{nn}^{O}}A_{nn}\right)^{1/(\sigma-1)} \\ &\leq \frac{1}{\overline{m}}\left[\frac{\eta}{\sigma E_{nn}^{O}}A_{nn}\right]^{1/(\sigma-1)} \\ &\leq \frac{P_n^O}{\overline{m}}\left[\frac{\eta}{\sigma E_{nn}^{O}}X_n\right]^{1/(\sigma-1)}, \end{aligned}$$

the first inequality holds because $\zeta_{nn} \geq 1$ and $1-t_{nn} \leq 1$, and the second inequality is from the fact that $P_n^P \leq P_n^O$, which will be very clear in the following subsection. The expression on the second line is the cutoff only with processing trade policy, which is bigger than the cutoff also with VAT because the firm with $\overline{c}_{nn}^{O}(\eta)$ will make positive profit for not paying VAT. The expression on the third line is the cutoff without both VAT and processing trade policy, and it is bigger than the cutoff only with processing trade policy because the processing trade policy makes the input price higher for firms selling in domestic market or foreign markets through ordinary trade than firms through processing exports.

[9]In a simple closed economy, VAT can cause the welfare loss of the representative agent, because it induces less varieties, and make the price index higher.

The total sales via trade mode TM can be written as

$$\begin{aligned} X_{ni}^{TM}(\alpha,\eta,c) &= \frac{\alpha}{\eta}\left[1-\left(\frac{c}{\bar{c}_{ni}^{TM}(\eta)}\right)^{\lambda(\sigma-1)}\right]\left(\frac{c}{\bar{c}_{ni}^{TM}(\eta)}\right)^{-(\sigma-1)}\frac{\sigma E_{ni}^{TM}}{1-t_{ni}}, \\ TM &= O \text{ or } P. \end{aligned}$$

Some of the profits is eaten up by its fixed cost, which are

$$E_{ni}^{TM}(\alpha,\eta,c) = \frac{\alpha}{\eta}E_{ni}^{TM}\frac{1-\left(c/\bar{c}_{ni}^{TM}(\eta)\right)^{(\lambda-1)(\sigma-1)}}{1-1/\lambda},\ TM = O \text{ or } P.$$

1.3.5 Price Index

Each buyer in market n has access to the same measure of goods (even though they are not necessarily the same goods). Every buyer faces the same probability of $f_{ni}^{TM}(\eta,c)$ to purchase a good sold via trade mode TM from country i with cost c and entry shock η for any value of α. Hence I can write the price index faced by a representative buyer in market n as

$$\begin{aligned} P_n^O &= \overline{m}\left[\int\int\sum_{TM}\sum_i\int_0^{\bar{c}_{ni}^{TM}(\eta)}\alpha\mathbb{I}_i^{TM}f_{ni}^{TM}(\eta,c)\left(\zeta_{ni}\tau_{ni}c\right)^{1-\sigma}\right. \\ &\quad \left.\times d\mu_{ni}^{TM}(c)\,g(\alpha,\eta)\,d\alpha d\eta\right]^{-1/(\sigma-1)}, \end{aligned}$$

$$\begin{aligned} \left(P_n^O\right)^{1-\sigma} &= (\overline{m})^{1-\sigma}\int\int\alpha\kappa_0\sum_{TM}\sum_i\mathbb{I}_i^{TM}\left(\zeta_{ni}\tau_{ni}\right)^{1-\sigma}\Phi_{ni}^{TM} \\ &\quad \times\left[\bar{c}_{ni}^{TM}(\eta)\right]^{\theta-(\sigma-1)}g(\alpha,\eta)\,d\alpha d\eta, \end{aligned}$$

where $\kappa_0 = \frac{\theta}{\theta-(\sigma-1)} - \frac{\theta}{\theta+(\sigma-1)(\lambda-1)}$,

$$\left(P_n^O\right)^{1-\sigma} = (\overline{m})^{-\theta}\kappa_1\sum_{i=1}^N\Psi_{ni}\left[A_{ni}\left(\tau_{ni}\right)^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}. \tag{1.2}$$

where $\Psi_{ni} = \sum_{TM} \Psi_{ni}^{TM}$, and

$$\Psi_{ni}^{TM} = \mathbb{I}_i^{TM} \Phi_{ni}^{TM} \left(\zeta_{ni}\tau_{ni}\right)^{-\theta} \left(\frac{1 - t_{ni}}{\sigma E_{ni}^{TM}}\right)^{\theta/(\sigma-1)-1}, \; TM = O \text{ or } P,$$

and $\kappa_1 = \int\int \alpha\eta^{\theta/(\sigma-1)-1} g\left(\alpha, \eta\right) d\alpha d\eta$. Repeat the same calculation, and I can get the price of the composite intermediate good used as input to produce processing exports if country n chose processing trade policy,

$$\left(P_n^P\right)^{1-\sigma} = \left(\overline{m}\right)^{-\theta} \kappa_1 \sum_{i=1}^{N} \left(\tau_{ni}\right)^{\sigma-1} \Psi_{ni} \left(A_{ni} \left(\tau_{ni}\right)^{(\sigma-1)}\right)^{\theta/(\sigma-1)-1}. \qquad (1.3)$$

Since $\left(\tau_{ni}\right)^{\sigma-1} \geq 1$, $P_n^O \geq P_n^P$. If $\mathbb{I}_n^P = 0$, then P_n^P is not defined, therefore, the price index P_n^O is simplified to the expression of price index in Eaton et al. (2011)

$$P_n^O = \overline{m} \left(\kappa_1 \Psi_n\right)^{-1/\theta} \left(X_n\right)^{1/\theta - 1/(\sigma-1)},$$

where $\Psi_n = \sum_{i=1}^{N} \Psi_{ni}$.

1.3.6 Sales, Entry and Fixed Costs

The total absorption in country n can be divided in the following way

$$\begin{aligned} X_n &= X_n^O + \mathbb{I}_n^P X_n^P \\ &= \left(X_n^{O,O} + X_n^{O,P}\right) + \mathbb{I}_n^P \left(X_n^{P,O} + X_n^{P,P}\right), \end{aligned}$$

where $X_n^{O,O}$ is country n's spending on goods imported by country n through ordinary trade and exported by all source countries through ordinary trade, in particular, the first superscript O indicates that the imports are considered ordinary trade in country n, and the second superscript O indicates that the exports are considered ordinary trade in source countries; $X_n^{O,P}$ is country n's spending on goods imported by country n through ordinary trade and exported by all source countries that have a processing trade policy through processing trade, where the first superscript O indicates that the imports are considered ordinary trade in country n, and the second superscript P indicates that the exports are considered processing trade in source countries; $X_n^{P,O}$ is country n's spending on goods imported by country n through processing trade and exported by all source countries through ordinary trade; $X_n^{P,P}$ is country n's spending on goods imported by country n through processing trade and exported by all source countries that have a processing trade policy through processing trade.

To obtain $X_{ni}^{TM,TM'}$,[10] I calculate the total amount with a given values of α and η, then integrate across the joint density $g(\alpha,\eta)$ to get

$$\begin{aligned} X_{ni}^{TM,TM'} &= \int\int X_{ni}^{TM,TM'}(\alpha,\eta)\, g(\alpha,\eta)\, d\alpha d\eta \\ &= \int\int \left(\int_0^{\bar{c}_{ni}^{TM'}(\eta)} X_{ni}^{TM,TM'}(\alpha,\eta,c)\, d\mu_{ni}^{TM'}(c)\right) \\ &= \pi_{ni}^{TM,TM'} X_n^{TM}, \\ TM &= O \text{ or } P \text{ and } TM' = O \text{ or } P, \end{aligned}$$

where

$$\pi_{ni}^{TM,TM'} = \begin{cases} \frac{\Psi_{ni}^{TM'}\left[A_{ni}(\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}{\sum_{i=1}^{N}\Psi_{ni}\left[A_{ni}(\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}, & \text{if } TM = O, \\ \frac{(\tau_{ni})^{\sigma-1}\Psi_{ni}^{TM'}\left[A_{ni}(\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}{\sum_{i=1}^{N}(\tau_{ni})^{\sigma-1}\Psi_{ni}\left[A_{ni}(\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}, & \text{if } TM = P. \end{cases} \tag{1.4}$$

Therefore, the spending on goods from country i consumed by households in country n or used by firms in country n to produce O is given by

$$\begin{aligned} X_{ni}^{O} &= \sum_{TM} X_{ni}^{O,TM} = \sum_{TM} \pi_{ni}^{O,TM} X_n^{O} \\ &= \pi_{ni}^{O} X_n^{O}, \end{aligned}$$

where

$$\pi_{ni}^{O} = \frac{\Psi_{ni}\left[A_{ni}(\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}{\sum_{i=1}^{N}\Psi_{ni}\left[A_{ni}(\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}; \tag{1.5}$$

the spending on goods from country i used by firms in country n to produce

[10] $X_{ni}^{TM,TM'}$, is country n's spending on goods imported by country n through trade mode TM and exported by country i through trade mode TM'.

processing exports is given by

$$\begin{aligned} X_{ni}^{P} &= \sum\nolimits_{TM} X_{ni}^{P,TM} = \sum\nolimits_{TM} \pi_{ni}^{P,TM} X_{n}^{P} \\ &= \pi_{ni}^{P} X_{n}^{P}, \end{aligned}$$

where

$$\pi_{ni}^{P} = \frac{(\tau_{ni})^{\sigma-1} \Psi_{ni} \left[A_{ni} (\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}{\sum_{i=1}^{N} (\tau_{ni})^{\sigma-1} \Psi_{ni} \left[A_{ni} (\tau_{ni})^{(\sigma-1)}\right]^{\theta/(\sigma-1)-1}}. \tag{1.6}$$

With equations (1.2) (1.3) (1.5) and (1.6), I have

$$\pi_{ni}^{P} = \pi_{ni}^{O} \left(\frac{P_{n}^{P}}{P_{n}^{O}} \tau_{ni}\right)^{(\sigma-1)}, \tag{1.7}$$

and the market demand index can be written as

$$\begin{aligned} A_{ni} &= X_{n}^{O} \left(P_{n}^{O}/\tau_{ni}\right)^{(\sigma-1)} + \mathbb{I}_{n}^{P} X_{n}^{P} \left(P_{n}^{P}\right)^{(\sigma-1)} \\ &= \left(X_{n}^{DO} + \mathbb{I}_{n}^{P} X_{n}^{P} \frac{\pi_{ni}^{P}}{\pi_{ni}^{O}}\right) \left(P_{n}^{O}/\tau_{ni}\right)^{(\sigma-1)}. \end{aligned}$$

Comparing π_{nn}^{O} and π_{nn}^{P}, one sees that the domestic sales or ordinary exports uses less imported inputs than processing exports. This is the key point made by the accounting exercise of Koopman, Wang and Wei (2012).

For firms from country i with a given value of η, a measure $\mu_{ni}^{TM}\left(\bar{c}_{ni}^{TM}(\eta)\right)$ pass the entry hurdle via TM. To obtain the total measure of firms from country i that sell in n via TM, denoted by J_{ni}^{TM}, I integrate across the marginal density $g_2(\eta)$,

$$\begin{aligned} J_{ni}^{TM} &= \int \mu_{ni}^{TM}\left(\bar{c}_{ni}^{TM}(\eta)\right) g_2(\eta)\, d\eta = \int \Phi_{ni}^{TM}\left(\bar{c}_{ni}^{TM}(\eta)\right)^{\theta} g_2(\eta)\, d\eta \\ &= \frac{\kappa_2}{\kappa_1} \frac{(1-t_{ni})}{\sigma E_{ni}^{TM}} \left(X_{n}^{O} \pi_{ni}^{O,TM} + \mathbb{I}_{n}^{P} X_{n}^{P} \pi_{ni}^{P,TM}\right),\ TM = O \text{ or } P, \end{aligned}$$

where $\kappa_2 = \int \eta^{\theta/(\sigma-1)} g_2(\eta)\, d\eta$.

To obtain an expression for the fixed costs incurred in market n by firms from country i via TM, given their values of α and η, I integrate

$$\begin{aligned} E_{ni}^{TM}(\alpha,\eta) &= \int_0^{\bar{c}_{ni}^{TM}(\eta)} \frac{\alpha}{\eta} E_{ni}^{TM} \frac{1-\left(c/\bar{c}_{ni}^{TM}(\eta)\right)^{(\lambda-1)(\sigma-1)}}{1-1/\lambda} d\mu_{ni}^{TM}(c) \\ &= \frac{\alpha}{\eta}\Phi_{ni}^{TM} E_{ni}^{TM} \frac{1}{1-1/\lambda}\left[1-\frac{\theta}{\theta+(\sigma-1)(\lambda-1)}\right]\left(\bar{c}_{ni}^{TM}(\eta)\right)^{\theta} \\ &= \alpha\eta^{\theta/(\sigma-1)-1}\frac{1-t_{ni}}{\sigma\kappa_1}\left(X_n^O\pi_{ni}^{O,TM}+\mathbb{I}_n^P X_n^P \pi_{ni}^{P,TM}\right)\left(\frac{\lambda}{\theta/(\sigma-1)+(\lambda-1)}\right), \\ TM &= O \text{ or } P. \end{aligned}$$

Integrating across the joint density $g(\alpha,\eta)$, total fixed cost incurred in market n by firm from country i via TM are

$$\overline{E}_{ni}^{TM} = \frac{1-t_{ni}}{\sigma}\left(X_n^O\pi_{ni}^{O,TM}+\mathbb{I}_n^P X_n^P \pi_{ni}^{P,TM}\right)\frac{\theta-(\sigma-1)}{\theta},\ TM = O \text{ or } P. \quad (1.8)$$

Summing across sources i, the total entry costs incurred in market n is

$$\overline{E}_n = \frac{1}{\sigma}\frac{\theta-(\sigma-1)}{\theta}\sum_i (1-t_{ni})\left(X_n^O\pi_{ni}^O+\mathbb{I}_n^P X_n^P\pi_{ni}^P\right).$$

1.3.7 Connecting the model to data

Entry patterns and sales distributions are almost identical in the Chinese firm-level data for processing trade and ordinary trade, and French firm-level data also reveals these robust features that can be rationalized by the model proposed in Eaton et al. (2011). The model in this paper replicates the structure in Eaton et al. (2011) for processing trade and ordinary trade. In particular, firms idenpendently face the same optimization problem to sell in a market via processing trade and ordinary trade, only differing in some parameters and realizations of shocks, therefore, identical entry patterns and sales distributions are generated, which is consistent with what I observed in the data. Details are delegated in appendix A.1.

1.4 Estimation

I estimate the elasticity of substitution by utilizing the additional information from processing trade. I estimate other parameters as the estimation procedure proposed by Eaton et al. (2011), adding two more sets of moments related to processing exporters.

1.4.1 Estimation of the Elasticity of Substitution

Using equation (1.7), the ratio of China's processing import share of goods from country n to China's ordinary import share of goods from country n is given by

$$\frac{\pi_{Cn}^{P}}{\pi_{Cn}^{O}} = \left(\frac{P_C^P}{P_C^O}\tau_{Cn}\right)^{(\sigma-1)}.$$

This ratio only depends on the price indices of composite intermediate goods used by Chinese ordinary exporters and processing exporters respectively, the import tariff rate specific to country n and value of elasticity of substitution. Since Chinese firms independently the identical optimization problem to sell to a market via processing trade and ordinary trade, I can think that the processing trade policy replicates the manufacturing sector in China. Two identical sectors use different composite intermediate goods as inputs, but these two composite intermediate goods only differ in composition of intermediate goods because the the identical set of intermediate goods are aggregated in them, but prices for imported intermediate goods are different for ordinary import and processing import, and the difference is the import tariff. For the sector doing processing trade, it receives the import duty exemption and pays less for the imported intermediate goods, so the ratio of these two import shares reveals the substitutability among varieties. Pick another country h, and I have the similar expression

$$\frac{\pi_{Ch}^{P}}{\pi_{Ch}^{O}} = \left(\frac{P_C^P}{P_C^O}\tau_{Ch}\right)^{(\sigma-1)}.$$

Dividing both equations above and taking log, the ratio of price indices is canceled out, and I obtain a relationship between observables and the parameter describing the substitutability among intermediate goods:

$$\log\left(\frac{\pi^{P}_{Cn}}{\pi^{O}_{Cn}}/\frac{\pi^{P}_{Ch}}{\pi^{O}_{Ch}}\right)=(\sigma-1)\log\left(\tau_{Cn}/\tau_{Ch}\right).$$

I can estimate σ from the following regression

$$\log\left(\frac{\pi^{P}_{Cn}}{\pi^{O}_{Cn}}/\frac{\pi^{P}_{Ch}}{\pi^{O}_{Ch}}\right)=(\sigma-1)\log\left(\tau_{Cn}/\tau_{Ch}\right)+\varepsilon_{nh},$$

where ε_{nh} captures the measurement error in bilateral trade flows, assumed to be orthogonal to tariff rates.

1.4.2 Parametrization

I Assume that $g\left(\alpha,\eta\right)$ is joint log normal. Specifically, $\ln\alpha$ and $\ln\eta$ are normally distributed with zero means and variances σ_{α}^{2} and σ_{η}^{2}, and correlation ρ. Let $\widetilde{\theta}=\frac{\theta}{\sigma-1}$, then I can write κ_1 and κ_2 as

$$\kappa_1=\left[\frac{\widetilde{\theta}}{\widetilde{\theta}-1}-\frac{\widetilde{\theta}}{\widetilde{\theta}+\lambda-1}\right]\exp\left\{\frac{\sigma_{\alpha}+2\rho\sigma_{\alpha}\sigma_{\eta}\left(\widetilde{\theta}-1\right)+\sigma_{\eta}\left(\widetilde{\theta}-1\right)^{2}}{2}\right\},$$

and

$$\kappa_2=\exp\left\{\frac{\left(\widetilde{\theta}\sigma_{\eta}\right)^{2}}{2}\right\}.$$

There are left with only five parameters to estimate:

$$\Theta=\left\{\widetilde{\theta},\lambda,\sigma_{\alpha},\sigma_{\eta},\rho\right\}.$$

These parameters are estimated by simualted method of moments. Details for simulation algorithm, moments constructed and estimation procedure are delegated in appendix A.2 since I closely follow Eaton et al. (2011) and add information regarding to processing trade.

Table 1.2: Estimate of Elasticity of Substitution

	Year
dif_log_porat	2005
dif_log_tariff	4.070
	(8.53)
Constant	-0.0195
	(-0.67)
Observations	2850

t statistics parentheses

Table 1.3: Estimation Results

	$\widetilde{\theta}$	λ	σ_α	σ_η	ρ
EKK	2.46	0.91	1.69	0.34	-0.65
Ordinary and Processing Trade	2.43	1.39	2.58	0.56	0.52
Ordinary Trade	2.56	1.39	2.29	0.48	0.58

1.4.3 Estimation Results

Table 1.2 reports the estimate of $\sigma, 4.07$, while Eaton et al. (2011) calibrated σ as 2.98. Table 1.3 reports estimates for all other parameters, values of which are not far away from those in Eaton et al. (2011), except the correlation between the entry shock and demand shock. The results suggest that if a French firm's product is more popular (bigger demand shock), then it is more likely for him to pay a larger fixed cost (a small entry shock) and generate a bigger sales. While the opposite is true for Chinese firms, one possible explanation is that almost 60 percent of Chinese total exports are done by foreign firms, parents of these foreign affiliates may provide connections and resources to facilitate entry.

1.5 General Equilibrium and Conterfactuals

Additional assumpsions are required before formally defining the general equilibrium.

