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Essays in Trade in Intermediates

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Knowledgement

Upon completing my thesis, I want to present my heartfelt thanks to those who have supported me during my Ph.D. studies. I learned a lot from my colleagues, teachers, and professors here, and their enlightening suggestions and instructions made me better. What is more, I am grateful for the help from my supervisors when I wrote the dissertation. Particularly, I'm truly grateful for Harlad's patience with my work. For my campus life, I also really appreciate the help from the officers of CDSE and the welcome center, especially Claudius, Julia, Ulrich, Caroline and Mrs. Rosenkranz, which enables me to concentrate on my studying. Finally, I would like to express my gratitude to my family and friends who have provided me with tremendous inspiration and love during the past years.

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Preface

The rising global value chains (GVCs) since the beginning of the 1990s have reshaped the global production process. This globalization of the production process has led to the increasing importance of trade in intermediates in recent years. The dispersal of trade in inputs has significant macroeconomic and microeconomic implications. On the one hand, global production fragmentation changes the effects of trade policies. For example, the trade war between the U.S and China in 2018 and the wave of protectionism remind researchers of the role of trade in intermediates in setting strategic trade policies. On the other hand, trade in intermediates has changed firms' competitive strategies, affecting the location and payment of production factors among different regions and industries.

The essays have grown out of my research on trade in intermediates during my Ph.D. study. The essays consist of two chapters: Chapter 1 analyses the impact of trade in intermediates on unilateral optimal trade policy; Chapter 2 explores the China labor market outcomes of the exposure to processing exports, especially the skill wage premium.

In Chapter 1, I construct a firm-heterogeneous trade model, including trade in both inputs and final goods, to explore the effects of trade in intermediates on unilateral optimal trade policies. Given the input-output market structure with heterogeneous firms and monopolistic competition, I figured out the implied policymakers' incentives and discussed how a specific trade policy affects these policy incentives. By calibrating the model to replicate import facts about the U.S trade data, I solved the unilateral second-best trade policies numerically in the absence of domestic production policy. The second-best trade policy solutions are applied to the case of constrained trade policies (the policymaker uses an individual trade policy) and the case of unconstrained trade policies (the policymaker implements all trade policies simultaneously), respectively. Finally, I do the comparative statics regarding the trade costs of input and study how it affects the second-best trade policies.

In Chapter 2, I examine the impact of skill-upgrading processing export expansion on regional skill premium across China after China's accession to the World Trade Organization(WTO). Although China served as the world's factory and played an essential role in the GVCs, very few researchers pay attention to how offshoring affects skill wage premium in China. In my studying, I firstly develop a two-country, two-factor Heckscher-Ohlin model of offshoring

and skill premium, which identifies the role of comparative advantage in shaping the offshoring pattern as Feenstra and Hanson (1996). The model implies that reducing offshoring costs raises the skill premium in developing countries. The conclusion can be applied to other shocks that raise developing countries' relative skill demand in the GVCs. Then, using the data on China's wage premium and processing exports between 2000 and 2006, the empirical analysis identifies that the high-skill processing export shocks increase the regional skill premium, whereas low-skill processing export shocks depress it after China joined the WTO.

Chapter 1

Trade in intermediates, heterogeneous firms and optimal trade policy

In this chapter, I construct a firm-heterogeneous trade model, including trade in both inputs and final goods, to explore the effects of trade in intermediates on unilateral optimal trade policies. I figure out four policymakers' incentives: terms-of-trade for final goods and inputs, respectively, correction of monopolistic distortion, and production efficiency. When the policymaker uses an individual trade policy, the second-best trade policies are import tariff and export subsidy on final goods and import subsidy and export tax on inputs, respectively. In the absence of the domestic production subsidy, the policymaker prefers to manipulate terms-of-trade for inputs, thus contributing to the monopolistic distortion correction and production efficiency. The second-best trade policies imply that the trade subsidies enlarge the final-good sector size at the cost of low-productivity firms, resulting in higher market concentration. The export tax on inputs protects domestic firms from import competition as the import tariff on final goods but is relatively more efficient in improving welfare. When all trade policies are available simultaneously, the policymaker implements the export tax on final goods to offset the negative effects of other second-best trade policies on terms-of-trade for final goods.