A1 Non-manufacturing is as in Alvarez and Lucas (2007). Final output, which is non-traded, is a Cobb-Douglas combination of manufactures and non-manufactures, with manufactures having a share γ. Labor is the only input to nonmanufactures. Hence the price of final output in country n is proportional to $\left(P_n^O\right)^\gamma w_n^{(1-\gamma)}$.

A2 Fixed costs pay for labor in the destination, I thus decompose the country-specific component of the entry costs $E_{ni}^O = w_n F_{ni}^O$ and $E_{ni}^P = w_n F_{ni}^P$, where F_{ni}^O and F_{ni}^P reflect the labor required for entry for seller from i in n through domestic sales or ordinary exports and processing exports, respectively.

A3 Each country n's manufacturing deficit D_n and overall trade deficit D_n^A are held at their 2005 values.

I write country n's total absorption of manufactures is the sum of final demand and use as intermediates as:

$$X_n^O + X_n^P = \gamma I_n + \sum_{i=1}^{N} \frac{(1-\beta)}{\overline{m}\zeta_{in}} \left(\pi_{in}^O \frac{X_i^O}{\tau_{in}} + \mathbb{I}_i^P \pi_{in}^P X_i^P \right), \tag{1.9}$$

and the total absorption of manufactures by processing exporters is given by

$$X_n^P = \frac{(1-\beta)}{\overline{m}\zeta_{nn}} \sum_{i \neq n} \left(\pi_{in}^{O,P} \frac{X_i^O}{\tau_{in}} + \mathbb{I}_i^P \pi_{in}^{P,P} X_i^P \right), \tag{1.10}$$

where

$$I_n = w_n L_n + R_n + D_n^A + \Pi_n,$$

represents final absorption in country n, as the sum of labor income, tariff revenues, trade deficit and pre-tax profit. In particular,

$$R_n = \sum_{i=1}^{N} (\tau_{ni} - 1) \pi_{in}^O \frac{X_n^O}{\tau_{in}},$$

and

$$\Pi_n = \sum_{i=1}^{N} \frac{\overline{m}\zeta_{in} - 1}{\overline{m}\zeta_{in}} \left(\pi_{in}^O \frac{X_i^O}{\tau_{in}} + \mathbb{I}_i^P X_i^P \pi_{in}^P \right) - \sum_{i=1}^{N} \left(\overline{E}_{in}^O + \overline{E}_{in}^P \right).$$

Finally, using the definition of expenditure and trade deficit I have that

$$\sum_{i=1}^{N}\left(\pi_{ni}^{O}\frac{X_n^O}{\tau_{ni}}+\mathbb{I}_n^P\pi_{ni}^P X_n^P\right)-D_n=\sum_{i=1}^{N}\left(\pi_{in}^{O}\frac{X_i^O}{\tau_{in}}+\mathbb{I}_i^P\pi_{in}^P X_i^P\right). \tag{1.11}$$

This condition reflects the fact that total expenditure, excluding tariff payments, in country n minus trade deficits equals the sum of each country's total expenditure, excluding tariff payments, on tradable goods from country n.

I now define formally the equilibrium under tariff $\{\tau_{ni}\}$, applied VAT rate $\{t_{ni}\}$ and process trade policy choice $\{\mathbb{I}_n^P\}$ in this model.

Definition: Given L_n, D_n, T_n, d_{ni} and fixed entry costs, an equilibrium under tariff structure, applied VAT rate and processing trade policy choices, is a wage vector $\mathbf{w}\in\mathbf{R}_{++}^N$ and prices $\mathbf{P}^O,\mathbf{P}^P\in\mathbf{R}_{++}^N$ that satisfies equilibrium conditions (1.1) (1.2) (1.3) (1.4) (1.5) (1.8) (1.6) (1.9) (1.10)and (1.11) for all n.

1.5.1 Compute Counterfactual Outcomes

It will be good to have Mexican processing trade data, unfortunately, I don't have it now. Due to the data limitation, I treat China to be the only country chose processing trade policy. I consider that China shuts down the processing trade policy, and I apply the method used in Dekle, Eaton and Kortum (2008; henceforth DEK) to calculate counterfactuals. Denote the counterfactual value of any variable x as x' and define $\widehat{x}=x'/x$ as its change. The counterfactual equilibrium is characterized by the following equations:

$$\pi_{ni}^{O\prime}=\frac{\pi_{ni}^{O,O}\left(\widehat{w}_i\right)^{\theta\beta}\left(\widehat{P}_i^O\right)^{\theta(1-\beta)}\left(1+\mathbb{I}_n^P\frac{X_{ni}^P}{X_{ni}^O}\right)^{\theta/(\sigma-1)-1}}{\sum_{k=1}^{N}\pi_{nk}^{O,O}\left(\widehat{w}_k\right)^{\theta\beta}\left(\widehat{P}_k^O\right)^{\theta(1-\beta)}\left(1+\mathbb{I}_n^P\frac{X_{nk}^P}{X_{nk}^O}\right)^{\theta/(\sigma-1)-1}}, \tag{1.12}$$

$$\widehat{P}_n^O=\left[\sum_{i=1}^{N}\pi_{ni}^{O,O}\left(\widehat{w}_i\right)^{\theta\beta}\left(\widehat{P}_i^O\right)^{\theta(1-\beta)}\frac{1}{\left(1+\mathbb{I}_n^P\frac{X_{ni}^P}{X_{ni}^O}\right)^{\theta/(\sigma-1)-1}}\right]^{-1/\theta}\left(\frac{\frac{X_n^{O\prime}}{X_n^O}}{\widehat{w}_n}\right)^{1/\theta-1/(\sigma-1)}, \tag{1.13}$$

$$X_n^{O\prime} = \sum_{i=1}^{N} \frac{(1-\beta)}{\overline{m}\zeta_{in}} \left(\pi_{in}^{O\prime} \frac{X_i^{O\prime}}{\tau_{in}} \right) + \gamma I_n', \tag{1.14}$$

where

$$I_n' = \widehat{w}_n w_n L_n + R_n' + D_n^A + \Pi_n',$$

$$R_n' = \sum_{i=1}^{N} \frac{(\tau_{ni}-1)}{\tau_{ni}} \pi_{ni}^{O\prime} X_n^{O'},$$

and

$$\Pi_n' = N \frac{\overline{m}\zeta_{in}-1}{\overline{m}\zeta_{in}} \pi_{in}^{O\prime} \frac{X_i^{O\prime}}{\tau_{in}} - \frac{\theta-(\sigma-1)}{\sigma\theta} \left[\sum_{i=1}^{N} (1-t_{ni}) X_i^{O\prime} \pi_{in}^{O'} \right]$$

finally, the counterfactual trade balance is given by

$$\sum_{i=1}^{N} \pi_{ni}^{O\prime} \frac{X_n^{O\prime}}{\tau_{ni}} - D_n = \sum_{i=1}^{N} \pi_{in}^{O\prime} \frac{X_i^{O\prime}}{\tau_{in}}. \tag{1.15}$$

I present a step by step procedure to solve the model.

Step 1 Guess a vector of wages $\widehat{\mathbf{w}}$ and a vector of price indices $\widehat{\mathbf{P}}^O$.

Step 2 Use equation (1.12) to calculate the bilateral trade shares given by $\widehat{\mathbf{w}}$ and $\widehat{\mathbf{P}}^O$.

Step 3 Use equation (1.15) to solve the total absorption of manufactures in each country given by the bilateral trade shares from step 2, $\widehat{\mathbf{w}}$ and $\widehat{\mathbf{P}}^O$.

Step 4 Use equation (1.14) to obtain the new vector of wages $\widehat{\mathbf{w}}$.

Step 5 Use equation (1.13) iteratively to calculate the new price indices given the new vector of wages $\widehat{\mathbf{w}}$ until it converges. Go back to Step 1 with the new vector of wages $\widehat{\mathbf{w}}$ and the new vector of price indices $\widehat{\mathbf{P}}^O$, and stop until the vector of price indices converge.

1.5.2 Counterfactual Results

Table 1.4 reports the counterfactual results. China's welfare is improved by around 8%. The most popular exporting destinations of Chinese firms, such as U.S. , Japan and U.K. etc, have welfare loss but less 1%, while China's competitors like Vietnam, Thailand have welfare gain, but also less than 1%. The intuition behind these results is quite straightforward. With shutdown of processing trade policy in China, Chinese firms sell more varieties in domestic market and export less varieties to foreign markets, and the price index declines much more than the wage rate in China; Price indices in countries, such as U.S., Japan and U.K. etc, increases more than the wage rate since less varieties imported from China; Countries, such as Vietnam and Thailand etc, start to produce and export more varieties, driving up the real wage.

A different way to understand the welfare gain of China is that processing trade policy is a destination based distortion, and removing this distortion is welfare improving for China. Then a natural question is that why countries like China adopt processing trade policy. In chapter 2, I extend the model in this chapter to a multi-country growth model with international knowledge spillover through trade, and I show that the welfare implication is reversed for China in the presence of international knowledge spillover.

Table 1.4: Real Wage Changes in the Counterfactual Exercise

Countries	Wage Change	Price Change	Welfare Change
Algeria	1.0010	0.9975	1.0035
Argentina	0.9998	0.9995	1.0003
Australia	0.9992	1.0001	0.9991
Austria	1.0017	1.0024	0.9994
Bangladesh	1.0053	0.9930	1.0123
Belgium	1.0026	1.0018	1.0008
Brazil	1.0015	1.0010	1.0005
Canada	1.0058	1.0046	1.0012
Chile	1.0001	0.9948	1.0053
China	0.9622	0.9253	1.0369
Colombia	1.0023	0.9994	1.0029
Czech Republic	1.0017	1.0040	0.9977
Denmark	1.0024	1.0015	1.0009

continued . . .

Table 1.4 Continued:

Countries	Wage Change	Price Change	Welfare Change
Finland	0.9997	1.0030	0.9967
France	1.0014	1.0023	0.9991
Germany	1.0001	1.0034	0.9967
Greece	1.0018	0.9997	1.0021
Hungary	1.0003	1.0055	0.9948
India	1.0006	0.9982	1.0025
Israel	1.0061	1.0004	1.0056
Italy	1.0017	1.0002	1.0014
Japan	0.9995	1.0034	0.9961
Korea, Rep.	0.9876	0.9955	0.9920
Mexico	1.0069	1.0045	1.0024
Morocco	1.0028	0.9967	1.0062
Netherlands	0.9947	1.0078	0.9869
New Zealand	1.0008	0.9992	1.0016
Norway	1.0023	0.9996	1.0027
Pakistan	1.0021	0.9970	1.0051
Peru	0.9997	0.9973	1.0024
Poland	1.0023	1.0006	1.0017
Portugal	1.0021	1.0011	1.0009
Russian Federation	0.9984	0.9968	1.0016
Slovak Republic	0.9981	0.9971	1.0010
Vietnam	1.0053	0.9962	1.0092
South Africa	1.0004	0.9969	1.0035
Spain	1.0016	0.9999	1.0017
Sweden	1.0014	1.0013	1.0001
Switzerland	1.0012	1.0016	0.9996
Thailand	1.0007	0.9995	1.0012
Turkey	1.0022	0.9994	1.0028
United Kingdom	1.0021	1.0030	0.9991
United States	1.0041	1.0076	0.9965

continued ...

Table 1.4 Continued:

Countries	Wage Change	Price Change	Welfare Change
ROW	0.9939	1.0042	0.9897

1.6 Conclusion

This chapter shows the entry pattern and sales distribution of Chinese firm for both ordinary and processing exports across destinations: more firms sell in the larger markets for both ordinary and processing exports; conditional on entry of a market, more firms sells through ordinary exports with a smaller average sales, sales distributions normalized by average sales are almost identical for both ordinary and processing exports. I build a multi-country general equilibrium model based on Eaton et al. (2011) that can term with these empirical regularities, and quantify the welfare implication of processing trade policy with the estimated model. The estimated model shows that China' real wage increases by about 4% when China eliminates the duty draw for processing trade, which implies that processing trade policy induces welfare loss for China. In the next chapter, I extend the model into a multi-country growth model with idea diffusion through imports, and the calibrated growth model shows that the welfare implication of processing trade is reversed in the presence of international idea diffusion.

Chapter 2

Processing Trade and Global Idea Diffusion

2.1 Introduction

Processing trade allows firms to claim an import duty exemption for imported inputs used to produce exports. For example, Foxconn China can claim a duty exemption for imported inputs used to assemble iPhones sold to the rest of the World, such as cameras imported from Japan, memory chips from South Korea and processors from the United States etc. This policy is also called a duty drawback scheme in some countries. Many developing countries have adopted this policy,[1] and processing exports account for 18% of world total exports from 2000 to 2008 (Maurer and Degain (2012)). Among these countries, China and Mexico are the two largest users of this policy, with China accounting for about 67% and Mexico another 18%(Maurer and Degain (2012)). Moreover, processing exports make up more than half of their total manufacturing exports during this period (Koopman et al. (2012), Bergin et al. (2009)).

Processing trade is perceived as useful for promoting exports from developing countries. However, how does processing trade affect growth and aggregate productivity? How does processing trade affect welfare? Structural models that

[1]Processing trade is usually adopted in developing countries in terms of Export Processing Zones (EPZ), and processing trade is restricted to certain geographic area. Amirahmadi and Wu (1995) is a good review of the history and development of EPZ.

quantify these connections are limited. In this paper, I present a multi-country growth model with diffusion of ideas through trade, and use the model to quantify the welfare implications of the duty drawback scheme associated with processing trade.

I connect processing trade with the global diffusion of ideas. As is widely and reasonably believed, trade serves as a vehicle for idea diffusion. Processing trade encourages firms to use more imported inputs compared with ordinary trade (no duty drawback for imported inputs), thus accelerating diffusion of ideas through imports. China's firm-level data suggests that the average productivity of entering firms relative to the continuing firms is positively correlated with the fraction of processing exports out of total exports across industries.[2] This evidence motivates me to model global idea diffusion such that the potential producers can learn from all the sellers (including foreign sellers) in the market. The larger the share of processing exports in an industry, the more imported inputs are used in production, the more likely potential producers in the industry are exposed to foreign sellers, and increase their productivity through learning.

In the model, firms produce outputs by using labor and intermediates as inputs, but differ in productivity. Firms can choose to sell in a market through processing trade, or ordinary trade, or both trade modes. I model firm entry and exit similar to Arkolakis (2016).[3] New ideas continuously arrive in each country at a constant rate, and each new idea can be used by a monopolistically competitive firm to produce differentiated goods. These ideas become firms only if they are used in production. If not, they enter a mothball state until a future shock to productivity makes production profitable. Potential firms (new ideas) imitate all firms (including foreign firms) selling in the country, and receive an initial productivity that is a scaled-down version of the average productivity of all firms selling in the country. Ideas evolve according to a geometric Brownian motion with a drift as in Luttmer (2007), whereby the growth rate of productivity is independent of its level. This specification generates a productivity distribution of firms (ideas

[2] See Appendix B.1 for details.

[3] In the model, processing trade results in a higher temporary growth rate for the host country, and a larger fraction of aggregate productivity is due to firm entry and exit when the growth rate is higher, which agrees with the finding of Asturias et al. (2017) that a larger fraction of aggregate productivity is due to firm entry and exit during the fast-growth episodes compared with slow-growth episodes by using Chilean and South Korean firm-level data.

put into production) that is Pareto matching the standard distribution assumptions in many trade models. The shape parameters of the Pareto distributions across countries are identical, but the scale parameters differ, depending on the new ideas' productivity and the stock of ideas in the country: the higher (larger) the new ideas' productivity (the stock of ideas), the larger the scale parameter.

Processing trade affects host-country welfare through a trade-off between the loss of consumption (static losses) and the increase in aggregate productivity (dynamic gains). Consider a country with a low scale parameter of its productivity distribution. Processing trade encourages firms to use more imported inputs, increasing the demand for imported inputs. More foreign firms from countries with larger scale parameters sell in the country, raising the average productivity of all sellers in the country. The new ideas' productivity is higher as knowledge diffuses from all sellers to the new ideas. The aggregate productivity increases with a larger scale parameter. Therefore, processing trade results in a temporarily higher productivity growth rate and a permanent higher productivity level. However, processing trade makes exports cheaper, increasing the labor demand. The increase in labor demand raises the nominal wage. The productivity cutoffs for firms selling in the market increase, reducing the measure of varieties sold in the market, and causing a loss of consumption.

I use the model to quantify the static losses and the dynamics gains from processing trade. I apply the method in Dekle et al. (2008) to calculate the counterfactual outcomes. To separate the static losses and dynamics gains, I compute two different counterfactual outcomes: in the first counterfactual exercise, I eliminate the duty drawback with processing trade in China and keep the scale parameters of all countries unchanged to quantify the static losses; in the second counterfactual exercise, I eliminate the duty drawback with processing trade in China, but allow for productivity spillovers.

The dynamic gains are about three times larger than the static losses for China. In the first counterfactual exercise (the model with no spillovers), the real wage in China increases by 3.7% when the duty drawback for China's processing trade is eliminated: this is the magnitude of static losses from processing trade. Processing exports bid up the nominal wage in China. The higher nominal wage raises the productivity cutoffs for firms selling in China, reducing the measure of varieties sold in China, causing a loss of consumption. For the rest of the world, real wages in countries that are popular destinations for China's exports, such as the United States, the United Kingdom and Germany, decrease as less varieties are imported from China, while real wages in countries with income levels similar to China's, such as Bangladesh, India, Pakistan and Vietnam, etc, increase because these countries export more to the countries that are important destinations for China's exports, but the changes are all less than 1%.

In the second counterfactual exercise(the model with spillovers), the real wage in China decreases by 7.6%, implying that the magnitude of dynamic gains is about three times larger than that of the static losses. Real wages in countries with income levels similar to China's increase more than that in the first counterfactual exercise because those countries export more and import more, and more imports from countries with higher scale parameters improve their aggregate productivity. Real wages in countries that are popular destinations for China's exports decrease more because aggregate productivity is dampened by less-productive imports from China. The direction of the impacts on the rest of the world are identical in both counterfactual exercises, and the diffusion of ideas amplifies these effects.

Related Literature This paper complements the empirical literature looking into processing trade in developing countries.[4] This paper quantifies the welfare implication of processing trade with a multi-country growth model in which ideas diffuse through trade, and the implication of the model is consistent with findings in some of these empirical studies. The model is consistent with the fact found in Koopman et al. (2012) and Kee and Tang (2016) that domestic value added is lower in China's processing exports than ordinary exports because firms in the model use more imported inputs to produce processing exports compared with ordinary exports. The model also provides an explanation why domestic value added is increasing in China's exports (Kee and Tang (2016)), this is because processing trade improves China's aggregate productivity, and

[4]Manova and Yu (2016) find that credit constraints induce firms in China to conduct more processing trade. Grant (2017) studies special economic zones (SEZs) in the United States: firms in SEZs can receive duty-reduced access to approved intermediate goods, while firms outside SEZs face a higher tariff for the same intermediate goods. He provides a theoretical framework in which tariff discrimination across firms is the optimal policy for a government motivated by both political and welfare consideration.

firms in China source more inputs from the domestic market, raising the domestic value-added in China's exports. Moreover, the model in this paper implies that the share of processing exports in total exports decreases as the import tariffs fall (Brandt and Morrow (2017)).

This paper contributes to the literature that studies the connection between trade and the diffusion of ideas. Sampson (2016) develops a dynamic version of Melitz (2003) with knowledge spillovers from incumbent firms to entrants, and studies the effect of trade on growth when there is a dynamic complementarity between selection and technology diffusion: trade causes the least-productive firms to exit and shifts the productivity distribution of incumbent firms upwards; because entrants learn from a better productivity distribution of incumbent firms, this induces further selection, leading to faster economic growth. Perla et al. (2015) studies the effect of trade on growth in a model where heterogeneous firms can choose to adopt a new technology already in use by other domestic producers. Trade causes low productivity firms to contract, reducing their opportunity cost to adopt a better technology. This leads to more frequent technology adoption, and generates faster economic growth. Instead, I study the effect of processing trade on growth for developing countries in a model where new potential producers learn from all the sellers operating in the country (including foreign sellers). Processing trade encourages firms to use more imported inputs, increasing the average productivity of all the sellers operating in the host-country. New ideas are productive through idea diffusion, leading to faster economic growth.

Moreover, Both Perla et al. (2015) and Sampson (2016) only model the scenario of symmetric countries. The model in this paper is tractable with asymmetric countries, and it is easy to calculate counterfactual outcomes because there is no cost for new ideas to enter, and firms pay a market penetration cost rather than a fixed cost to sell in a market following Arkolakis (2016). However, new ideas' productivity is exogenously given in Arkolakis (2016), new ideas' productivity is endogenously determined through idea diffusion in this paper.

Buera and Oberfield (2016) also allow learning from all sellers operating in the country, but there is no firm entry and exit in their model, therefore, they cannot address the increase in aggregate productivity due to firm entry and exit. In Buera and Oberfield (2016), the distribution of firm productivities for each country converges to Fréchet, where the evolution of the scale parameters of the Fréchet distributions across countries is linked through trade and governed by a system of differential equations. In this paper, the distribution of firm productivities for each country is Pareto in the balanced growth path, where the evolution of the scale parameters of the Pareto distributions across countries is also linked through trade but governed by a system of equations. Lashkari (2017) presents a model with firm innovation and a more general spill-over from incumbents to potential entrants, and he focuses on the design of innovation policy to internalize the externality from knowledge diffusion and selection.

The rest of the paper is organized as follows. Section 2 presents the model and characterizes the balanced growth path. Section 3 discusses the welfare implication of processing trade. Section 4 formally defines the Balanced Growth Path equilibrium. Section 5 calibrates the model and uses the model to calculate counterfactual outcomes. Finally, Section 6 concludes.

2.2 The Model

The model builds on Eaton et al. (2011) and Arkolakis (2016), incorporating processing trade and global idea diffusion. In the model, firms choose to sell in a market through ordinary trade, or processing trade, or both trade modes, by paying iceberg trade costs and market penetration costs separable for each trade mode. New ideas arrive continuously at a constant rate. Firms are heterogeneous in productivity, while countries vary in size, location and stock of ideas.

2.2.1 Model Setup

Time is continuous, and indexed by t. There are N countries. The importing country is denoted by n, and the exporting country is denoted by i, where $i, n = 1, 2, ..., N$. Country n is populated with a continuum of households of measure $L_{nt} = L_n e^{g_\eta t}$ at time t, and each household supply one unit of labor inelastically at every point in time and live in an infinite horizon. Households are immobile across countries.

2.2.1.1 Households

Each household in market n has preference over a stream of composite goods $\{Q_{nt}\}_{t\geq 0}$ from which she derives utility according to

$$\int_0^{\infty} e^{-\rho t}\big(Q_{nt}\big)^{\frac{\iota-1}{\iota}} dt,$$

where $\rho > 0$ is the discount rate and $\iota > 0$ is the inter-temporal elasticity of substitution. The composite good is made from a continuum of differentiated intermediate goods available in market n at time t [5]

$$Q_{nt} = \left(\sum_{i=1}^{N}\int_{\omega\in\Omega_{nit}} \alpha_{nit}(\omega)\big(q_{nit}(\omega)\big)^{\frac{\sigma-1}{\sigma}} d\omega\right)^{\frac{\sigma}{\sigma-1}}, \tag{2.1}$$

where Ω_{nit} is the set of intermediate goods from country i available in market n at time t, and $\alpha_{nit}(\omega)$ is the probability that the intermediate good ω reaches consumers in market n at time t, and σ is the elasticity of substitution.[6] The demand of good ω from country i in market n at time t is given by

$$X_{nit}(\omega) = \alpha_{nit}(\omega)\big(p_{nit}(\omega)\big)^{1-\sigma} A_{nit},$$

where $X_{nit}(\omega)$ is total expenditure on good ω from country i in market n at time t, and A_{nit} is the demand shifter for every good from country i in market n at time t.[7]

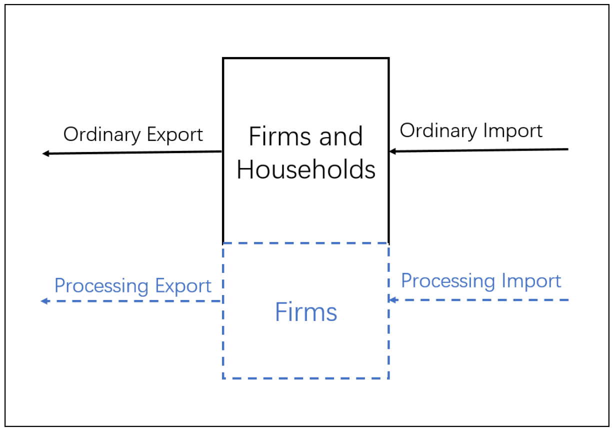

Figure 2.1: Description of Ordinary and Processing Trade

2.2.1.2 Policies

Processing trade allows firms to claim an import duty exemption for imported inputs to produce exports, but not to produce domestic sales. This policy is also called Duty Drawback Scheme in some countries. Hence, a country's total imports can be divided into two parts: the first part is the imports exempted from import duty to produce exports, and I refer to these imports as processing imports and the corresponding exports produced by using the processing imports as processing exports; the second part is the imports not exempted from import duty, and I refer to these imports as ordinary imports, moreover, I refer to all exports except processing exports as ordinary exports as is shown in Figure 2.1.

To simplify exposition, let O and P denote ordinary trade and processing trade, respectively, where ordinary trade contains ordinary export, ordinary import and domestic sales, and processing trade contains processing export and processing import. Let TM denote trade mode that can be either O or P. Let $\mathbb{I}_{nt}^{P}$ denote the

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[5]the price index of the composite is defined as

$$P_{nt} = \left(\sum_{i=1}^{N} \int_{\omega \in \Omega_{nit}} \alpha_{nit}(\omega) \big(p_{nit}(\omega)\big)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$$

where $p_{nit}(\omega)$ is the price of the intermediate good ω from country i selling in market n at time t.

[6]Ω_{nit} and $\alpha_{nit}(\omega)$ will be determined in equilibrium.

[7]The expression of A_{nit} will be written down after processing trade and price indices are introduced in later sessions.

choice of processing trade in country n at time t, where $\mathbb{I}_{nt}^{P}$ equals to 1 if country n chose processing trade policy, and 0 otherwise. Choices of processing trade are exogenously given for each country. I use $\mathbb{I}_{nt}^{O}$ to denote ordinary trade in market n at time t, and $\mathbb{I}_{nt}^{O}$ is always equal to 1 for each market n. Let τ_{nit} denote 1 plus the ad-valorem flat-rate tariff of intermediate goods imported from country i by market n.

2.2.1.3 Firms

A firm puts an idea to work, using the idea with labor and composite goods to produce outputs. Composite goods are produced by aggregating all the intermediate goods available in each country i with technology given in equation (2.1). There are two kinds of composite goods in country i in equilibrium if country i adopts processing trade: the first composite good is the composite good consumed by households and used by firms to produce ordinary exports and domestic sales, denoted as Q_{it}^{O}; the second composite good is the composite good used by firms to produce processing exports, denoted as Q_{it}^{P}. Let P_{it}^{P} and P_{it}^{O} denote the price indices of composite goods Q_{it}^{O} and Q_{it}^{P}, respectively. $P_{it}^{P} \leq P_{it}^{O}$, because imported intermediate goods aggregated in Q_{it}^{P} are exempted from import tariff.

I treat the outputs produced by a firm using different kinds of composite goods as different goods. Denote the good produced by a firm using composite good Q_{it}^{TM} as ω^{TM}, where $TM = O$ or P. Each good ω^{TM} is produced by the following technology:

$$q_{it}(\omega^{TM}) = z_{it}(\omega^{TM})\big(l_{it}(\omega^{TM})\big)^{\beta}\big(Q_{it}^{TM}\big)^{1-\beta}, TM = O \text{ or } P,$$

where $z_{it}(\omega^{O}) = z_{it}(\omega^{P})$ is the productivity of the idea adopted by the firm, $l_{it}(\omega^{TM})$ is labor used to produce variety ω^{TM}, and the parameter β is the output elasticity of labor.

There are several things to be noted. First, a firm could produce two goods (products): the good produced by using composite goods Q_{it}^{O} is a different good from the good produced by using composite goods Q_{it}^{P}, and these two goods are assumed to use the same technology but with different composite goods. Second, given that these two composite goods are aggregated by the same technology and with the identical set of intermediate goods, composite goods Q_{it}^{P} has higher expenditure share on imported intermediate goods than composite goods Q_{it}^{O} since imported intermediate goods are exempted from import tariff in composite goods Q_{it}^{P}.[8]

Since production of intermediate goods is at constant return to scale, the cost of a bundle of inputs under trade mode TM in country i is given by

$$c_{it}^{TM} = \Upsilon (w_{it})^{\beta} (P_{it}^{TM})^{1-\beta}, \; TM = O \text{ or } P, \tag{2.2}$$

where w_{it} is the wage in country i, and Υ is a constant. The unit cost to a potential firm producing good ω^{TM} from country i with productivity $z_{it}(\omega^{TM})$ delivering 1 unit to country n through trade mode TM is given by

$$c_{nit}^{TM}(\omega^{TM}) = \frac{c_{it}^{TM} d_{nit}}{z_{it}(\omega^{TM})}, \; TM = O \text{ or } P,$$

where d_{nit} describes the iceberg trade cost of delivering intermediate goods from country i to country n at time t.

To sell to a fraction α of all consumers in market n at time t, a firm from country i selling good ω^{TM} in country n under trade mode TM must incur a market penetration cost

$$E_{nit}^{TM}(\omega^{TM}) = E_{nit}^{TM} \frac{1-(1-\alpha)^{1-1/\lambda}}{1-1/\lambda}$$

where E_{nit}^{TM} is the constant component in the costs faced by all sellers from country i in destination n at time t under trade mode TM, $\frac{1-(1-\alpha)^{1-1/\lambda}}{1-1/\lambda}$ is derived from a model of the micro-foundations of marketing by Arkolakis (2010), and λ is the parameter that governs the convexity of the market penetration cost function: higher λ implies more convexity and steeper increases in the marginal cost to reach more consumers.

I follow Eaton et al. (2011) to introduce the market penetration cost function as this formulation can explain why some firms sell a very small amount while others stay out entirely. The new thing is that I introduce a different market penetration

[8]Koopman et al. (2012) estimated that foreign value-added in China's processing export is higher than that in China's ordinary export.

cost function for processing trade, and I assume that the market penetration cost function for processing is separable from the market penetration cost function for ordinary trade.

2.2.2 Dynamic Evolution of Ideas and Global Idea Diffusion

An "idea" is interpreted similarly as Arkolakis (2016). An "idea" is a way to produce a good ω^O, and a second good ω^P if the country where the idea resides adopts processing. A firm is an idea put to work to produce and market goods. If an idea is not put to work, it enters a mothball state until a future shock in productivity makes production profitable.

To obtain a simple characterization of the cross-sectional distribution of the productivity of ideas and firms we assume a constant population growth rate, g_η. Assume that each market innovates at an exogenous rate $g_B \geq 0$ so that the measure of existing ideas at time t is $J_{it} = J_i e^{g_B t}$, where $J_i > 0$ is the initial measure of ideas in country i. Denote $F_i(z,t)$ as the cumulative distribution function of the productivity of ideas from country i at time t, and $f_i(z,t)$ as the corresponding probability density function at time t.

The productivity of ideas follows a geometric Brownian motion as in Luttmer (2007), that is, the productivity of ideas born in country i at time t^b, $z_{it,a}$, are assumed to evolve independently with age a according to

$$z_{it,a} = z_{it^b,0} \exp(g_I a + \sigma_I W_a), t = t^b + a,$$

where g_I is the drift parameter of the geometric Brownian motion governing the rate at which incumbent ideas improve on average, σ_I is the diffusion parameter of the geometric Brownian motion governing the volatility, $W_a \sim N(0,a)$ is a standard Brownian motion with independent increments and $z_{it^b,0}$ is the initial productivity when the ideas are born at time t^b.

All new ideas born at time t^b in country i enter with the productivity:

$$z_{it^b,0} = \delta_1 \left(\overline{z}_{it^b}\right)^{\delta_2}, \tag{2.3}$$

where $\delta_1, \delta_2 \in (0,1)$[9], and $\overline{z}_{it^b}$ is the average productivity of all the firms selling in market i, and I will write down the expression of $\overline{z}_{it^b}$ in next subsection after solving firms' optimization problem.

In contrast to Arkolakis (2016), the productivity of new ideas is not exogenously given, and the new ideas enter with a scaled-down version of the average productivity of all firms (including foreign firms) selling in the market. I add international knowledge spillovers (or idea diffusion) by assuming that new ideas imitate all sellers (including foreign sellers) in the market while there is no knowledge spillovers in Arkolakis (2016). In Luttmer (2007), a firm pay an entry cost to draw an idea, and the firm also has to pay a fixed cost every period to keep the idea alive if the firm decided to put the idea to work. In this paper and Arkolakis (2016), the measure of ideas grows at an exogenous rate, and never die and keep evolving with age according a geometric Brownian motion, so that we don't need a free entry condition as in Luttmer (2007) to pin down the measure of ideas.

2.2.3 Firm Optimization

Before writing down firms' optimization problem, I introduce the expression of A_{nit}, the demand shifter for every good from country i selling in market n at time t, which is given by

$$A_{nit} = X_{nt}^{O}\big(P_{nt}^{O}/\tau_{nit}\big)^{(\sigma-1)} + \mathbb{I}_{nt}^{P} X_{nt}^{P}\big(P_{nt}^{P}\big)^{(\sigma-1)},$$

where X_{nt}^{O} is the spending on goods consumed by households in country n or absorbed by firms in country n to produce domestic sales or ordinary exports at time t; X_{nt}^{P} is the spending on goods absorbed by firms in country n to produce processing exports at time t, thus, $X_{nt} = X_{nt}^{O} + \mathbb{I}_{nt}^{P} X_{nt}^{P}$ is the total absorption in country n.

Given the constant return to scale production technology and separability of

[9]This assumption makes idea diffusion at a moderate speed that new entrants are small compared with existing firms since in the data, almost with no exception, new firms are very small. There are also two technical reasons why I need this assumption. First, this assumption makes new ideas not put to work immediately after birth so that firms' productivity distribution is Pareto, and this point will be straightforward after I derive the stationary distribution of productivity of ideas. Second, I need $\delta_2 \in (0,1)$ to ensure that equilibrium exists.

market penetration cost across markets and trade mode, each firm's decision are independent across markets and trade modes. Therefore, a firm producing good ω^{TM} in country i selling in market n under trade mode TM with a unit cost of $c_{nit}^{TM}(\omega^{TM})$ chooses price p and a fraction of α consumers to maximize its profit in the market

$$\max_{p,\alpha}\Big(\frac{p - c_{nit}^{TM}(\omega^{TM})}{p}\Big)\alpha p^{1-\sigma}A_{nit} - E_{nit}^{TM}\frac{1-(1-\alpha)^{1-1/\lambda}}{1-1/\lambda},\ TM = O \text{ or } P.$$

Since firms from country i selling in market n with the same productivity make identical decisions, we now describe a firm's behavior in market n from country i in term of its productivity $z = z_{it}(\omega)$. By solving the maximization problem, we have

$$p_{nit}^{TM}(z) = \overline{m}\frac{c_{it}^{TM}d_{nit}}{z},\ \text{where } \overline{m} = \frac{\sigma}{\sigma-1}, \tag{2.4}$$

$$\alpha_{nit}^{TM}(z) \quad = \quad \begin{cases} 0, & \text{if } z < \overline{z}_{nit}^{TM}; \\ 1 - \left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}, & \text{if } z \geq \overline{z}_{nit}^{TM}, \end{cases} \tag{2.5}$$

where

$$\overline{z}_{nit}^{TM} = \overline{m}c_{it}^{TM}d_{nit}\left(\frac{A_{nit}}{\sigma E_{nit}^{TM}}\right)^{1/(1-\sigma)}. \tag{2.6}$$

A natural question to ask is that why a firm needs to pay a separate marketing penetration cost for goods sold under processing trade in a market if the firm already paid the marketing penetration cost for goods sold under ordinary trade in the same market. There are two main reasons behind this setup. First, most goods produced under processing trade are offshore production, meaning that these goods will be marketed with foreign brands of the foreign firms who offshored their production, and goods produced under ordinary trade are marketed with their own brands not the foreign brands. For example, the small kitchen appliance Hamilton Beach has offshored production to Chinese firms since 2000, and these Chinese firms produced for Hamilton Beach export these products labeled with Hamilton Beach brand under processing trade, but their own products cannot use the Hamilton Beach brand since these firms did not own the brand Hamilton Beach, therefore, their own products sold under ordinary trade are marketed with their own brands. Second, this specification rationalizes Chinese processing and ordinary trade data in terms of entry and sales distribution across destinations by introducing a separate marketing penetration cost for processing trade.

Because there is no indivisible cost of production or entry, there are no forward looking decisions for the firms. Ideas from country i with productivity higher than $\overline{z}_{nit}^{TM}$ are used in production and appear as firms selling to market n under trade mode TM. The sales in market n via trade mode TM can be written as

$$X_{nit}^{TM}(z) = \left[1 - \left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(1-\sigma)}\right]\left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{-(\sigma-1)} \sigma E_{nit}^{TM}, \text{ where } TM = O \text{ or } P. \quad (2.7)$$

Some of the profits are eaten up by its fixed costs, which are

$$E_{nit}^{TM}(z) = E_{nit}^{TM} \frac{1 - (\overline{z}_{nit}^{TM}/z)^{(\lambda-1)(\sigma-1)}}{1 - 1/\lambda}, \text{ where } TM = O \text{ or } P.$$

Having obtained the productivity cutoffs, I can derive the average productivity of all sellers in market i at time t,

$$\overline{z}_{it} = \sum_{k=1}^{N}\sum_{TM}\left[\mathbb{I}_{kt}^{TM}\left(\int_{\overline{z}_{ikt}^{TM}}^{+\infty} z f_k(z,t)dz\right)\frac{(1 - F_k(\overline{z}_{ikt}^{TM}, t))J_{kt}}{\sum_{k=1}^{N}\sum_{TM}\mathbb{I}_{kt}^{TM}(1 - F_k(\overline{z}_{ikt}^{TM}, t))J_{kt}}\right], \quad (2.8)$$

where $\int_{\overline{z}_{ikt}^{TM}}^{+\infty} z f_k(z,t)dz$ is the average productivity of firms from country k selling in market i through trade mode TM, and $\frac{(1-F_k(\overline{z}_{ikt}^{TM},t))J_{kt}}{\sum_{k=1}^{N}\sum_{TM}(1-F_k(\overline{z}_{ikt}^{TM},t))J_{kt}}$ is the fraction of firms from country k selling in market i through trade mode TM among total firms selling in market i.

2.2.4 Balanced Growth Path

I am interested in versions of this world that has a balanced growth path. In this section, I first derive the ideas' productivity distribution in the balanced growth path. Given the productivity distribution in the balanced growth path, I then derive price indices of composite goods, and characterize entry, sales, fixed costs, and connection of productivity distributions across countries through idea diffusion in balanced growth path.