1.1 Introduction

Firms in the global value chain look for ideal inputs to reduce production costs and improve product quality. This globalization of the production process has led to the increasing importance of trade in intermediates in recent years. Johnson and Noguera (2012) report that the volume of trade in intermediates accounts for two-thirds of international trade. However, very few authors pay attention to how trade in intermediates affects trade policies.[1] How does the government take trade in intermediates into account in negotiations between countries? This question becomes meaningful when the government manipulates trade policies in its favor. For example, in the trade war between U.S. and China in 2018, the U.S. companies were banned from selling chips to the China company ZTC, which affected ZTC's production badly because the U.S. supplies account for 25%-30% chips imported by ZTC. China restricted the rare earth exports to the U.S. in 2019 as retaliation because 80% of rare earth imports by the U.S. in 2014-2017 came from China. Furthermore, Bown and Zhang (2019) show that around 60 percent of the U.S. tariffs in the trade war were on intermediate inputs, affecting approximately 20 percent of all U.S. imports of inputs.

In the traditional discussion about optimal trade policy, the terms-of-trade effect is regarded as the primary policy incentive. For example, Bagwell and Staiger (2009) show that when the government can set import and export policy strategically, the only remaining international policy incentive is the terms-of-trade effect. However, the arising trade in intermediates reduces the fraction of trade in final goods in total trade volume and connects domestic production activities with variations of foreign factor prices. Therefore, it is more complex for the government to manipulate the terms-of-trade for final goods through trade policies. Besides, changes in terms-of-trade for inputs and final goods also affect labor force reallocation between the input and final-good sectors within a specific country.

Although trade in intermediates has become popular, not all firms can access foreign input markets because fixed and variable trade costs exist. The trade data shows that high-productivity firms are more likely to source from foreign markets. In contrast, low-productivity firms are only active in the domestic market. The U.S data displays that American input importers are averagely around 12 percent more productive than non-importers (Bernard et al., 2007).[2] In addition, firms that simultaneously import inputs and export final goods generally have the highest productivity levels (Bernard et al., 2009).

[1] To the best of my knowledge, Caliendo and Parros (2015), Blanchard et al. (2016), and Antras et al. (2022) are the only papers studying the effects of trade in intermediates on optimal trade policy design. Caliendo and Parros (2015) introduce trade in intermediates and input-output sectoral linkages into the Ricardian model and identify the impact of NAFTA's tariff reductions. They find that welfare effects due to tariff reductions are reduced when the input-output linkages are not taken into account. Their results call attention to the importance of trade in intermediates for quantifying the welfare gains from tariffs reductions. Blanchard et al. (2016) introduce the supply chain linkage into a trade policy model with political economy. By regressing the tariff on the domestic and foreign value adds, they find that the final goods tariff will decrease in the domestic content of foreign-produced final goods. To study the tariff escalation between upstream and downstream sectors, Antras et al. (2022) construct the model including the input and final-good sectors separately, both featuring increasing returns to scale and being exposed to tariffs. They find that first-best trade policies are in agreement with tariff escalation, and second-best import tariffs feature tariff escalation.

[2] Antras et al. (2018) obtain similar results by using the data of U.S. manufacturing firms between 1997 and 2007 to compare the difference between U.S importers and non-importers in productivity.

In this chapter, I use the heterogeneous-firms trade model of Melitz (2003), including both trades in intermediates and final goods between two countries (Home and Foreign), where trade results from product differentiation, final-good producers are monopolistic competition and different in productivity, intermediate input suppliers are perfectly competitive and produce firm-specific intermediates, and international trade is subject to trade costs. As Melitz(2003), the fixed cost of selling final goods in the domestic market is lower than that of exporting to the foreign market. Following Antras et al. (2018), the fixed cost of sourcing from the domestic market is set to be lower than that of sourcing from the foreign market. Here the fixed costs cause the selection effect among heterogeneous firms, and firms self-select their outsourcing and exporting strategies to maximize profits. Firms should be productive enough to generate a large production volume and high profits that help them finance the fixed costs of outsourcing and exporting.

In the model calibration, I replicate essential facts about the US's trade data between 2000 and 2010. Then I numerically solve the unilateral second-best trade policy from the welfare maximization problem. The optimal solutions are firstly for each instrument (the constrained case) and then for the case where all instruments are implemented simultaneously (the unconstrained case).[3] Finally, I do comparative statics regarding trade costs of inputs. As the trade cost of inputs increases, firms are less likely to source from the foreign market, and the volume of trade in intermediates decreases. So changes in the second-best trade policies show the effects of trade in intermediates on trade policies.