2.2.4.1 Productivity Distribution

In the balanced growth path, new born ideas' productivity will grow at the same rate as the productivity cutoffs z_{nit}^{TM}. Therefore, It is convenient to first characterize the distribution of productivity normalized by the new born ideas' productivity in the balanced growth path. Let $\phi_i(s,t)$ denote the probability density function at time t of normalized productivity $s = z/z_{it,0}$. We have $f_i(z,t) = \frac{1}{z_{it,0}}\phi_i(s,t)|_{s=z/z_{it,0}}$, and $\phi_i(s,t)$ evolves according to the following partial differential equation:[10]

$$\frac{\partial \phi_i(s,t)}{\partial t} + g_B\phi_i(s,t) = -(g_I + \frac{1}{2}\sigma_I^2 - \frac{\dot{z}_{it,0}}{z_{it,0}})\frac{\partial}{\partial s}[s\phi_i(s,t)] + \frac{1}{2}\sigma_I^2\frac{\partial^2}{\partial s^2}[s^2\phi_i(s,t)],$$

To ensure the stationary distribution of normalized productivity, I need following assumptions:

A1 *The rate of innovation is positive:* $g_B > 0$.

A2 *The diffusion parameter is positive:* $\sigma_I > 0$.

The stationary distribution of normalized productivity, $\phi_i(s)$, is characterized as following ordinary differential equation

$$g_B\phi_i(s) = -(\mu + \frac{1}{2}\sigma_I^2)\frac{\partial}{\partial s}[s\phi_i(s)] + \frac{1}{2}\sigma_I^2\frac{\partial^2}{\partial s^2}[s\phi_i(s)],\ s \in (0,1)\cup(1,+\infty),$$

where $\mu = g_I - g_E$, and $g_E = \frac{\dot{z}_{it,0}}{z_{it,0}}$ on the balanced growth path. The probability density function also satisfies following requirements:

$$\phi_i(s) \geq 0 \forall s \in (0,+\infty), \int_0^1 \phi_i(s)ds + \int_1^{+\infty} \phi_i(s)ds = 1,$$

and

$$\frac{1}{2}\sigma_I^2\Big[\frac{\partial}{\partial s}[s^2\phi_i(s)]\Big|_{s=1-} - \frac{\partial}{\partial s}[s^2\phi_i(s)]\Big|_{s=1+}\Big] = g_B.$$

The last equation says that the net inflow into the productivity distribution at $1/\delta$

[10] To derive the partial differential equation, I proceed in two steps. First, I write down the partial differential equation characterizing the productivity distribution of ideas for any given cohort, where the partial differential equation is called Kolmogorov Forward Equation (KFE) in the literature. Second, I integrate the KFE over all cohorts born before time t, and derive the partial differential equation. Derivation of this partial differential equation are provided in Appendix B.2.

is equal to the new outflow due to new idea entry.

The resulting stationary distribution of normalized productivity $s \in (0, +\infty)$ is the double Pareto distribution (Reed (2001) and Arkolakis (2016)) with probability density function:

$$\phi_i(s) = \begin{cases} \frac{\theta_1\theta_2}{\theta_1+\theta_2} s^{\theta_1 - 1} & \text{if } s < 1; \\ \frac{\theta_1\theta_2}{\theta_1+\theta_2} s^{-\theta_2 - 1} & \text{if } s \geq 1, \end{cases} \tag{2.9}$$

where

$$\theta_1 = \frac{\mu + \sqrt{\mu^2 + 2\sigma_I^2 g_B}}{\sigma_I^2}, \text{ and } \theta_2 = -\frac{\mu - \sqrt{\mu^2 + 2\sigma_I^2 g_B}}{\sigma_I^2}.$$

Since $f_i(z,t) = \frac{1}{z_{it,0}}\phi_i(s,t)|_{s=z/z_{it,0}}$, the productivity distribution in the balanced growth path is given by

$$f_i(z,t) = \begin{cases} \frac{\theta_1\theta_2}{\theta_1+\theta_2} \frac{z^{\theta_1 - 1}}{(z_{it,0})^{\theta_1}} & \text{if } z < z_{it,0}; \\ \frac{\theta_1\theta_2}{\theta_1+\theta_2} \frac{z^{-\theta_2 - 1}}{(z_{it,0})^{-\theta_2}} & \text{if } z \geq z_{it,0}, \end{cases} \tag{2.10}$$

At each date, a constant fraction of ideas, $\frac{\theta_1}{\theta_1+\theta_2}$, is above the threshold $z_{it,0}$. I assume that δ_1 is sufficient small in the rest of this paper so that $z_{nit}^{TM} > z_{it,0}, \forall n, i, t, TM$, in order to keep all expressions in the model simple. In this case, the cross-sectional distribution of operating ideas (firms) in each market n is Pareto with shape parameter θ_2.

Given that A1, A2 are necessary for a stationary distribution. Additional assumption guarantees that the resulting distribution of firm productivity and sales have a finite mean.

A3 *Productivity and sales parameters satisfy:*

$$g_B > \max\{\mu + \sigma_I^2/2, (\sigma - 1)\mu + (\sigma - 1)^2\sigma_I^2/2\}.$$

A3 ensures that the entry rate of new ideas is larger than the growth rate of an incumbent's productivity and sales of the largest incumbent firms.

2.2.4.2 Price Indices

Each buyer in market n has access to the same measure of goods (even though there are not necessarily the same goods.) Every buyer faces the same probability of $\alpha_{nit}^{TM}(z)$ to purchase a good sold via trade mode TM from country i with productivity z. Hence I can write the price index of the composite good for ordinary trade in market n as

$$P_{nt}^{O} = \left[\sum_{TM} \sum_{i=1}^{N} \int_{\overline{z}_{nit}^{TM}}^{+\infty} \mathbb{I}_{it}^{TM} \alpha_{nit}^{TM}(z) \big(\tau_{nit} p_{nit}^{TM}(z) \big)^{(1-\sigma)} f_i(z,t) J_{it} dz \right]^{-1/(\sigma-1)}.$$

Using equation (2.4), (2.5), (2.6) and (2.10), I get

$$(P_{nt}^{O})^{1-\sigma} = \kappa_0 \overline{m}^{-\theta_2} \left[\sum_{TM} \sum_{i=1}^{N} \mathbb{I}_{it}^{TM} \Psi_{nit}^{TM} \big(A_{nit} \tau_{nit}^{(\sigma-1)} \big)^{\theta_2/(\sigma-1)-1} \right], \tag{2.11}$$

where $\kappa_0 = \frac{\theta_1\theta_2}{\theta_1+\theta_2}\left(\frac{\theta_2}{\theta_2-(\sigma-1)} - \frac{\theta_2}{\theta_2+(\sigma-1)(\lambda-1)}\right)$, and

$$\Psi_{nit}^{TM} = \Big(J_{it} (z_{it,0})^{\theta_2} \Big) \Big(c_{it}^{TM} d_{nit} \tau_{nit} \Big)^{-\theta_2} \Big(\sigma E_{nit}^{TM} \Big)^{1-\frac{\theta_2}{\sigma-1}}.$$

Similarly, the price index of the composite intermediate good used as input to produce processing exports is given by

$$(P_{nt}^{P})^{1-\sigma} = \kappa_0 \overline{m}^{-\theta_2} \left[\sum_{TM} \sum_{i=1}^{N} \mathbb{I}_{it}^{TM} (\tau_{nit})^{\sigma-1} \Psi_{nit}^{TM} \big(A_{nit} \tau_{nit}^{(\sigma-1)} \big)^{\theta_2/(\sigma-1)-1} \right]. \tag{2.12}$$

2.2.4.3 Trade Shares, Entry and Fixed Costs

Market n's total absorption contains two parts: $X_{nt} = X_{nt}^{O} + \mathbb{I}_{nt}^{P} X_{nt}^{P}$, and firms in country i could export through ordinary and processing trade. Therefore, market n's spending on goods from country i can be divided into four parts as is shown in Figure 2.2: $\pi_{nit}^{O,O} X_{nt}^{O}$ is country n's spending on goods imported by country n through ordinary trade and exported by country i through ordinary trade, that is, these goods shown on country i's custom record as ordinary exports when were shipped from country i, and shown in country n's custom record as ordinary imports when arrived in country n, where $\pi_{nit}^{O,O}$ represents the percentage of X_{nt}^{O} that

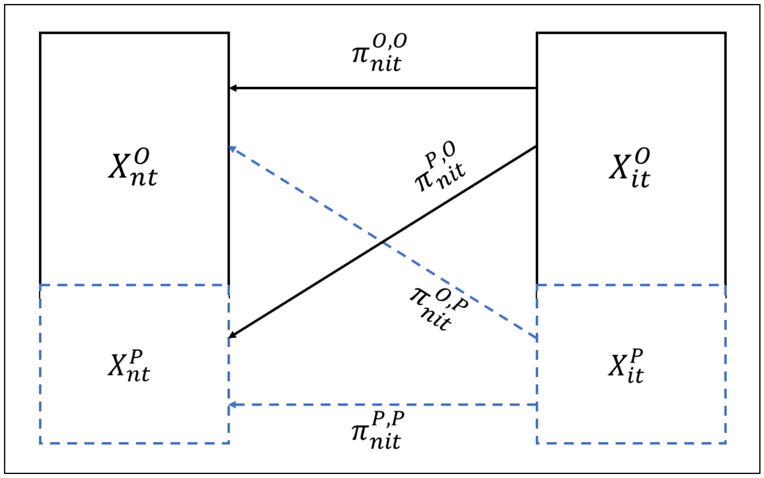

Figure 2.2: Decomposition of Country n's Total Imports from Country i

is spent on goods exported by country i through ordinary trade; $\mathbb{I}_{it}^{P}\pi_{nit}^{O,P}X_{nt}^{O}$ is country n's spending on goods imported by country n through ordinary trade and exported by country i through processing trade, where $\pi_{nit}^{O,P}$ represents the percentage of X_{nt}^{O} that is spent on goods exported by country i through processing trade; $\mathbb{I}_{nt}^{P}\pi_{nit}^{P,O}X_{nt}^{P}$ is the spending on goods imported by country n through processing trade and exported by country i through ordinary trade, where $\pi_{nit}^{P,O}$ represents the percentage of X_{nt}^{P} that is spent on goods exported by country i through ordinary trade; $\mathbb{I}_{nt}^{P}\mathbb{I}_{it}^{P}\pi_{nit}^{P,P}X_{nt}^{P}$ is the spending on goods imported by country n through processing trade and exported by country i through processing trade.

To obtain trade shares $\pi_{nit}^{TM,TM'}$, I integrate exports through trade mode TM' of firms from country i absorbed into X_{nt}^{TM} divided by X_{nt}^{TM},

$$\pi_{nit}^{TM,TM'} = \frac{\int_{\bar{z}_{nit}^{TM'}}^{+\infty} X_{nit}^{TM,TM'}(z) f_i(z,t) \frac{\theta_1\theta_2}{\theta_1+\theta_2} J_{it} dz}{X_{nit}^{TM}}$$

Using equation (2.7), (2.10), I obtain

$$\pi_{nit}^{TM,TM'} = \begin{cases} \dfrac{\mathbb{I}_{it}^{TM'}\Psi_{nit}^{TM'}\left(A_{nit}\tau_{nit}^{(\sigma-1)}\right)^{\theta_2/(\sigma-1)-1}}{\sum_{TM'}\sum_{i=1}^{N}\mathbb{I}_{it}^{TM'}\Psi_{nit}^{TM'}\left(A_{nit}\tau_{nit}^{(\sigma-1)}\right)^{\theta_2/(\sigma-1)-1}} & \text{if } TM = O; \\ \dfrac{\mathbb{I}_{it}^{TM'}(\tau_{nit})^{\sigma-1}\Psi_{nit}^{TM'}\left(A_{nit}\tau_{nit}^{(\sigma-1)}\right)^{\theta_2/(\sigma-1)-1}}{\sum_{TM'}\sum_{i=1}^{N}\mathbb{I}_{it}^{TM'}(\tau_{nit})^{\sigma-1}\Psi_{nit}^{TM'}\left(A_{nit}\tau_{nit}^{(\sigma-1)}\right)^{\theta_2/(\sigma-1)-1}} & \text{if } TM = P. \end{cases} \tag{2.13}$$

Let π_{nit}^{O} denote the share of X_{nt}^{O} that is spent on exports from country i through both ordinary and processing trade, and $\pi^{O}_{nit} = \pi^{O,O}_{nit} + \pi^{O,P}_{nit}$. Let π^{P}_{nit} denote the share of X^{P}_{nt} that is spent on exports from country i through both ordinary and processing trade, and $\pi^{P}_{nit} = \pi^{P,O}_{nit} + \pi^{P,P}_{nit}$. Using equation (2.13), I get

$$\pi^{O}_{nit} = \frac{\sum_{TM'} \mathbb{I}^{TM'}_{it} \Psi^{TM'}_{nit} \left(A_{nit} \tau^{(\sigma-1)}_{nit}\right)^{\theta_2/(\sigma-1)-1}}{\sum_{TM'} \sum_{i=1}^{N} \mathbb{I}^{TM'}_{it} \Psi^{TM'}_{nit} \left(A_{nit} \tau^{(\sigma-1)}_{nit}\right)^{\theta_2/(\sigma-1)-1}}, \tag{2.14}$$

and

$$\pi^{P}_{nit} = \frac{\sum_{TM'} \mathbb{I}^{TM'}_{it} (\tau_{nit})^{\sigma-1} \Psi^{TM'}_{nit} \left(A_{nit} \tau^{(\sigma-1)}_{nit}\right)^{\theta_2/(\sigma-1)-1}}{\sum_{TM'} \sum_{i=1}^{N} \mathbb{I}^{TM'}_{it} (\tau_{nit})^{\sigma-1} \Psi^{TM'}_{nit} \left(A_{nit} \tau^{(\sigma-1)}_{nit}\right)^{\theta_2/(\sigma-1)-1}}. \tag{2.15}$$

The measure of firms from country i selling in market n through trade mode TM, denoted by J^{TM}_{nit}, is given by

$$J^{TM}_{nit} = \mathbb{I}^{TM}_{it} \frac{\pi^{O,TM}_{nit} X^{O}_{nt} + \pi^{P,TM}_{nit} \mathbb{I}^{P}_{it} X^{P}_{nt}}{\sigma E^{TM}_{nit}}, \tag{2.16}$$

where the numerator, $\mathbb{I}^{TM}_{it}(\pi^{O,TM}_{nit} X^{O}_{nt} + \pi^{P,TM}_{nit} \mathbb{I}^{P}_{it} X^{P}_{nt})$, is the total exports through trade mode TM from country i to market n, and the denominator is the average sales in market n of firms from country i through trade mode TM.

Total fixed costs incurred in market n by firms from country i through trade mode TM are

$$\overline{E}^{TM}_{nit} = \frac{1}{\sigma} \mathbb{I}^{TM}_{it} \left(\pi^{O,TM}_{nit} X^{O}_{nt} + \pi^{P,TM}_{nit} \mathbb{I}^{P}_{it} X^{P}_{nt}\right) \left(\frac{\theta_2 - (\sigma - 1)}{\theta_2}\right). \tag{2.17}$$

Summing across sources i and trade modes, the total fixed costs incurred in market n are

$$\overline{E}_{nt} = \frac{1}{\sigma} \frac{\theta_2 - (\sigma - 1)}{\theta_2} X_{nt}. \tag{2.18}$$

2.2.4.4 Productivity Linkage across Countries

The average productivity of all sellers in market i at time t in the balanced growth path is given by,

$$\overline{z}_{it} = \sum_{k=1}^{N} \sum_{TM} \left[\left(\frac{\theta_2}{\theta_2 - 1} \overline{z}^{TM}_{ikt} \right) \frac{\mathbb{I}^{TM}_{kt} J^{TM}_{ikt}}{\sum_{k=1}^{N} \sum_{TM} \mathbb{I}^{TM}_{kt} J^{TM}_{ikt}} \right], \tag{2.19}$$

where $\frac{\theta_2}{\theta_2-1}\overline{z}_{ikt}^{TM}$ is the average productivity of firms from country k selling in market i through trade mode TM since the productivity distribution is Pareto with shape parameter θ_2, and $\frac{\mathbb{I}_{kt}^{TM} J_{ikt}^{TM}}{\sum_{k=1}^{N}\sum_{TM}\mathbb{I}_{kt}^{TM} J_{ikt}^{TM}}$ is the fraction of all firms selling in market i that are from country k selling in market i through trade mode TM.

The productivity cutoffs can be rewritten as

$$\overline{z}_{ikt}^{TM} = \left(J_{ikt}^{TM}\right)^{-\frac{1}{\theta_2}} \left(\frac{\theta_1}{\theta_1+\theta_2} J_{kt}(z_{kt,0})^{\theta_2}\right)^{1/\theta_2}. \tag{2.20}$$

Substituting equation (2.19) and (2.20) into equation (2.3), the new ideas' productivity born in country i at time t in the balanced growth path is given by

$$z_{it,0} = \kappa_1 \left(\sum_{k=1}^{N} \sum_{TM} \left(\left(J_{ikt}^{TM}\right)^{-\frac{1}{\theta_2}} \left(\frac{\theta_1}{\theta_1+\theta_2} J_{kt}(z_{kt,0})^{\theta_2}\right)^{1/\theta_2} \right) \frac{\mathbb{I}_{kt}^{TM} J_{ikt}^{TM}}{\sum_{k=1}^{N}\sum_{TM}\mathbb{I}_{kt}^{TM} J_{ikt}^{TM}} \right)^{\delta_2}, \tag{2.21}$$

where $\kappa_1 = \delta_1 \left(\frac{\theta_2}{\theta_2-1}\right)^{\delta_2}$.

2.3 Welfare Implication of Processing Trade Policy

In this section, I provide intuition for how processing trade affects welfare of the host country. First, I derive the expression of real wage in each country. Second, I show that processing trade reduces the set of varieties available for consumption compared with the case that the country did not implemented processing trade. Third, I show that the host country can improve its productivity distribution through processing trade when there is idea diffusion. The exact magnitudes will be investigated in the section of quantitative exercise.

2.3.1 Real Wages

To illustrate the welfare implication of processing trade policy, I first derive the real wage. Using the equation (2.13), the share of X_{it}^{O} that is spent on goods from domestic market for ordinary trade is

$$\pi_{iit}^{O,O} = \frac{\Psi_{nit}^{O}\left(A_{nit}\tau_{nit}^{(\sigma-1)}\right)^{\theta_2/(\sigma-1)-1}}{\sum_{TM'}\sum_{i=1}^{N}\mathbb{I}_{it}^{TM'}\Psi_{nit}^{TM'}\left(A_{nit}\tau_{nit}^{(\sigma-1)}\right)^{\theta_2/(\sigma-1)-1}}. \tag{2.22}$$

Rewriting this equation yields the following expression for the real wage:

$$\frac{w_{it}}{P_{it}^{O}} = \kappa_2\left(\frac{\frac{\theta_1}{\theta_1+\theta_2}J_{it}(z_{it,0})^{\theta_2}}{\pi_{iit}^{O,O}}\right)^{\frac{1}{\beta\theta_2}}\left[\left(\frac{X_{it}}{\sigma E_{iit}^{O}}\right)\left(1-\frac{\mathbb{I}_{it}^{P}(\pi_{iit}^{O,O}-\pi_{iit}^{P,O})X_{it}^{P}}{\pi_{iit}^{O,O}X_{it}}\right)\right]^{\frac{1}{\beta(\sigma-1)}-\frac{1}{\beta\theta_2}} \tag{2.23}$$

where $\kappa_2 = (\kappa_0)^{\frac{1}{\beta\theta_2}}(\overline{m}\Gamma)^{-\frac{1}{\beta}}$. The expression of real wage is a multiplication of three terms except the constant: the first term, $\left(\frac{\frac{\theta_1}{\theta_1+\theta_2}J_{it}(z_{it,0})^{\theta_2}}{\pi_{iit}^{O,O}}\right)^{\frac{1}{\beta\theta_2}}$, says that trade augments a country's effective technology by a factor of $1/\pi_{iit}^{O,O}$, that is, country that trades more gains more; the second term, $\left(\frac{X_{it}}{\sigma E_{iit}^{O}}\right)^{\frac{1}{\beta(\sigma-1)}-\frac{1}{\beta\theta_2}}$, says that a larger market sustains more varieties, raising welfare; The third term, $\left(1-\frac{\mathbb{I}_{it}^{P}(\pi_{iit}^{O,O}-\pi_{iit}^{P,O})X_{it}^{P}}{\pi_{iit}^{O,O}X_{it}}\right)^{\frac{1}{\beta(\sigma-1)}-\frac{1}{\beta\theta_2}} < 1$, says that the market size effect described in the second term is partly offset by processing trade as the share of spending on domestic intermediate goods in the absorbtion for ordinary trade is higher than that for processing trade.

2.3.2 Real Wage Change with No Idea Diffusion

In order to show that processing trade reduces the set of varieties available for consumption, I assume there is no diffusion of ideas in the following analysis. Consider the equilibrium that country i implemented processing trade, $\mathbb{I}_{it}^{P} = 1$, and the real wage in country i is given by[11]

$$\frac{w_{it}}{P_{it}^{O}} = \kappa_2\left(\frac{\frac{\theta_1}{\theta_1+\theta_2}J_{it}(z_{it,0})^{\theta_2}}{\pi_{iit}^{O,O}}\right)^{\frac{1}{\beta\theta_2}}\left(\frac{X_{it}^{O}+\frac{\pi_{iit}^{P,O}}{\pi_{iit}^{O,O}}X_{it}^{P}}{\sigma E_{iit}^{O}}\right)^{\frac{1}{\beta(\sigma-1)}-\frac{1}{\beta\theta_2}}. \tag{2.24}$$

Consider the second equilibrium that country i eliminated the duty drawback

[11]Equation (2.24) is identical to equation (2.23).

for processing trade. Denote the value of any variable x as x' in the second equilibrium, and define $\hat{x} = \frac{x'}{x}$ as its change. The real wage in country i in the second equilibrium is given by

$$\frac{w'_{it}}{P^{O'}_{it}} = \kappa_2 \left(\frac{\frac{\theta_1}{\theta_1+\theta_2} J'_{it} (z'_{it,0})^{\theta_2}}{\pi^{O,O'}_{iit}} \right)^{\frac{1}{\beta\theta_2}} \left(\frac{X^{O'}_{it}}{\sigma E^{O'}_{iit}} \right)^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}}. \tag{2.25}$$

Dividing equation (2.25) by equation (2.24), I get

$$\frac{\hat{w}_{it}}{\hat{P}^{O}_{it}} = \left(\frac{\pi^{O,O}_{iit}}{\pi^{O,O'}_{iit}} \right)^{\frac{1}{\beta\theta_2}} \left[\left(\frac{X^{O'}_{it}}{\sigma E^{O'}_{iit}} \right) \Big/ \left(\frac{X^{O}_{it} + \frac{\pi^{P,O}_{iit}}{\pi^{O,O}_{iit}} X^{P}_{it}}{\sigma E^{O}_{iit}} \right) \right]^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}}. \tag{2.26}$$

where technology parameters are cancelled out since there is no idea diffusion. Processing trade induces country i to export more, increasing the wage so that the share of spending on domestic intermediate goods in the absorption for ordinary trade decreases compared with the share with no processing trade, that is, $\frac{\pi^{O,O}_{iit}}{\pi^{O,O'}_{iit}} < 1$. If $\theta_2/(\sigma-1) > 2$,[12] then $\frac{1}{\beta\theta_2} < \frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}$. With this inequality, I have

$$\begin{aligned}
\frac{\hat{w}_{it}}{\hat{P}^{O}_{it}} &= \left(\frac{\pi^{O,O}_{iit}}{\pi^{O,O'}_{iit}} \right)^{\frac{1}{\beta\theta_2}} \left[\left(\frac{X^{O'}_{it}}{\sigma E^{O'}_{iit}} \right) \Big/ \left(\frac{X^{O}_{it} + \frac{\pi^{P,O}_{iit}}{\pi^{O,O}_{iit}} X^{P}_{it}}{\sigma E^{O}_{iit}} \right) \right]^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}} \\
&> \left(\frac{\pi^{O,O}_{iit}}{\pi^{O,O'}_{iit}} \right)^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}} \left[\left(\frac{X^{O'}_{it}}{\sigma E^{O'}_{iit}} \right) \Big/ \left(\frac{X^{O}_{it} + \frac{\pi^{P,O}_{iit}}{\pi^{O,O}_{iit}} X^{P}_{it}}{\sigma E^{O}_{iit}} \right) \right]^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}} \\
&= \left(\frac{J^{O'}_{iit}}{J^{O}_{iit}} \right)^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}} \\
&> 1,
\end{aligned}$$

where the second equality is obtained by using equation (2.16) related to firm measures, and last inequality holds because processing trade raises wage, and increasing the productivity cutoff for firms selling in domestic market through ordinary trade, thus, the measure of firms selling in domestic market though ordinary trade with no processing trade is larger than that with processing trade. Therefore, processing trade causes a loss of varieties ($\frac{J^{O'}_{it}}{J^{O}_{it}} > 1$), further a loss of consumption ($\frac{\hat{w}_{it}}{\hat{P}^{O}_{it}} > 1$)

[12]This inequaty holds for the estimated parameters.

compared with the case that country i eliminated the duty drawback for processing trade.

2.3.3 Productivity Gains through Processing Trade Policy with Idea Diffusion

In order to show the productivity gains through processing trade with idea diffusion, I only need to show that new born ideas' productivity with processing trade is higher than that with no processing trade since the productivity distributions are Pareto with the same shape parameter θ_2.

Consider a simple version of this model with only two countries: China and U.S., denoted by C and U, respectively. Assume that U.S. does not implement processing trade for simplicity. In the balanced growth path, the new born ideas' productivity in China with processing trade is given by equation (2.21):

$$z_{Ct,0} = \kappa_1 \left(\frac{(J^O_{CCt})^{\frac{\theta_2-1}{\theta_2}} + (J^P_{CCt})^{\frac{\theta_2-1}{\theta_2}}}{J^O_{CUt} + J_{CCt}} (J_{Ct})^{\frac{1}{\theta_2}} z_{Ct,0} + \frac{(J^O_{CUt})^{\frac{\theta_2-1}{\theta_2}}}{J^O_{CUt} + J_{CCt}} (J_{Ut})^{\frac{1}{\theta_2}} z_{Ut,0} \right)^{\delta_2}, \tag{2.27}$$

where $J_{CCt} = J^O_{CCt} + J^P_{CCt}$. If China eliminated duty drawback for processing trade, the new born ideas' productivity in China is given by

$$z'_{Ct,0} = \kappa_1 \left(\frac{(J^{O'}_{CCt})^{\frac{\theta_2-1}{\theta_2}}}{J^{O'}_{CUt} + J'_{CCt}} (J_{Ct})^{\frac{1}{\theta_2}} z'_{Ct,0} + \frac{(J^{O'}_{CUt})^{\frac{\theta_2-1}{\theta_2}}}{J^{O'}_{CUt} + J'_{CCt}} (J_{Ut})^{\frac{1}{\theta_2}} z'_{Ut,0} \right)^{\delta_2}. \tag{2.28}$$

The measure of Chinese firms selling in their domestic market with China implementing processing trade, J'_{CCt}, is larger than the measure of Chinese firms selling in their domestic market with China not implementing processing trade, J_{CCt}. This is because the fixed component in the market penetration cost for Chinese firms selling in domestic market through processing trade, E^P_{CCt}, is much larger than the counterpart for ordinary trade, E^O_{CCt}[13]. The measure of U.S. firms selling in China with China not implementing processing trade, J'_{CUt}, is smaller than the measure of U.S. firms sell in China with China implementing processing trade, J_{CUt}. This is because processing trade increases demand for U.S. goods and the

[13]This is consistent with the values that are backed out by using the structure of this model with China's firm-level data.

measure of U.S. firms selling in China. Therefore, the new potential producer in China are more likely exposed to U.S. sellers operating in China with China implementing processing trade, and the new potential producers' productivity is higher since they are likely to learn from more productive U.S. firms selling in China. The same argument goes through for the general case.

2.4 A Balanced Growth Path Equilibrium

Additional assumptions are required before formally defining the Balanced Growth Path (BGP) equilibrium.

A4 *Non-manufacturing is as in Alvarez and Lucas (2007). Final output, which is non-traded, is a Cobb-Douglas combination of manufactures and non-manufactures, with manufactures having a share γ. Labor is the primary input to nonmanufactures. Hence the price of final output in country n is proportional to $\left(P^O_{nt}\right)^\gamma w_{nt}^{(1-\gamma)}$.*

A5 *Fixed costs are incurred in terms of destination market labor, I thus decompose the country-specific component of the entry costs $E^O_{nit} = w_{nt}F^O_{nit}$ and $E^P_{nit} = w_{nt}F^P_{nit}$, where F^O_{nit} and F^P_{nit} reflect the labor required for entry for seller from i in n through ordinary and processing trade, respectively. F^O_{nit} and F^P_{nit} grow at the rate of $g_\eta\psi$, where $\psi \in (0,1)$.*

A6 *Iceberg trade costs are constant over time $d_{nit} = d_{ni}$.*

A7 *Tariffs are constant over time $\tau_{nit} = \tau_{ni}$.*

Country n's total absorption of manufactures is the sum of final demand and use as intermediates as:

$$X^O_{nt} + X^P_{nt} = \gamma I_{nt} + \frac{(1-\beta)}{\overline{m}} \sum_{i=1}^{N} \left(\pi^O_{int} \frac{X^O_{it}}{\tau_{int}} + \mathbb{I}^P_{it} \pi^P_{int} X^P_{it} \right), \tag{2.29}$$

and the absorption of manufactures of processing trade is given by

$$X^P_{nt} = \frac{(1-\beta)}{\overline{m}} \sum_{i=1}^{N} \left(\pi^{O,P}_{int} \frac{X^O_{it}}{\tau_{int}} + \mathbb{I}^P_{it} \pi^{P,P}_{int} X^P_{it} \right), \tag{2.30}$$

where

$$I_{nt} = w_{nt}L_{nt} + R_{nt} + \Pi_{nt}, \tag{2.31}$$

represents final absorption in country n, as the sum of labor income, tariff revenues and profit. In particular,

$$R_{nt} = \sum_{i=1}^{N} (\tau_{nit} - 1)\, \pi_{nit}^{O} \frac{X_{nt}^{O}}{\tau_{nit}}, \tag{2.32}$$

and

$$\Pi_{nt} = \frac{1}{\sigma} \sum_{i=1}^{N} \left(\pi_{int}^{O} \frac{X_{it}^{O}}{\tau_{int}} + \mathbb{I}_{it}^{P} \pi_{int}^{P} X_{it}^{P} \right) - \frac{\theta_2 - (\sigma - 1)}{\sigma \theta_2} \sum_{i=1}^{N} \left(\pi_{int}^{O} X_{it}^{O} + \mathbb{I}_{nt}^{P} \pi_{int}^{P} X_{it}^{P} \right). \tag{2.33}$$

Trade balance is given by

$$\sum_{i=1}^{N} \left(\pi_{nit}^{O} \frac{X_{nt}^{O}}{\tau_{nit}} + \mathbb{I}_{nt}^{P} \pi_{nit}^{P} X_{nt}^{P} \right) = \sum_{i=1}^{N} \left(\pi_{int}^{O} \frac{X_{it}^{O}}{\tau_{int}} + \mathbb{I}_{it}^{P} \pi_{int}^{P} X_{it}^{P} \right). \tag{2.34}$$

Since processing trade policy does not affect the growth rate in the balanced growth path, I focus on a BGP equilibrium that productivity cutoffs grow at rate of 0 in the balanced growth path. Therefore, I specify the entry rate of new ideas to be

$$g_B = g_\eta (1 - \gamma),$$

implying that the measure of ideas above the entry point is $\frac{\theta_1}{\theta_1 + \theta_2} e^{g_\eta (1-\gamma) t}$. In the balanced the growth path, wages will grow at the rate g_k, where

$$g_\kappa = \frac{g_\eta (1 - \gamma)}{\beta(\sigma - 1)}.$$

I define a BGP equilibrium such that wage rate w_{it} grows at a constant rate of g_κ for each country i, the productivity distribution keeps unchanged for each country i, the price index P_{it}^{TM} for each trade mode TM and each country i keeps constant over time, the productivity cutoff $\overline{z}_{nit}^{TM}$ keeps constant over time, for each $n, i = 1, 2, ..., N$ and $TM = O$ or P, and the new born ideas' productivity $z_{it,0}$ keeps constant over time for each country i.

Definition: *Suppose that assumptions hold. Given a constant growth rate of population g_η, a constant growth rate of the measure of ideas g_B and choices of processing trade policy unchanged for each country i, a Balanced Growth Path Equilibrium consists of a sequence of distributions $f_i(z,t) = f_i(z)$, the decision policies of firms $\{p_{nit}^{TM}(z), \alpha_{nit}^{TM}(z)\}$, the productivity cutoff $\overline{z}_{nit}^{TM} = \overline{z}_{ni}^{TM}$, the new born ideas' productivity $z_{it,0} = z_{i,0}$ wage $w_{it} = w_i e^{g_\kappa t}$, and price index $P_{it}^{TM} = P_i^{TM}$ for each $n, i = 1, 2, ..., N$ and $TM = O$ or P such that:*

- *Given price indices, costs and total absorptions*
    - *$\overline{z}_{nit}^{TM}$ is the optimal productivity cutoff, and given by equation (2.6).*
    - *$p_{nit}^{TM}(z)$ and $\alpha_{nit}^{TM}(z)$ are optimal static firm policies, and given by equation (2.4) and (2.5), respectively.*
- *Price indices are given by equation (2.11) and (2.12).*
- *Bilateral trade shares are given by equation (2.13), (2.14) and (2.15).*
- *Total absorption of manufactures is given by equation (2.29), and the absorption of manufactures for processing trade is given by equation (2.30).*
- *Trade balance is given by equation (2.34).*
- *The idea productivity distribution is stationary for each country i such that*

$$f_i(z) = \begin{cases} \frac{\theta_1\theta_2}{\theta_1+\theta_2}\frac{z^{\theta_1-1}}{(z_{i,0})^{\theta_1}} & \text{if } z < z_{i,0}; \\ \frac{\theta_1\theta_2}{\theta_1+\theta_2}\frac{z^{-\theta_2-1}}{(z_{i,0})^{-\theta_2}} & \text{if } z \geq z_{i,0}. \end{cases}$$

- *The new born ideas' productivity is given by equation (2.21).*

2.5 Counterfactual

In this section, I use the model to quantify the welfare implication of processing trade policy. First, I show how to calculate counterfactual outcomes. Second, I discuss the parameters needed for the counterfactual exercise and the calibration. Third, I show the results.

2.5.1 Calculating Counterfactual outcomes

The sample of countries in my quantitative analysis consists of 46 countries and a constructed rest of world[14]. The criterion was to maximize the number if countries covered in the sample conditional on obtaining reliable tariff, production and trade flow data in 2005.

I assume that the world in 2005 is in the balanced growth path, and China is the only country implementing processing trade policy.[15] In the counterfactual exercise, I shut down processing trade policy in China and apply the method used in Dekle et al. (2008) to calculate counterfactual outcomes given that tariffs, iceberg trade costs, market penetration cost function, the measure of ideas and population for each country i keep unchanged as are in 2005, and manufacturing deficits, D_i and trade dificits, D_i^A for each country i, are held at their 2005 values. Denote the counterfactual value of any variable x as x' and define $\widehat{x} = x'/x$ as its change.

The counterfactual outcomes in the balanced growth path are characterized by the following equations:

$$\pi_{ni}^{O,O'} = \frac{\pi_{ni}^{O,O} (\widehat{z}_{i,0})^{\theta_2} (\widehat{w}_i)^{-\theta_2 \beta} \left(\widehat{P}_i^O\right)^{-\theta_2(1-\beta)} \left(1 + \mathbb{I}_n^P \frac{\pi_{ni}^P X_n^P}{\pi_{ni}^O X_n^O}\right)^{-\theta_2/(\sigma-1)+1}}{\sum_{k=1}^N \pi_{nk}^{O,O} (\widehat{z}_{i,0})^{\theta_2} (\widehat{w}_k)^{-\theta_2 \beta} \left(\widehat{P}_k^O\right)^{-\theta_2(1-\beta)} \left(1 + \mathbb{I}_n^P \frac{\pi_{nk}^P X_n^P}{\pi_{nk}^O X_n^O}\right)^{-\theta_2/(\sigma-1)+1}}, \tag{2.35}$$

$$\widehat{P}_n^O = \left[\sum_{i=1}^N \pi_{ni}^{O,O} (\widehat{z}_{i,0})^{\theta_2} (\widehat{w}_i)^{-\theta_2 \beta} \left(\widehat{P}_i^O\right)^{-\theta_2(1-\beta)} \frac{1}{\left(1 + \mathbb{I}_n^P \frac{\pi_{ni}^P X_n^P}{\pi_{ni}^O X_n^O}\right)^{\theta_2/(\sigma-1)-1}} \right]^{-1/\theta_2} \tag{2.36}$$

$$\times \left(\frac{\frac{X_n^{O'}}{X_n^O}}{\widehat{w}_n} \right)^{1/\theta_2 - 1/(\sigma-1)}, \tag{2.37}$$

[14] Argentina, Australia, Austria, Bangladesh, Belgium, Brazil, Canada, Chile, China, Taiwan, Colombia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary India, Israel, Italy, Japan, South Korea, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Peru, Poland, Portugal, Romania, Russia, Saudi Arabia, Slovak Republic, Vietnam, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, United States.

[15] I only have China's processing trade data due to data limitation.

$$X_n^{O\prime} = \sum_{i=1}^{N} \frac{(1-\beta)}{\overline{m}} \left(\pi_{in}^{O,O\prime} \frac{X_i^{O\prime}}{\tau_{in}} \right) + \gamma I_n', \tag{2.38}$$

where

$$I_n' = \widehat{w}_n w_n L_n + R_n' + D_n^A + \Pi_n',$$

$$R_n' = \sum_{i=1}^{N} \frac{(\tau_{ni}-1)}{\tau_{ni}} \pi_{ni}^{O,O\prime} X_n^{O'},$$

and

$$\Pi_n' = \frac{1}{\sigma} \sum_{i=1}^{N} \pi_{in}^{O'} \frac{X_i^{O'}}{\tau_{in}} - \frac{\theta_2 - (\sigma-1)}{\sigma\theta_2} \sum_{i=1}^{N} \pi_{in}^{O'} X_i^{O'}.$$

The counterfactual trade balance is given by

$$\sum_{i=1}^{N} \pi_{ni}^{O,O\prime} \frac{X_n^{O\prime}}{\tau_{ni}} - D_n = \sum_{i=1}^{N} \pi_{in}^{O,O\prime} \frac{X_i^{O\prime}}{\tau_{in}}. \tag{2.39}$$

Finally, the counterfactual new born ideas' productivity is given by

$$z_{n,0}' = \kappa_1 \left(\sum_{k=1}^{N} \frac{\left(\pi_{ikt}^{O,O'}\right)^{\frac{\theta_2-1}{\theta_2}} \left(\frac{X_n^{O'}}{\sigma E_{nk}^{O'}}\right)^{\frac{\theta_2-1}{\theta_2}}}{\sum_{k=1}^{N} \pi_{ik}^{O,O'} \left(\frac{X_n^{O'}}{\sigma E_{nk}^{O'}}\right)} \left(\frac{\theta_1}{\theta_1+\theta_2} J_k (z_{k,0}')^{\theta_2} \right)^{1/\theta_2} \right)^{\delta_2}. \tag{2.40}$$

It is useful to compare these equation system above with the equation system that characterize the counterfactual equilibrium in Eaton et al. (2011). Since no country implements processing trade policy in the counterfactual world, the equilibrium in Eaton et al. (2011) can be considered as outcomes in the balanced growth path of this model. The new thing in this model is that productivity distributions are linked across countries through idea diffusion, and there is one more set of equations as is shown in equation (2.40) to characterize the idea diffusion, while productivity distributions across countries are exogenously given in Eaton et al. (2011). Therefore, I need more parameters to calculate the counterfactual outcomes than that in Eaton et al. (2011), and I will discuss it in the next subsection.