I figure out four trade policy incentives in the above firm-heterogeneous model: terms-of-trade for final goods, terms-of-trade for inputs, monopolistic distortion correction, and production efficiency. The trade policies are set partly to alleviate this domestic distortion in the absence of the domestic production subsidy, which perfectly counters the monopolistic distortion. In this way, the trade policies can improve the free trade allocation to a second-best level, so my numerical solutions of Home's unilateral optimal trade policies are the second-best trade policies.

When Home is restricted to using trade policies on final goods, the second-best trade policies are import tariffs and export subsidies on final goods, respectively. Intuitively, the final-good import tariff protects the domestic final-good sector from import competition, leading to monopolistic distortion correction and production efficiency improvement. Moreover, Home's terms-of-trade for inputs increases with domestic wage, but Home's terms-of-trade for final goods decreases because of the increasing relative number of exporters. Regarding the second-best export subsidy on final goods, it reallocates the domestic labor force from the input sector to the final-good sector. Still, it reduces the amount of active domestic firms because low-productivity firms suffer from the reduction in domestic market demand size due to the subsidy. Besides, the export subsidy on final goods directly reduces the terms-of-trade for final goods correspondingly

[3]It is consistent with Campolmi et al. (2021) idea that they begin by studying the optimal domestic production subsidy and export and import tax/subsidy separately. Then they explore the optimal policy combination when all instruments are available simultaneously.

but raises the terms-of-trade for inputs.

When Home only accesses trade policies on inputs, the policymaker should impose import subsidies and export taxes on inputs. Intuitively, the import subsidy on inputs, as the export subsidy on final goods, reallocates the domestic labor force from the input sector to the final-good sector at the cost of worsening domestic monopolistic distortion. Besides, the input subsidy reduces the terms-of-trade for both inputs and final goods. Regarding the export tax on inputs, it protects domestic firms from import competition by raising production costs for foreign exporters. So its effects on terms-of-trade for inputs and final goods, monopolistic distortion, and production efficiency are similar to that of import tariffs on final goods. However, the export tax on inputs is more efficient in improving domestic welfare than the import tariff on final goods.

In the firm-heterogeneous model, high-productivity firms benefit from the subsidies on imported inputs and exporting final goods. In contrast, low-productivity firms suffer from the reducing market demand size induced by the fiscal burden of subsidies. It implies that although the final-good sector expands as the domestic workers are reallocated from the input sector to the final-good sector, these trade subsidies worsen the monopolistic distortion. Besides, these subsidies on imported inputs and exporting final goods reduce the terms-of-trade for final goods. In contrast, given either the import tariff on final goods or the export tax on inputs, although the terms-of-trade for final goods reduce because of the relative reducing amount of exporters, the terms-of-trade for inputs increase. Furthermore, both the import tariff on final goods and the export tax on inputs correct monopolistic distortion and improve production efficiency simultaneously. So the export subsidy on final goods and import subsidy on inputs are less efficient in enhancing domestic welfare than the import tariff on final goods and the export tax on inputs.

When all trade policies are available simultaneously, the second-best trade policies include import tariffs and export taxes on final goods and import subsidies and export taxes on intermediate inputs. Compared with the constrained second-best trade policies separately, the import tariff on final goods decreases, whereas the export tax on inputs increases. It could be attributed to the relatively higher efficiency of export tax on inputs in improving domestic welfare than import tariffs on final goods. In addition, the increasing import subsidy on inputs enlarges the size of high-productivity firms. Using the export tax on final goods, the policymaker intends to partly offset the negative effects of other trade policies on terms-of-trade for final goods.