2.5.2 Calibration

I need to calibrate common parameters, $(\theta_2, \sigma, \beta, \delta_2)$, and four sets of parameters that are country specific, the share of manufactures in final consumption $(\gamma_1, ..., \gamma_N)$, the matrix of fixed costs $E^{TM} = [E_{ni}^{TM}]$ for $TM = O, P$, the measure of ideas $(J_1, ..., J_N)$, and the new born ideas' productivity $(z_{1,0}, ..., z_{N,0})$.

I take $\theta = 7.29$ and $\sigma = 4$ from Deng (2016), in which these two parameters are structurally estimated according to a model that can be considered as the steady state of this model by using Chinese firm-level data. I set $\beta = 0.36$ as Eaton et al. (2011). I set $\delta_2 = 0.7$ as the value of the diffusion parameter in Buera and Oberfield (2016). I calculate γ_i the same way as Eaton et al. (2011).

The fixed cost E_{ni}^{TM} is equal to the average sales of firms from country i selling in market n through trade mode TM, but I only have the number of firms from China selling in every market through trade mode TM. Fixed Costs for processing trade is only relevant for China, I set σE_{nC}^{P} equal to the average sales of firms from China selling in market n through processing trade, calculated by using China's custom data of 2005 where ordinary and processing trade can be separated. I make a assumption that the fixed cost for ordinary trade is market specific, $E_{ni}^{O} = E_{n}^{O}$, and the fixed cost can be back out by using the equation of real wage

$$\frac{w_i}{P_i^O} = \kappa_2 \left(\frac{\frac{\theta_1}{\theta_1+\theta_2} J_i(z_{i,0})^{\theta_2}}{\pi_{ii}^{O,O}} \right)^{\frac{1}{\beta\theta_2}} \left[\left(\frac{X_i}{\sigma E_i^O} \right) \left(1 - \frac{\mathbb{I}_i^P (\pi_{ii}^{O,O} - \pi_{ii}^{P,O}) X_i^P}{\pi_{ii}^{O,O} X_i} \right) \right]^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}}. \tag{2.41}$$

The real wage for each country i, $\frac{w_i}{P_i^O}$ is from Penn World Table 8.1 (Feenstra et al. (2015)). I set the technology parameter for each country, $\frac{\theta_1}{\theta_1+\theta_2} J_i(z_{i,0})^{\theta_2}$, equal to the TFP measure in Penn World Table 8.1. I set the total absorption of manufactures for each country i equal to the manufacture output plus imports minus exports, where the manufacture output is from UNIDO Statistics Database, and imports and exports from UN COMTRADE Database. I calculate the trade shares by using bilateral trade data from UN COMTRADE and the total absorption of manufactures. Since I assume that China is the only country implemented processing trade policy, I use China's custom data of 2005 where ordinary and processing trade can be separated, to calculate the absorption of manufactures for processing trade and trade shares related to processing trade. With all these data, I back out the fixed cost for ordinary trade. With all these data, E_i^O can be back out from equation (2.41).

Rewrite equation (2.21), and the new born ideas' productivity can be calculated according to the following equation:

$$z_{i,0} = \kappa_2 \left[\sum_{k=1}^{N} \sum_{TM} \frac{\left(\frac{\pi_{ik}^{O,TM} X_{ik}^{O} + \pi_{ik}^{P,TM} X_{ik}^{P}}{\sigma E_{ik}^{TM}} \right)^{\frac{\theta_2 - 1}{\theta_2}}}{\sum_{k=1}^{N} \sum_{TM} \frac{\pi_{ik}^{O,TM} X_{ik}^{O} + \pi_{ik}^{P,TM} X_{ik}^{P}}{\sigma E_{ik}^{TM}}} \left(\frac{\theta_1}{\theta_1 + \theta_2} J_i (z_{i,0})^{\theta_2} \right)^{\frac{1}{\theta_2}} \right]^{\delta_2}, \quad (2.42)$$

where the values of variables on the right hand side of the equation is already calibrated. $\frac{\theta_1}{\theta_1+\theta_2} J_i$ is calculated from dividing $\frac{\theta_1}{\theta_1+\theta_2} J_i (z_{i,0})^{\theta_2}$ by $(z_{i,0})^{\theta_2}$.

2.5.3 Results

In this part, I show the results of two counterfactual exercises to separate the static losses and dynamic gains associated with processing trade policy. In the first counterfactual exercise, I shut down the processing trade policy in China and keep the ideas' productivity distribution for each country, while in the second counterfactual exercise, I shut down the processing trade policy in China but let the ideas' productivity distribution for each country adjust according to the model. The real wage changes for both counterfactual exercises are shown in Table B.1. The values in the second column of Table B.1 are the real wages changes for all countries in the first exercise where the processing trade policy is shut down in China and the ideas' productivity distribution for each country is kept unchanged. The values in the third column of Table B.1 are the real wages changes for all countries in the second exercise where the processing trade policy is shut down in China and the ideas' productivity distribution for each country is adjusted according to the model. All the tables are in Appendix B.6.

The first counterfactual exercise (keeping the scale parameter unchanged for each country) shows that real wage of China increases by 3.7% when processing trade policy is shut down in China, which is the magnitude of static loss associated with processing trade policy. For the rest countries in the world, real wages of popular destination countries for Chinese exports, such as U.S., U.K. and Germany, decrease as less varieties are imported from China, while real wages of competing countries of China, such as Bangladesh, India, Pakistan and Vietnam, etc, increase because these countries export more to the destination countries for Chinese exports, but the magnitudes are all less than 1%.

The second counterfactual exercise, with the spillovers from all the sellers in the market to the new ideas, shows that real wage of China decreases by 7.6% when processing trade policy is shut down in China, suggesting that the magnitudes of dynamic gains is about three times larger than that of static losses. While real wages in the competing countries of China increase more than that in the first counterfactual exercise because they exports more and imports more, and more imports from countries with the higher scale parameters improve their aggregate productivity. Real wages in popular destination countries of Chinese exports decrease more because aggregate productivity are dampened by less productive China's imports. The direction of effects on both competing countries and popular destination countries of China's exports are the same in both counterfactual exercises, and the spillovers amplify these effects[16].

In order to see the trade-off on welfare of China associated with processing trade policy, I decompose the real wage change for country i according to the following equation

$$\frac{\hat{w}_{it}}{\hat{P}^{O}_{it}} = \left(\frac{z'_{it,0}}{z_{it,0}}\right)^{\frac{1}{\beta}} \left(\frac{\pi^{O,O}_{iit}}{\pi^{O,O'}_{iit}}\right)^{\frac{1}{\beta\theta_2}} \left[\left(\frac{X^{O'}_{it}}{\sigma E^{O'}_{iit}}\right) \Big/ \left(\frac{X^{O}_{it} + \frac{\pi^{P,O}_{iit}}{\pi^{O,O}_{iit}} X^{P}_{it}}{\sigma E^{O}_{iit}}\right)\right]^{\frac{1}{\beta(\sigma-1)} - \frac{1}{\beta\theta_2}}. \qquad (2.43)$$

Therefore, we can decompose the real wage change into three terms: the first terms of the real wage change is associated the change of new ideas' productivity; the second term of the real wage change is associated with the change of domestic expenditure share; the third term is associated with the change of measure of varieties. Table B.2 shows the decomposition of the real wage changes for the first counterfactual exercise. Since I assume that the productivity distribution for each country is unchanged, the fist term is 1 for each country, thus omitted. Table B.3

[16] OECD countries have large decreases in real wages. This is partly because I assume that the fixed components of the market penetration costs are only market specific. For example, the fixed component is identical for both Chinese firms and U.S. firms selling in U.S. market, inducing more Chinese firms selling in U.S. market than the case with a larger fixed component for Chinese firms selling in U.S. market, therefore, dampening U.S's aggregate productivity and causing large decrease in real wage of U.S..

shows the decomposition of the real wage changes for the second counterfactual exercise.

Table B.2 shows that increase in real wage in China is completely from the third term which is the increase in varieties for the first counterfactual exercise. Table B.3 shows that the real wage changes are dominated by the change in productivity, and China has a large decrease in productivity in the second counterfactual exercise. These numbers are consistent with trade-off on welfare associated with processing trade policy.

2.6 Conclusion

This paper quantifies the welfare implication of processing trade policy by using a multi-country general equilibrium trade model building on Eaton et al. (2011) and Arkolakis (2016), in paricular, separates the magnitudes of dynamics gains and static losses associated with processing trade policy in terms of the real wage change. The results show that the magnitude of dynamic gains is five times larger than that of static losses. Processing trade policy results in a temporary higher growth rate for the host countries (developing countries) and a permanent higher level.

Foreign Direct Investment (FDI) is omitted from this paper, may also affects the welfare implication of processing trade policy since one of the main objectives of processing trade policy from the policy maker's perspective is to attract FDI. If most of the processing exports are produced by foreign firms in the developing countries, there is a larger loss of consumption (static losses) for the host countries because the profits made by foreign firms through processing trade will be transferred back to the foreign firms' source countries. FDI may also affect the firms' productivity distribution in the host countries of processing trade policy, and how does it affect the dynamic gains? I leave these questions to future research.

Appendix A

Supplemental Material for Chapter 1

A.1 Connecting the Model to Data

Transform the efficiency of any potential firm in China as EKK(2011)

$$u(\omega) = T_C z_C(\omega)^{-\theta}.$$

We refer to $u(\omega)$ as firm ω's standardized unit cost, and standardized unit costs have a uniform measure that does not depend on any parameter.

Associated with the entry hurdles $\overline{c}_{nC}^{TM}(\eta)$ is standardized entry hurdles $\overline{u}_{nC}^{TM}(\eta)$, satisfying

$$\overline{c}_{nC}^{TM}(\eta) = \left(\frac{\overline{u}_{nC}^{TM}(\eta)}{\Phi_{nC}^{TM}}\right)^{1/\theta}, \; TM = \; O \text{ or } P.$$

Firm ω enters market n via TM if its $u(\omega)$ and $\eta_n(\omega)$ satisfy

$$\begin{aligned} u(\omega) &\leq \overline{u}_{nC}^{TM}(\eta_n(\omega)) \\ &= \overline{u}_{nC}^{TM}(\eta) = \Phi_{nC}^{TM}\left(\overline{c}_{nC}^{TM}(\eta)\right), \end{aligned}$$

and we have

$$\overline{u}_{nC}^{TM}(\eta) = \eta^{\theta/(\sigma-1)} \frac{1-t_{nC}}{\kappa_1 \sigma E_{nC}^{TM}} \left(\pi_{nC}^{O,O} X_n^O + \mathbb{I}_n^P \pi_{nC}^{P,O} X_n^P\right).$$

Conditional on firm ω's passing on this hurdle, its sales in market n via TM in terms of $u(\omega)$ is given by

$$X_{nC}^{TM}(\omega) = \varepsilon_n(\omega)\left[1 - \left(\frac{u(\omega)}{\overline{u}_{nC}^{TM}(\eta_n(\omega))}\right)^{\lambda(\sigma-1)/\theta}\right]\left(\frac{u(\omega)}{\overline{u}_{nC}^{TM}(\eta_n(\omega))}\right)^{-(\sigma-1)/\theta}\frac{\sigma E_{nC}^{TM}}{1-t_{nC}}.$$

We equate the measure of Chinese firms J_{nC}^{TM} through trade mode TM selling in each destination with the actual integer number N_{nC}^{TM}, and equate $\overline{X}_{nC}^{TM}$ their average sales, while $\overline{X}_{nC}^{TM} = \frac{\left(\pi_{nC}^{O,TM}X_n^O + \mathbb{I}_n^P \pi_{nC}^{P,TM}X_n^P\right)}{J_{nC}^{TM}}$ in the model.

Entry

We have

$$N_{nC}^{TM} = \frac{\kappa_2}{\kappa_1}\frac{1-t_{nC}}{\sigma E_{nC}^{TM}}\left(\pi_{nC}^{O,TM}X_n^O + \mathbb{I}_n^P \pi_{nC}^{P,TM}X_n^P\right),$$

that is,

$$\frac{\sigma E_{nC}^{TM}}{(1-t_{nC})} = \frac{\kappa_2}{\kappa_1}\overline{X}_{nC}^{TM}.$$

Using equations above, the standardized cost hurdle can be written as

$$\overline{u}_{nC}^{TM}(\eta_n(\omega)) = \frac{N_{nC}^{TM}}{\kappa_2}(\eta_n(\omega))^{\widetilde{\theta}},$$

where $\widetilde{\theta} = \frac{\theta}{\sigma-1}$. This equation is the same as the equation (29) in EKK(2011). With or without import tariff, VAT, export VAT rebate and processing trade policy, the cutoff of the standardized cost only depends on the number of entries and the entry shock.

Sales in a Market

Conditional in a firm's entry into market n through domestic sales or ordinary exports, the term

$$v_{nC}^{TM}(\omega) = \frac{u(\omega)}{\overline{u}_{nC}^{TM}(\eta_n(\omega))}$$

is distributed uniformly on $[0,1]$. Replacing $u(\omega)$ with $v_{nC}^{TM}(\omega)$, we can write the sales as

$$X_{nC}^{TM}(\omega)=\varepsilon_n(\omega)\left[1-\left(v_{nC}^{TM}(\omega)\right)^{\lambda/\widetilde{\theta}}\right]\left(v_{nC}^{TM}(\omega)\right)^{-1/\widetilde{\theta}}\frac{\kappa_2}{\kappa_1}\overline{X}_{nC}^{TM},$$

which is the same as the equation (31) in EKK(2011).

A.2 Simulated Method of Moments

In this section, we describe the simulation algorithm, moments constructed and estimation procedure in detail.

Simulation Algorithm

We denote an artificial Chinese exporter by s and the number of such exporters by S. Prior to running any simulations, (i) we draw S realizations of $v(s)$ independently from the uniform distribution $U[0,1]$, putting them aside to construct standardized unit cost below, and (ii) we draw two sets of $S \times N$ realizations of $a_n(s)$ and $h_n(s)$ independently from $N(0,1)$, putting them aside to construct $\alpha_n^O(s)$ and $\eta_n^O(s)$, and $\alpha_n^P(s)$ and $\eta_n^P(s)$ below.

A given simulation of the model requires a set of parameters Θ, data for each destination n on average domestic sales or ordinary exports $\overline{X}_{nC}^O$ by Chinese ordinary exporters, average processing exports $\overline{X}_{nC}^P$ by Chinese processing exporters, and the numbers N_{nC}^O and N_{nC}^P of Chinese firms selling there via domestic sales or ordinary exports and processing exports, respectively. It involves nine steps:

Step 1 Calculate κ_1 and κ_2.

Step 2 Calculate $\frac{\sigma E_{nC}^{TM}}{1-t_{nC}}$ for each destination according to $\frac{\sigma E_{nC}^{TM}}{1-t_{nC}} = \frac{\kappa_2}{\kappa_1}\overline{X}_{nC}^{TM}$.

Step 3 We use the $a_n^{TM}(s)$'s and $h_n^{TM}(s)$'s to construct $S \times N$ realizations for each of $\ln \alpha_n^{TM}(s)$ and $\ln \eta_n^{TM}(s)$ as

$$\begin{bmatrix} \ln \alpha_n^{TM}(s) \\ \ln \eta_n^{TM}(s) \end{bmatrix} = \begin{bmatrix} \sigma_\alpha \sqrt{1-\rho^2} & \sigma_\alpha \rho \\ 0 & \sigma_\eta \end{bmatrix} \begin{bmatrix} a_n^{TM}(s) \\ h_n^{TM}(s) \end{bmatrix},$$

where $TM = DO, P$.

Step 4 We construct the $S \times N$ entry hurdles for domestic sales and ordinary exports

$$\overline{u}_n^O(s) = \frac{N_{nC}^O}{\kappa_2} \eta_n^O(s)^{\widetilde{\theta}},$$

and $S \times N$ entry hurdles for processing exports

$$\overline{u}_n^P(s) = \frac{N_{nC}^P}{\kappa_2} \eta_n^P(s)^{\widetilde{\theta}}.$$

Step 5 We calculate

$$\overline{u}(s) = \max_n \left\{ \overline{u}_n^O(s), \overline{u}_n^P(s) \right\},$$

the maximum u consistent with selling somewhere through domestic sales, ordinary exports or processing exports.

Step 6 To simulate ordinary and processing exporters that sell in China, $u(s)$ should be a realization from the uniform distribution over the interval $[0, \overline{u}(s)]$. Therefore, we construct

$$u(s) = v(s)\,\overline{u}(s).$$

Step 7 In the model, a measure of $\overline{u}$ firms have standardized unit cost below $\overline{u}$. Our artificial Chinese exporter s therefore gets an importance weight $\overline{u}(s)$. This importance weight is used to construct statistics on artificial Chinese exporters that relate to statistics on actual Chinese exporters.

Step 8 We calculate $\delta_{nC}^O(s)$, which indicates whether artificial exporters s enters market n through domestic sales or ordinary exports, as determined by the entry hurdles

$$\delta_{nC}^O(s) = \begin{cases} 1 & \text{if } u(s) \leq \overline{u}_n^O(s), \\ 0, & \text{otherwise.} \end{cases}$$

Wherever $\delta_{nC}^O(s) = 1$, we calculate sales as

$$X_{nC}^O(s) = \frac{\alpha_n^O(s)}{\eta_n^O(s)} \left[1 - \left(\frac{u(s)}{\overline{u}_n^O(s)} \right)^{\lambda/\widetilde{\theta}} \right] \left(\frac{u(s)}{\overline{u}_n^O(s)} \right)^{-1/\widetilde{\theta}} \frac{\sigma E_{nC}^O}{(1 - t_{nC})},$$

Step 9 We calculate $\delta_{nC}^P(s)$, which indicates whether artificial exporters s enters market n through domestic sales or ordinary exports, as determined by the entry hurdles

$$\delta_{nC}^{P}(s)=\begin{cases}1 & \text{if } u(s)\leq \overline{u}_{n}^{P}(s),\\ 0, & \text{otherwise.}\end{cases}$$

Wherever $\delta_{nC}^{P}(s)=1$, we calculate sales as

$$X_{nC}^{P}(s)=\frac{\alpha_{n}^{P}(s)}{\eta_{n}^{P}(s)}\left[1-\left(\frac{u(s)}{\overline{u}_{n}^{P}(s)}\right)^{\lambda/\widetilde{\theta}}\right]\left(\frac{u(s)}{\overline{u}_{n}^{P}(s)}\right)^{-1/\widetilde{\theta}}\frac{\sigma E_{nC}^{P}}{(1-t_{nC})},$$

Moments

For a candidate value Θ, we use the algorithm above to simulate the sales of S artificial Chinese exporting firms in N markets. From these artificial data, we compute a vector of moments $\widehat{m}(\Theta)$ analogous to particular moments m in the actual data. Here we choose six sets of moments. The first four sets of moments are related to ordinary exports:

- We compute the proportion $\widehat{m}^{k}(1;\Theta)$ of simulated ordinary exporters selling to each possible combination k of the seven most popular ordinary export destinations. One possibility is exporting yet selling none of the top seven via ordinary exports, giving us 2^{7} possible combinations. The corresponding moments from the actual data are simply the proportion $m^{k}(1)$ of exporters selling to combination k. Stacking these proportions gives us $\widehat{m}(1;\Theta)$ and $m(1)$ with 128 elements (subject to 1 adding up constraint).

- For firms selling in each $N-1$ export destinations n, we compute the qth percentile of ordinary export sales $s_{n}^{q}(2)$ in that market for $q=50,75,95$, from actual data. Using these $s_{n}^{q}(2)$, we assign firms that sell in n into four mutually exclusive and exhaustive bins determined by these three ordinary export sales levels. We compute the proportion $\widehat{m}_{n}(2;\Theta)$ of artificial firms falling into each bin analogous to the actual proportion $m_{n}(2)=(0.5,0.25,0.2,0.05)'$. Stacking across $N-1$ countries gives us the proportion $\widehat{m}(2;\Theta)$ and $m(2)$, each with $4(N-1)$ elements (subject to $N-1$ adding up constraints).

- For firms selling via ordinary exports in each $N-1$ destinations n, we compute the qth percentile of sales $s_{n}^{q}(3)$ in Chinese (excluding firm with no sales in

China) for $q = 50, 75, 95$, from actual data. Proceeding as above, we get $\widehat{m}(3;\Theta)$ and $m(3)$, each with $4(N-1)$ elements (subject to $N-1$ adding up constraints).

- For firms selling via ordinary exports in each 112 destinations n, we compute the qth percentile ratio of ordinary export sales $s_n^q(4)$ in n to sales in China (excluding firms with no sales in China) for $q = 50, 75$, from actual data. Proceeding as above, we get $\widehat{m}(4;\Theta)$ and $m(4)$, each with $3(N-1)$ elements (subject to $N-1$ adding up constraints).

The last two sets of moments are related to processing exports:

- We compute the proportion $\widehat{m}^k(5;\Theta)$ of simulated processing exporters selling to each possible combination k of the seven most popular processing export destinations. One possibility is exporting yet selling none of the top seven via processing exports, giving us 2^7 possible combinations. The corresponding moments from the actual data are simply the proportion $m^k(5)$ of exporters selling to combination k. Stacking these proportions gives us $\widehat{m}(5;\Theta)$ and $m(5)$ with 128 elements (subject to 1 adding up constraint).

- For firms selling in each $N-1$ export destinations n, we compute the qth percentile of processing export sales $s_n^q(6)$ in that market for $q = 50, 75, 95$, from actual data. Using these $s_n^q(6)$, we assign firms that sell in n into four mutually exclusive and exhaustive bins determined by these three processing export sales levels. We compute the proportion $\widehat{m}_n(6;\Theta)$ of artificial firms falling into each bin analogous to the actual proportion $m_n(6) = (0.5, 0.25, 0.2, 0.05)'$. Stacking across $N-1$ countries gives us the proportion $\widehat{m}(6;\Theta)$ and $m(6)$, each with $4(N-1)$ elements (subject to $N-1$ adding up constraints).

Stacking the six sets of moments gives us a $(15(N-1)+256)$-element vector of deviations between the moments of the actual and artificial data:

$$y(\Theta) = \begin{bmatrix} m(1) - \widehat{m}(1;\Theta) \\ m(2) - \widehat{m}(2;\Theta) \\ m(3) - \widehat{m}(3;\Theta) \\ m(4) - \widehat{m}(4;\Theta) \\ m(5) - \widehat{m}(5;\Theta) \\ m(6) - \widehat{m}(6;\Theta) \end{bmatrix}.$$

Estimation Procedure

We base our estimation procedure on the moment condition

$$\mathbb{E}[y(\Theta_0)] = 0,$$

where Θ_0 is the true value of Θ. We thus seek a $\widehat{\Theta}$ that achieves

$$\widehat{\Theta} = \arg\min_{\Theta} \left[y(\Theta)' W y(\Theta) \right],$$

where W is the weighting matrix.

A.3 Closing the Model

In this part, we will write down the market clearing conditions in detail. The composite intermediate goods produced in country n, used as inputs to produce domestic sales and ordinary exports, is equal to the final consumption of composite intermediate goods and inputs demanded by firms in country n to produce domestic sales and ordinary exports. The equation is given by

$$Q_n^O = Q_{nf}^O + \int m_n^O(\omega)\, d\omega,$$

where Q_n^O is the total quantity demanded in country n, and Q_{nf}^O is the quantity demanded for final consumption. Since the share of expenditure on composite intermediate goods is fixed for firms in country n, $m_n^O(\omega) = \sum_{i=1}^N \frac{(1-\beta)}{\overline{m}\zeta_{in}P_n^O} q_{in}(\omega)\, p_{in}(\omega)\,,$ and we have

$$Q_n^O = Q_{nf}^O + \sum_{i=1}^N \int \frac{(1-\beta)}{\overline{m}\zeta_{in}P_n^O} q_{in}(\omega)\, p_{in}(\omega)\, d\omega,$$

Since $\int q_{in}(\omega)\, p_{in}(\omega)\, d\omega = \pi_{in}^{O,O}\frac{P_i^O Q_i^O}{\tau_{in}} + \mathbb{I}_i^P \pi_{in}^{P,O} P_i^P Q_i^P$, we have

$$Q_n^O = Q_{nf}^O + \sum_{i=1}^N \left(\pi_{in}^{O,O}\frac{P_i^O Q_i^O}{\tau_{in}} + \mathbb{I}_n^P \pi_{in}^{P,O} P_i^P Q_i^P \right),$$

that is,

$$X_n^O = \gamma I_n + \sum_{i=1}^N \frac{(1-\beta)}{\overline{m}\zeta_{in}} \left(\pi_{in}^{O,O}\frac{X_i^{DO}}{\tau_{in}} + \mathbb{I}_i \pi_{in}^{P,O} X_i^P \right).$$

The composite intermediate goods produced in country n, used as inputs to produce processing exports, is equal to the inputs demanded by firms in country n to produce processing exports. The equation is given by

$$Q_n^P = \int m_n^P(\omega)\, d\omega.$$

Since the share of expenditure on composite intermediate goods is fixed in country n, $m_n^P(\omega) = \frac{(1-\beta)\sum_{i\neq n} q_{in}(\omega) p_{in}(\omega)}{\overline{m}\zeta_{in}P_n^P}$, and we have

$$Q_n^P = \int \frac{(1-\beta)\sum_{i\neq n} q_{in}(\omega)\, p_{in}(\omega)}{\overline{m}\zeta_{in} P_n^P} d\omega.$$

We can rewrite the equation as

$$Q_n^P = \sum_{i\neq n} \frac{(1-\beta)}{\overline{m}\zeta_{in} P_n^P} \int q_{in}(\omega)\, p_{in}(\omega)\, d\omega.$$

Since $\int q_{in}(\omega)\, p_{in}(\omega)\, d\omega = \pi_{in}^{O,P} \frac{X_i^O}{\tau_{in}} + \mathbb{I}_i^P \pi_{in}^{P,P} X_i^P$, we have

$$X_n^P = \sum_{i\neq n} \frac{(1-\beta)}{\overline{m}\zeta_{in}} \left(\pi_{in}^{O,P} \frac{X_i^O}{\tau_{in}} + \mathbb{I}_i^P \pi_{in}^{P,P} X_i^P \right).$$

A.4 Data Source

There are two data sources used in this paper to construct the Chinese firm-level data in year 2005. The first is Annual Survey of Chinese Manufacturing (ASCM), which contains the balance sheets information for manufacturung firms in China with sales more than 5 million Chinese Yuan (about 0.6 million dollars). The second is the Chinese Custom Records (CCR) which covers the universal transactions, containing information, such as firm name, 8-digit HS code, trade mode, import or export, value, quantity, destination, etc. We aggregate the custom data by firm, trade mode, import or export and destination, then merge it with the data of ASCM.

Data for counterfactual exercise includes: bilateral trade flows data comes from UN COMTRADE database, tariff data is from UNCTAD-TRAINS database. GDP, manufacturing trade deficit and total trade deficit are from the World Bank World Development Index database. Manufacturing output and value-added are obtained from UNIDO Industrial Statistical Database.

Appendix B

Supplemental Material for Chapter 2

B.1 the Suggesting Evidence for Global Idea Diffusion

In this section, I show the regression results mentioned in the introduction regarding the positive correlation between the average productivity of entering firms relative to the continuing firms in an industry and the fraction of processing exports out of total exports in the industry found in China's firm-level data from 2000 to 2006, and the results is shown in the following table

	y_{it}
x_{it}	0.308***
	(3.59)
constant	0.756***
	(17.14)
year FE	YES
industry FE	YES
N	774

t statistics in parentheses
$* \ p < 0.05$, $** \ p < 0.01$, $*** \ p < 0.001$

where i denotes a 4-digit industry according to the International Standard Industry Classification Version 3, t denotes a year.

y_{it} is the average productivity of entering firms relative to the continuing firms of industry i in year t and I calculated the measure in three steps. First, I calculated firms' total factor productivity for each industry i and year t using the method of Olley and Pakes (1996) with China's firm-level data from 2000 to 2006. Second, I calculated the average productivity of entering firms weighted by their value-added and the average productivity of the continuing firms weighted by their valued for each industry i. Third, I obtained the average productivity of the entering firms relative to continuing firms by dividing the average productivity of the entering firms by the average productivity of continuing firms.

x_{it} is the share of processing exports among total exports of China of industry i in year t. Processing (Ordinary) exports are aggregated across all the transactions on China's Custom Data labelled as processing (ordinary) export, and total exports are the sum of processing exports and ordinary exports. The share of processing exports is calculated by dividing the processing export by the total exports.

B.2 Characterization of the Evolution of Productivity Distribution

In this section, I provide the characterization of the evolution of productivity distribution in terms of Kolmogorov Forward Equation (KFE), and solve the stationary distribution. First, I introduce the KFE, and some intuition about KFE. Second, I derive the KFE that determines the law of motion of idea distribution. Third, I derive the KFE that determines the law of motion of normalized idea distribution, and solve the stationary distribution.

B.2.1 Intuition for Kolmogorov Forward Equation

Let z be a scalar diffusion with initial probability density function $f(z,0)$, given by

$$dz_t = \mu(z)dt + \frac{1}{2}\sigma(z)^2 dW_t,$$

z where W_t is the standard Brownian motion. Kolmogorov Forward Equation is the partial differential equation (PDE) that characterizes the evolution of the distribution of z over time t, and is given by

$$\frac{\partial f(z,t)}{\partial t} = -\frac{\partial}{\partial z}[\mu(z)f(z,t)] + \frac{1}{2}\frac{\partial^2}{\partial z^2}[\sigma(z)^2 f(z,t)],$$

where $f(z,t)$ is the probability density function of z at time t.

I will not prove the claim, but illustrate the intuition instead. Consider the case that $\mu(z) = \mu$ and $\sigma(z) = \sigma$, and the corresponding KFE is given by

$$\frac{\partial f(z,t)}{\partial t} = -\frac{\partial}{\partial z}[\mu f(z,t)] + \frac{1}{2}\frac{\partial^2}{\partial z^2}[\sigma^2 f(z,t)]. \tag{B.1}$$

Suppose that the diffusion parameter σ is equal to 0, and the diffusion process is simply $dz_t = \mu dt$, implying that the probability density function of z is moving to the right at the speed of μ, equivalently, $f(z,t) = f(z-\mu t, 0)$. $f(z,t)$ is characterized by the following PDE

$$\frac{\partial f(z,t)}{\partial t} = -\frac{\partial}{\partial z}[\mu f(z,t)], \tag{B.2}$$

which is exactly equation (B.1) when $\sigma = 0$.

Suppose that the drifting parameter μ is equal to 0, and the diffusion process is simply $dz_t = \frac{1}{2}\sigma^2 dW_t$. The probability density function of z at time t conditional on z_0 is given by

$$f(z,t|z_0) = \frac{1}{\sigma\sqrt{2\pi t}} \exp -\frac{(z-z_0)^2}{2\sigma^2 t},$$

and $f(z,t|z_0)$ is characterized by the following PDE

$$\frac{\partial f(z,t|z_0)}{\partial t} = \frac{1}{2}\frac{\partial^2}{\partial z^2}[\sigma^2 f(z,t|z_0)]. \tag{B.3}$$

Integrating equation (B.3) over z_0, we get

$$\frac{\partial f(z,t)}{\partial t} = \frac{1}{2}\frac{\partial^2}{\partial z^2}[\sigma^2 f(z,t)], \tag{B.4}$$

which is exactly equation (B.1) when $\mu = 0$. Combining equation (B.2) and (B.4), we obtain equation (B.1) intuitively.

B.2.2 Law of Motion of the Idea Distribution

I am now ready to characterize the evolution of idea distribution in terms of partial differential equation, and will proceed in two steps. First, I write down the KFE characterizing the idea distribution for any given cohort Second, I integrate the KFE over all cohorts born before time t, and derive the partial differential equation characterizing the evolution of idea distribution.

The productivity distribution of ideas born at time t^b in country i, $f_i^{t^b}(z,t)$, evolves according to the following Kolmogorov Forward Equation:

$$\frac{\partial f_i^{t^b}(z,t)}{\partial t} = -(g_I + \frac{1}{2}\sigma_I^2)\frac{\partial}{\partial z}[z f_i^{t^b}(z,t)] + \frac{1}{2}\sigma_I^2 \frac{\partial^2}{\partial z^2}[z^2 f_i^{t^b}(z,t)].$$

Let $m_i^{t^b}(z,t)$ denote the measure of ideas with productivity z at time t born at time t^b, and we can rewrite the KFE in terms of the measure of ideas:

$$\frac{\partial m_i^{t^b}(z,t)}{\partial t} = -(g_I + \frac{1}{2}\sigma_I^2)\frac{\partial}{\partial z}[z m_i^{t^b}(z,t)] + \frac{1}{2}\sigma_I^2 \frac{\partial^2}{\partial z^2}[z^2 m_i^{t^b}(z,t)]. \tag{B.5}$$

Let $m_i(z,t)$ denote the measure of ideas with productivity z at time t, and $m_i(z,t) = \int_0^t m_i^{t^b}(z,t)dt^b$. Taking derivative with respective to t, we have $\frac{\partial m_i(z,t)}{\partial t} = m_i^t(z,t) + \int_0^t \frac{\partial m_i^{t^b}(z,t)}{\partial t} dt^b$. Integrate equation (B.5) with respect to t^b from 0 to t, and we have

$$\frac{\partial m_i(z,t)}{\partial t} - m_i^t(z,t) = -(g_I + \frac{1}{2}\sigma_I^2)\frac{\partial}{\partial z}[zm_i(z,t)] + \frac{1}{2}\sigma_I^2 \frac{\partial^2}{\partial z^2}[z^2 m_i(z,t)]. \quad \text{(B.6)}$$

The relationship between the probability density function of ideas and the measure of ideas is given by $f_i(z,t) = \frac{m_i(z,t)}{J_{it}}$. Taking derivative with respect to t, we have

$$\frac{\partial m_i(z,t)}{\partial t} = \frac{\partial f_i(z,t)}{\partial t} J_{it} + f_i(z,t)\frac{\partial J_{it}}{\partial t}. \quad \text{(B.7)}$$

Substitute equation (B.7) into equation (B.6) and divided by J_{it}, and we get

$$\frac{\partial f_i(z,t)}{\partial t} + \frac{\frac{\partial J_{it}}{\partial t}}{J_{it}} f_i(z,t) - \frac{m_i^t(z,t)}{J_{it}} = -(g_I + \frac{1}{2}\sigma_I^2)\frac{\partial}{\partial z}[zf_i(z,t)] + \frac{1}{2}\sigma_I^2 \frac{\partial^2}{\partial z^2}[z^2 f_i(z,t)]. \quad \text{(B.8)}$$

B.2.3 Law of Motion of the Normalized Idea Distribution

Let $\phi_i(s,t)$ denote the probability density function at time t of normalized productivity $s = z/\overline{z}_{it}$. We have $f_i(z,t) = \frac{1}{z_{it,0}}\phi_i(s,t)|_{s=z/z_{it,0}}$. To Characterize the normalized KFE, first differentiate $f_i(z,t)$ with respect to t, and I have

$$\frac{\partial f_i(z,t)}{\partial t} = \frac{1}{z_{it,0}}\Big(\frac{\partial \phi_i(s,t)}{\partial t} - \frac{\dot{z}_{it,0}}{z_{it,0}}\frac{\partial}{\partial s}[s\phi_i(s,t)]\Big)\Big|_{s=z/z_{it,0}}.$$

Differentiating $zf_i(z,t)$ with respect to z yields

$$\frac{\partial}{\partial z}[zf_i(z,t)] = \frac{1}{z_{it,0}}\frac{\partial}{\partial s}[s\phi_i(s,t)]\Big|_{s=z/z_{it,0}}.$$

Differentiating $z^2 f_i(z,t)$ with respect to z yields

$$\frac{\partial^2}{\partial z}[z^2 f_i(z,t)] = \frac{1}{\overline{z}_{it}}\frac{\partial^2}{\partial s^2}[s^2\phi_i(s,t)]\Big|_{s=z/z_{it,0}}.$$

Substituting equations above into equation (B.8) yields

$$\frac{\partial\phi_i(s,t)}{\partial t} + \frac{\frac{\partial J_{it}}{\partial t}}{J_{it}}\phi_i(s,t) - \frac{z_{it,0}m_i^t(z_{it,0}s,t)}{J_{it}} = -(g_I + \frac{1}{2}\sigma_I^2 - \frac{\dot{z}_{it,0}}{z_{it,0}})\frac{\partial}{\partial s}[s\phi_i(s,t)] + \frac{1}{2}\sigma_I^2\frac{\partial^2}{\partial s^2}[s^2\phi_i(s,t)], \tag{B.9}$$

where

$$\frac{z_{it,0}m_i^t(z_{it,0}s,t)}{J_{it}} = \begin{cases} \frac{\frac{\partial J_{it}}{\partial t}}{J_{it}} & \text{if } s = 1, \\ 0 & \text{otherwise.} \end{cases}$$

I rewrite equation (B.9) as

$$\frac{\partial\phi_i(s,t)}{\partial t} + g_B\phi_i(s,t) = -(g_I + \frac{1}{2}\sigma_I^2 - \frac{\dot{z}_{it,0}}{z_{it,0}})\frac{\partial}{\partial s}[s\phi_i(s,t)] + \frac{1}{2}\sigma_I^2\frac{\partial^2}{\partial s^2}[s^2\phi_i(s,t)],$$

The stationary normalized productivity distribution, $\phi_i(s)$, is characterized as following

$$g_B\phi_i(s) = -(\mu + \frac{1}{2}\sigma_I^2)\frac{\partial}{\partial s}[s\phi_i(s)] + \frac{1}{2}\sigma_I^2\frac{\partial^2}{\partial s^2}[s^2\phi_i(s)],\ s \in (0,1) \cup (1,+\infty),$$

where $\mu = g_I - g_E$, and $g_E = \frac{\dot{z}_{it,0}}{z_{it,0}}$ in the balanced growth path. The probability density function also satisfies following requirements:

$$\phi_i(s) \geq 0 \forall s \in (0,+\infty), \int_0^1 \phi_i(s)ds + \int_1^{+\infty} \phi_i(s)ds = 1,$$

and

$$\frac{1}{2}\sigma_I^2\Big[\frac{\partial}{\partial s}[s^2\phi_i(s)]\Big|_{s=1-} - \frac{\partial}{\partial s}[s^2\phi_i(s)]\Big|_{s=1+}\Big] = g_B.$$

The last equation says that the net inflow into the productivity distribution at 1 is equal to the new outflow due to new idea entry.