In the absence of domestic production subsidy, the policymaker has incentives to correct domestic monopolistic distortion and improve production efficiency through trade policies. The rising terms-of-trade for inputs reallocates the labor force from the input sector to the final-good sector, thus correcting monopolistic distortion and improving production efficiency. So the policymaker prefers to manipulate terms-of-trade for inputs instead of that for final goods. However, as the trade volume of inputs decreases with the trade costs, the contribution of manipulating the terms-of-trade for inputs to welfare improvement decreases. In the comparative statics, as the trade cost of inputs increases, the constrained second-best import subsidy on inputs increases, whereas the second-best export tax on intermediates decreases; both the second-best import tariff and the export subsidy on final goods decrease, and the latter turns to be export tax at some point. The comparative statics results imply that as the trade cost of inputs increases, the effects of outsourcing inputs on production activities decrease. Hence, policymakers are less likely to manipulate the terms-of-trade for inputs to improve production efficiency and correct monopolistic distortion. Instead, they emphasize the improvement of terms-of-trade for final goods.

The rest of the chapter is organized as follows. Section 1.2 reviews relevant literature. Section 1.3 illustrates the model and the corresponding equilibrium. Section 1.4 constructs the welfare maximization problem and discusses the trade policy incentives. Section 1.5 solves the unilateral optimal trade policy. Section 1.6 concludes.

1.2 Literature

The chapter is relevant to three areas of literature: (1) the quantitative analysis of cooperative and uncooperative trade policy in the general equilibrium; (2) the effect of heterogeneous market structure on trade policy; (3) the role of trade in intermediates in trade policy design.

For the quantitative analysis of the cooperative and uncooperative trade policy in the general equilibrium, Perroni and Whalley (2000) use a calibrated numerical general equilibrium trade model to compute post-retaliation Nash tariffs under different regional trade arrangements. They take advantage of the one-good Armington model that only focuses on the traditional terms-of-trade effect. In contrast, Ossa (2011) uses a Krugman(1980) model, featuring new trade production relocation effects, to estimate the non-cooperative tariff and identifies reasonable non-cooperative tariffs and moderate gains from GATT/WTO negotiations. Then Ossa (2014) combines the traditional, new trade and political economy motives for protection into a general equilibrium framework and explores the optimal tariff and Nash tariff in the trade war. He finds that the government welfare loss due to uncooperative trade policy is 2.9 percent, whereas the estimated welfare gains from trade negotiation are 0.5 percent. Finally, Ossa (2016) applies the quantitative model of commercial policy and summarizes the empirical analysis of cooperative and uncooperative trade policy within the general equilibrium framework. In this chapter, I will follow the general equilibrium framework and solve the welfare maximization problem for the unilateral optimal trade policy as Ossa (2014) and Ossa (2016).

For how firm heterogeneity affects the optimal trade policy, since the pioneering work by Melitz (2003), very few authors have paid attention to the role of firm heterogeneity in trade policy design. As far as I know, only Demidova and Rodrguez-Clare (2009), Felbermayr et al. (2013), and Haaland and Venables (2014) used the firm-heterogeneous model of Melitz (2003) to explore the effects of firm heterogeneity on optimal trade policy. But all these papers are restricted to specific environmental assumptions, including CES utility functions, Pareto distributions of productivity, and constant fixed costs of exporting across firms. Costinot et al. (2016) relax these assumptions and characterize optimal trade policy in a generalized version of the trade model with monopolistic competition and firm-level heterogeneity. In particular, they break down the optimal trade policy problem into a series of microeconomic problems and a macro problem and use the Lagrange multiplier method to characterize optimal wedges. Campolmi et al. (2021) explore the domestic and trade policies in the Nash equilibrium with a monopolistic competition model featuring heterogeneous firms. They solve the Nash equilibrium policies in two different situations: (1) both the domestic and trade policies are available to the government; (2) the trade policies are limited by trade agreement without the coordination of domestic policy. I would be consistent with the classical firm heterogeneous model of Melitz (2003) and follow the idea of Campolmi et al. (2021) to discuss the unilateral optimal trade policy in the situations of constrained and unconstrained trade policies.