The resulting stationary distribution of normalized productivity $s \in (0,+\infty)$ is the double Pareto distribution (Reed(2001) and Arkolakis (2016)) with probability density function:

$$\phi_i(s) = \begin{cases} \frac{\theta_1\theta_2}{\theta_1+\theta_2}s^{\theta_1-1} & \text{if } s < 1/\delta; \\ \frac{\theta_1\theta_2}{\theta_1+\theta_2}s^{-\theta_2-1} & \text{if } s \geq 1/\delta, \end{cases} \tag{B.10}$$

where

$$\theta_1 = \frac{\mu + \sqrt{\mu^2 + 2\sigma_I^2 g_B}}{\sigma_I^2},$$

and

$$\theta_2 = -\frac{\mu - \sqrt{\mu^2 + 2\sigma_I^2 g_B}}{\sigma_I^2}.$$

B.3 Derivation of Price Indices

Each buyer in market n has access to the same measure of goods (even though there are not necessarily the same goods.) Every buyer faces the same probability of $\alpha_{nit}^{TM}(z)$ to purchase a good sold via trade mode TM from country i with productivity z. Hence I can write the price index of the composite good for ordinary trade in market n as

$$P_{nt}^{O} = \left[\sum_{TM} \sum_{i=1}^{N} \int_{\overline{z}_{nit}^{TM}}^{+\infty} \mathbb{I}_{it}^{TM} \alpha_{nit}^{TM}(z) \big(\tau_{nit} p_{nit}^{TM}(z)\big)^{(1-\sigma)} f_i(z,t) J_{it} dz \right]^{-1/(\sigma-1)}.$$

Taking both sides to the power of $1-\sigma$, I obtain

$$(P_{nt}^{O})^{1-\sigma} = \left[\sum_{TM} \sum_{i=1}^{N} \int_{\overline{z}_{nit}^{TM}}^{+\infty} \mathbb{I}_{it}^{TM} \alpha_{nit}^{TM}(z) \big(\tau_{nit} p_{nit}^{TM}(z)\big)^{(1-\sigma)} f_i(z,t) J_{it} dz \right].$$

Using equation (2.4), (2.5) and (2.6) with respect to firms' decision, I get

$$\begin{aligned}
(P_{nt}^{O})^{1-\sigma} =& \Bigg[\sum_{TM} \sum_{i=1}^{N} \int_{\overline{z}_{nit}^{TM}}^{+\infty} \mathbb{I}_{it}^{TM} \left(1 - \left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}\right) \\
& \times \left(\overline{m}\tau_{nit} \frac{c_{it}^{TM} d_{nit}}{z}\right)^{(1-\sigma)} f_i(z,t) J_{it} dz \Bigg] \\
=& \Bigg[\sum_{TM} \sum_{i=1}^{N} \left(\overline{m}\tau_{nit} c_{it}^{TM} d_{nit}\right)^{(1-\sigma)} \\
& \times \int_{\overline{z}_{nit}^{TM}}^{+\infty} \mathbb{I}_{it}^{TM} \left(1 - \left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}\right) z^{(\sigma-1)} f_i(z,t) J_{it} dz \Bigg].
\end{aligned}$$

Similarly, the price index of the composite intermediate good used as input to produce processing exports is given by

$$\begin{aligned}
(P_{nt}^{P})^{(1-\sigma)} =& \Bigg[\sum_{TM} \sum_{i} \mathbb{I}_{it}^{TM} \left(\overline{m} c_{it}^{TM} d_{nit}\right)^{(1-\sigma)} \\
& \int_{\overline{z}_{nit}^{TM}}^{+\infty} \left(1 - \left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}\right) z^{(\sigma-1)} f_i(z,t) J_{it} dz \Bigg].
\end{aligned}$$

Using the idea productivity distribution in steady state, the price index of the composite good for ordinary trade is given by

$$
\begin{aligned}
(P_{nt}^{O})^{1-\sigma} =& \Bigg[\sum_{TM}\sum_{i=1}^{N}\Big(\overline{m}\tau_{nit}c_{it}^{TM}d_{nit}\Big)^{(1-\sigma)} \\
&\times \int_{\overline{z}_{nit}^{TM}}^{+\infty}\mathbb{I}_{it}^{TM}\Big(1-\Big(\frac{\overline{z}_{nit}^{TM}}{z}\Big)^{\lambda(\sigma-1)}\Big)z^{(\sigma-1)}\frac{\theta_1\theta_2}{\theta_1+\theta_2}\frac{z^{-\theta_2-1}}{\overline{z}_{it}^{-\theta_2}}J_{it}dz\Bigg] \\
=& \frac{\theta_1\theta_2}{\theta_1+\theta_2}\Bigg[\sum_{TM}\sum_{i=1}^{N}\Big(\overline{m}\tau_{nit}c_{it}^{TM}d_{nit}\Big)^{(1-\sigma)}(J_{it}\overline{z}_{it}^{\theta_2}) \\
&\times \int_{\overline{z}_{nit}^{TM}}^{+\infty}\mathbb{I}_{it}^{TM}\Big(1-\Big(\frac{\overline{z}_{nit}^{TM}}{z}\Big)^{\lambda(\sigma-1)}\Big)z^{(-\theta_2+\sigma-2)}dz\Bigg] \\
=& \kappa_0\Bigg[\sum_{TM}\sum_{i=1}^{N}\mathbb{I}_{it}^{TM}\Big(\overline{m}\tau_{nit}c_{it}^{TM}d_{nit}\Big)^{(1-\sigma)}(J_{it}\overline{z}_{it}^{\theta_2})(\overline{z}_{nit}^{TM})^{(-\theta_2+\sigma-1)}\Bigg] \\
=& \kappa_0\overline{m}^{-\theta_2}\Bigg[\sum_{TM}\sum_{i=1}^{N}\mathbb{I}_{it}^{TM}\tau_{nit}^{(1-\sigma)}\Big(c_{it}^{TM}d_{nit}\Big)^{-\theta_2}(J_{it}\overline{z}_{it}^{\theta_2})\Big(\frac{A_{nit}}{\sigma E_{nit}^{TM}}\Big)^{\theta_2/(\sigma-1)-1}\Bigg] \\
=& \kappa_0\overline{m}^{-\theta_2}\Bigg[\sum_{TM}\sum_{i=1}^{N}\mathbb{I}_{it}^{TM}\Big(c_{it}^{TM}d_{nit}\tau_{nit}\Big)^{-\theta_2}(J_{it}\overline{z}_{it}^{\theta_2})\Big(\frac{A_{nit}\tau_{nit}^{(\sigma-1)}}{\sigma E_{nit}^{TM}}\Big)^{\theta_2/(\sigma-1)-1}\Bigg],
\end{aligned}
$$

where $\kappa_0 = \frac{\theta_1\theta_2}{\theta_1+\theta_2}(\frac{\theta_2}{\theta_2-(\sigma-1)} - \frac{\theta_2}{\theta_2+(\sigma-1)(\lambda-1)})$.

Define $\Psi_{nit}^{TM} = (J_{it}\overline{z}_{it}^{\theta_2})\Big(c_{it}^{TM}d_{nit}\tau_{nit}\Big)^{-\theta_2}\Big(\sigma E_{nit}^{TM}\Big)^{1-\frac{\theta_2}{\sigma-1}}$, and the price index of the composite good can be written as

$$
(P_{nt}^{O})^{1-\sigma} = \kappa_0\overline{m}^{-\theta_2}\Bigg[\sum_{TM}\sum_{i=1}^{N}\mathbb{I}_{it}^{TM}\Psi_{nit}^{TM}\big(A_{nit}\tau_{nit}^{(\sigma-1)}\big)^{\theta_2/(\sigma-1)-1}\Bigg].
$$

B.4 Derivation of Trade Shares

Country i's exports to country n via trade mode TM is given by

$$X_{nit}^{TM} = \int_{\overline{z}_{nit}^{TM}}^{+\infty} X_{nit}^{TM}(z) f_i(z,t) J_{it} dz.$$

Using equation (2.7), we get

$$X_{nit}^{TM} = (\overline{z}_{nit}^{TM})^{1-\sigma}(\sigma E_{nit}^{TM}) \int_{\overline{z}_{nit}^{TM}}^{+\infty} \left[1 - \left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}\right] z^{(\sigma-1)} f_i(z,t) J_{it} dz.$$

$$\begin{aligned} X_{nit}^{TM} &= A_{nit}\mathbb{I}_{it}^{TM}\left(\overline{m}c_{it}^{TM}d_{nit}\right)^{(1-\sigma)} \int_{\overline{z}_{nit}^{TM}}^{+\infty} \left[1 - \left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}\right] z^{(\sigma-1)} f_i(z,t) J_{it} dz \\ &= \pi_{nit}^{O,TM} X_{nt}^{O}, \end{aligned}$$

where $\pi_{nit}^{O,TM}$ is the trade share of source i exported via trade mode TM and absorbed via ordinary trade in market n, and

$$\begin{aligned} \pi_{nit}^{O,TM} &= \frac{X_{nit}^{TM} \frac{X_{nt}^{O}(P_{nt}^{O}/\tau_{nit})^{\sigma-1}}{A_{nit}}}{X_{nt}^{O}} \\ &= \frac{\mathbb{I}_{it}^{TM}\left(\overline{m}\tau_{nit}c_{it}^{TM}d_{nit}\right)^{(1-\sigma)} \int_{\overline{z}_{nit}^{TM}}^{+\infty}\left(1-\left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}\right) z^{(\sigma-1)} f_i(z,t) J_{it} dz}{\sum_{TM}\sum_{i} \mathbb{I}_{it}^{TM}\left(\overline{m}\tau_{nit}c_{it}^{TM}d_{nit}\right)^{(1-\sigma)} \int_{\overline{z}_{nit}^{TM}}^{+\infty}\left(1-\left(\frac{\overline{z}_{nit}^{TM}}{z}\right)^{\lambda(\sigma-1)}\right) z^{(\sigma-1)} f_i(z,t) J_{it} dz} \end{aligned}$$

Total fixed costs incurred in market n by firm from country i via TM are

$$\overline{E}_{nit}^{TM} = \int_{\overline{z}_{nit}^{TM}}^{+\infty} E_{nit}^{TM} \frac{1-(\overline{z}_{nit}^{TM}/z)^{(\lambda-1)(\sigma-1)}}{1-1/\lambda} f_i(z,t) J_{it} dz$$

B.5 Algorithm to Solve Counterfactual Outcomes

I present a step by step procedure to solve the counterfactual outcomes.

Step 1 *Guess a vector of new born idea's productivity* $\mathbf{z}_0^{(0)}$*, a vector of wages* $\widehat{\mathbf{w}}^{(0)}$ *and a vector of price indices* $\widehat{\mathbf{P}}^{O(0)}$*.*

Step 2 *Use equation (2.40) to update the new born ideas' productivity given* $\widehat{\mathbf{w}}^{(0)}$ *and* $\widehat{\mathbf{P}}^{O(0)}$*, denoted by* $\mathbf{z}_0^{(1)}$*.*

Step 3 *Use equation (2.36) to update the price indices given* $\widehat{\mathbf{w}}^{(0)}$ *and* $\mathbf{z}_0^{(1)}$*, denoted by* $\widehat{\mathbf{P}}^{O(1)}$*.*

Step 4 *Calculate trade shares by using equation (2.35) given* $\widehat{\mathbf{w}}^{(0)}$*,* $\mathbf{z}_0^{(1)}$ *and* $\widehat{\mathbf{P}}^{O(1)}$*.*

Step 5 *Find a new vector of wage,* $\widehat{\mathbf{w}}^{(1)}$*, so that trade is balanced given* $\mathbf{z}_0^{(1)}$ *and* $\widehat{\mathbf{P}}^{O(1)}$*. Let* $\widehat{\mathbf{w}}^{(0)} = \widehat{\mathbf{w}}^{(1)}$*.*

Step 6 *Use equation (2.36) to update the price indices given* $\widehat{\mathbf{w}}^{(0)}$ *and* $\mathbf{z}_0^{(1)}$*. If the new price indices is not equal to* $\widehat{\mathbf{P}}^{O(1)}$*, change the values of* $\widehat{\mathbf{P}}^{O(1)}$ *to the values of the new price indices and go to step 4. Otherwise, proceed.*

Step 7 *Use equation (2.40) to update the new born ideas' productivity given* $\widehat{\mathbf{w}}^{(0)}$ *and* $\widehat{\mathbf{P}}^{O(1)}$*. Stop if the updated vector of productivity is equal to* $\mathbf{z}_0^{(1)}$*. Otherwise, Change the values of* $\mathbf{z}_0^{(1)}$ *to the values of the updated productivity and go to step 3.*

B.6 Tables for Counterfactual Exercises

Table B.1: Real Wage Changes in both Counterfactual Exercises

Country	No Diffusion	Diffusion
Argentina	0.9995	1.0638
Australia	0.9946	0.8141
Austria	0.9986	0.9608
Bangladesh	1.0070	1.6435
Belgium	0.9987	1.0010
Brazil	0.9999	1.2209
Canada	0.9983	0.9064
Chile	0.9931	1.0800
China	1.0369	0.9338
Taiwan	0.9599	0.8235
Colombia	1.0011	1.1875
Czech Republic	0.9970	1.0381
Denmark	0.9974	0.9654
Finland	0.9947	0.9039
France	0.9980	0.8867
Germany	0.9962	0.9063
Greece	0.9282	0.9226
Hungary	0.9951	1.0802
India	1.0003	1.4743
Israel	1.0013	0.9326
Italy	0.9999	0.8893
Japan	0.9913	0.8363
South Korea	0.9834	0.8631
Malaysia	0.9719	1.1550
Mexico	1.0005	1.2227
Morocco	1.0004	1.5608
Netherlands	0.9863	1.0775
New Zealand	0.9974	0.9336

continued . . .

Table B.1 Continued:

Country	No Diffusion	Diffusion
Norway	0.9983	0.8804
Pakistan	0.9996	1.3019
Peru	1.0011	1.1837
Poland	1.0003	1.0498
Portugal	1.0002	1.0393
Romania	1.0026	1.2891
Russia	0.9988	1.0916
Saudi Arabia	0.9947	0.8978
Slovak Republic	1.0001	1.592
Vietnam	1.0064	1.7784
South Africa	1.0001	1.1317
Spain	1.0003	0.9038
Sweden	0.9983	0.9619
Switzerland	0.9983	0.9669
Thailand	0.9892	1.3318
Turkey	1.0014	1.0435
U.K.	0.9977	0.8883
U.S.	0.9950	0.7803
Rest of World		

Table B.2: Decomposition of Real Wage changes for the First Counterfactual Exercise

Country	Second Term	Third Term
Argentina	0.9995	0.9999
Australia	0.9951	0.9995
Austria	0.9986	0.9999
Bangladesh	1.0077	0.9993
Belgium	0.9988	0.9999

continued . . .

Table B.2 Continued:

Country	Second Term	Third Term
Brazil	0.9998	1.0000
Canada	0.9982	1.0001
Chile	0.9937	0.9994
China	0.9708	1.0680
Taiwan	0.9503	1.0101
Colombia	1.0013	0.9999
Czech Republic	0.9970	1.0000
Denmark	0.9974	0.9999
Finland	0.9942	1.0005
France	0.9979	1.0001
Germany	0.9959	1.0003
Greece	1.0011	0.9999
Hungary	0.9950	1.0001
India	1.0003	1.0001
Israel	1.0014	1.0000
Italy	0.9998	1.0000
Japan	0.9902	1.0010
Korea, Rep.	0.9809	1.0026
Malaysia	0.9686	1.0033
Mexico	1.0005	1.0001
Morocco	1.0007	0.9997
Netherlands	0.9859	1.0004
New Zealand	0.9977	0.9998
Norway	0.9989	0.9994
Pakistan	0.9997	0.9999
Peru	1.0012	0.9999
Poland	1.0003	1.0000
Portugal	1.0002	1.0000
Romania	1.0027	0.9999
Russian Federation	0.9991	0.9997

continued . . .

Table B.2 Continued:

Country	Second Term	Third Term
Saudi Arabia	0.9980	0.9967
Slovak Republic	1.0000	1.0001
Vietnam	1.0064	1.0000
South Africa	1.0002	1.0000
Spain	1.0003	1.0000
Sweden	0.9995	1.0001
Switzerland	0.9983	1.0000
Thailand	0.9883	1.0009
Turkey	1.0014	1.0000
United Kingdom	0.9976	1.0000
United States	0.9948	1.0001
ROW	0.9843	0.9995

Table B.3: Decomposition of Real Wage Changes for the Second Counterfactual Exercise

Country	First Term	Second Term	Third Term
Argentina	1.0546	1.0025	1.0062
Australia	0.8051	1.0084	1.0028
Austria	0.9544	0.9982	1.0085
Bangladesh	1.7167	0.9697	0.9873
Belgium	1.0000	0.9768	1.0247
Brazil	1.2295	0.9982	0.9948
Canada	0.9144	0.9868	1.0045
Chile	1.0806	0.9870	1.0126
China	0.9403	0.9751	1.0185
Taiwan	0.8464	0.9793	0.9935
Colombia	1.1831	0.9744	1.0300
Czech Republic	1.0360	0.9913	1.0109

continued . . .

Table B.3 Continued:

Country	First Term	Second Term	Third Term
Denmark	0.9603	0.9959	1.0094
Finland	0.9011	1.0125	0.9907
France	0.8782	1.0092	1.0005
Germany	0.8980	1.0165	0.9929
Greece	0.9201	0.9835	1.0196
Hungary	1.0993	0.9799	1.0029
India	1.5048	0.9900	0.9896
Israel	0.9238	1.0140	0.9956
Italy	0.8810	1.0108	0.9986
Japan	0.8403	0.9988	0.9964
Korea, Rep.	0.8740	0.9932	0.9943
Malaysia	1.2086	0.9909	0.9644
Mexico	1.3142	0.9120	1.0201
Morocco	1.6547	0.9179	1.0276
Netherlands	1.1170	0.9646	0.9999
New Zealand	0.9317	0.9947	1.0074
Norway	0.8617	1.0004	1.0212
Pakistan	1.3292	0.9767	1.0029
Peru	1.1794	0.9972	1.0064
Poland	1.0483	0.9897	1.0119
Portugal	1.0542	0.9755	1.0106
Romania	1.3414	0.9560	1.0053
Russian Federation	1.0721	1.0018	1.0163
Saudi Arabia	0.8547	1.0099	1.0401
Slovak Republic	1.8820	0.8424	1.0042
Vietnam	1.8880	0.9054	1.0404
South Africa	1.1377	0.9960	0.9987
Spain	0.8972	1.0027	1.0046
Sweden	0.9575	1.0123	0.9924
Switzerland	0.9615	1.0062	0.9994

continued . . .

Table B.3 Continued:

Country	First Term	Second Term	Third Term
Thailand	1.4139	0.9644	0.9767
Turkey	1.0419	0.9913	1.0103
United Kingdom	0.8769	1.0059	1.0071
United States	0.7721	1.0106	1.0000
ROW	1.4922	0.9291	1.0294

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