The literature on global value chain and trade in intermediates focuses on analyzing the location choice and property rights in the incomplete contract environment, like Antras and Helpman (2004) and Antras and Chor (2013), and the determinants of outsourcing and its impact, like Goldberg et al. (2010) and De Loecker et al. (2016). However, very few authors pay attention to how the global value chain affects optimal trade policies. Caliendo and Parros (2015) use a Ricardian model featuring sector linkages and trade in intermediate goods to quantify the effects of tariff changes on welfare. Their results show that welfare effects due to tariff reductions are reduced when the input-output linkages are not taken into account. However, their analysis assumes the tariff is exogenous and doesn't consider the optimal tariffs under trade in intermediates. Blanchard et al. (2016) introduce the supply chain linkage into a trade policy model with political economy. By regressing the tariff on the domestic and foreign value adds, they find that the final goods tariff will decrease in the domestic content of foreign-produced final goods. In contrast to Blanchard et al. (2016), Antras et al. (2022) model the input and final-good sectors separately, both featuring increasing returns to scale and being exposed to tariffs. They find that first-best trade policies are in agreement with tariff escalation, and second-best import tariffs feature tariff escalation. However, all of these work disregard the existence of heterogeneous firms within the global value chain. In this chapter, I will construct a trade model including a final-good sector and an intermediate-input sector separately, as Antras et al. (2022), but feature it with firm-heterogeneity.

1.3 Model and equilibrium

There are two countries in the open economy, Home (H) and Foreign (F), endowed with consumers L_i in country i, $i = H, F$. The consumers serve as the local labor supplies and are immobile across the border. A final-good sector and an intermediate-input sector exist in each country. Both the final goods and intermediate inputs can be traded across countries. There exist ice-berg trade costs d_{ij} and d_{ij}^M for final goods and intermediate inputs, respectively, exporting from country i to country j. Assume $d_{ij} = d > 1$ and $d_{ij}^M = d^M > 1$ if $i \neq j$, whereas $d_{ii} = d_{ii}^M = 1$. The government in country i has access to the following policy tools:

(i) $\tau_{X,i}^M$, $X = I, E$, the import and export tax/subsidy on intermediate inputs;

(ii) $\tau_{X,i}$, $X = I, E$, the import and export tax/subsidy on final goods;

These policy tools indicate the gross value, so a specific policy represents a relevant subsidy if its value is smaller than 1. In the following discussion, I use the word tax whenever I mention a policy tool without specifying whether it is larger or smaller than one.

1.3.1 Preference

The utility function of households in country i is given by:

$$U_i = \left[\sum_{j=H,F} C_{ji}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{1.1}$$

where $C_{ji} = \left[\int_{\omega \in \Omega_{ji}} q_{ji}^{\frac{\sigma-1}{\sigma}}(\omega) d\omega \right]^{\frac{\sigma}{\sigma-1}}$ is the aggregate consumption bundle of varieties produced in country j. Ω_{ji} denotes the set of varieties exporting from country j to country i. σ is the elasticity of substitution across varieties. For utility maximization, the demand for variety ω exporting from country j to country i is

$$q_{ji}(\omega) = P_i^{\sigma-1} p_{ji}(\omega)^{-\sigma} E_i \tag{1.2}$$

where P_i is the aggregate price index in country i. $p_{ji}(\omega)$ denotes the price at which consumers in country i can procure variety ω from country j. E_i is the total expenditure on varieties in country i. The household income includes their labor income and the transfer payment from the government.

1.3.2 Final and intermediate goods producers

The final-good sector in each country is characterized by monopolistic competition with a group of producers, each choosing to produce a specific variety ω. Firms in country i should pay f_i^E units of domestic labor as entry costs. Once entering, firms draw their initial productivity ψ from a country-specific Pareto distribution $G_i(\psi) = 1 - \left(\underline{\psi_i}/\psi\right)^k$, $i = H, F$, where $\underline{\psi_i}$ is the lower bound of support in the productivity distribution for country i and $k > 0$ describes the productivity dispersion.[4] Since the mapping between productivity ψ and variety ω is single, each final good producer can be denoted by its productivity

[4] I assume that $G_i(\psi)$ is continuously differentiable with derivative $g_i(\psi)$. Besides, the relationship between the productivity dispersion k and the elasticity of substitution across varieties σ satisfies $k + 1 > \sigma$

ψ. The production of firm ψ requires direct labor input and a continuous set of intermediate inputs (v, ψ) with measure one, $v \in (0, 1)$. So the technology of firm ψ in country i is given by:

$$f_i(\psi) = \psi L_i(\psi)^\alpha [\int_0^1 x_i(\psi, v)^{\frac{\epsilon-1}{\epsilon}} dv]^{\frac{\epsilon}{\epsilon-1}(1-\alpha)} \tag{1.3}$$

where $L_i(\psi)$ and $x_i(\psi, v)$, respectively, are the demand for direct labor input and intermediate inputs v by firm ψ in country i. ϵ is the elasticity of substitution across different intermediate inputs and α is the fraction of direct labor input in production.

The intermediate-input sector is characterized by perfect competition without entry costs. In this chapter, I assume that intermediate inputs are firm-specific and can't be substituted perfectly with each other. Besides, all intermediate inputs are produced with labor under constant return technology: $Z_i(v, \psi)$ units of intermediate input (v, ψ) can be produced in country i with one unit of labor. So the ex-factory price of intermediate input (v, ψ) produced in country i is $\frac{w_i}{Z_i(v,\psi)}$, where w_i is the wage in country i. Following Eaton and Kortum (2002), the random variable $Z_i(v, \psi)$ is drawn from the country-specific Frechet distribution as follows:

$$F_i^\psi(z) = Pr(Z_i(v) < z) = exp(-T_i z^\theta) \qquad i = H, F \tag{1.4}$$

where $T_i \geq 0$ denotes the technology average state in country i and $\theta > 0$ measures productivity variation. The value of $Z_i(v, \psi)$ is drawn independently across countries, varieties, and inputs.

Since the final-good sector is characterized by monopolistic competition, the ex-factory price of variety produced by firm ψ in country i is

$$p_i(\psi) = \mu \frac{\sigma}{\sigma - 1} \frac{w_i^\alpha P_i^M(\psi)^{1-\alpha}}{\psi} \quad \text{with} \quad \mu = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \tag{1.5}$$

where $P_i^M(\psi) = \left(\int_0^1 p_i(\psi, v)^{1-\epsilon} dv\right)^{\frac{1}{1-\epsilon}}$ is the aggregate intermediate input costs for firm ψ located in country i. Here $p_i(\psi, v)$ is the available price of intermediate input (ψ, v) in country i.

Following Antras et al. (2018), I assume final good producers in country i can source intermediate inputs from either the domestic market without fixed costs or the foreign market with f_i^S units of domestic labor as fixed costs. Since they look for the lowest supply price, the available price of intermediate input (ψ, v) is

$$p_i(\psi, v) = min\{\frac{w_i}{Z_i(v)}, \tau_{ji}^M d_{ji}^M \frac{w_j}{Z_j(v)}\} \tag{1.6}$$

where $\tau_{ji}^M = \tau_{E,j}^M \tau_{I,i}^M$ represents the interaction term between the export tax by country j and the import tariff by country i for intermediate inputs. According to the Frechet distribution's characteristic,

$$P_i^M(\psi) = \gamma \Phi_i^m(\psi)^{-\frac{1}{\theta}} \quad \text{with} \quad \Phi_i^m(\psi) = \begin{cases} T_i(w_i)^{-\theta} & if \quad m = 1 \\ \sum_{j=H,F} T_j(\tau_{ji}^M d_{ji}^M w_j)^{-\theta} & if \quad m = 2 \end{cases} \tag{1.7}$$

where $\gamma = \left[\Gamma\left(\frac{\theta+1-\epsilon}{\theta}\right)\right]^{\frac{1}{1-\sigma}}$ and $\Phi_i^m(\psi)$, $m = 1, 2$, describes the sourcing capability of firm ψ in country i.[5] Here the superscript m represents firm ψ's sourcing state: $m = 1$ means firm ψ only sources inputs from the domestic market, whereas $m = 2$ refers it sources inputs from both domestic and foreign markets. Equations (1.5)-(1.7) imply that the higher the sourcing capability $\Phi_i^m(\psi)$ is, the lower the ex-factory price $p_i(\psi)$ is because firms are more likely to find cheaper intermediate inputs if they simultaneously source inputs from domestic and foreign markets. It also captures the effect of trade in intermediates on firms' pricing strategy.

Let $\widetilde{\psi}_i(\psi^*) = \left(\int_{\psi^*}^{\infty} \frac{[\Phi_i^m(\psi)^{\frac{1-\alpha}{\theta}}\psi]^{\sigma-1}}{1-G(\psi^*)} dG(\psi)\right)^{\frac{1}{\sigma-1}}$ represents the aggregate sourcing-capability-weighted productivity over $[\psi^*, +\infty)$ for country i. According to the composition of $\Phi_i^m(\psi)$, $\widetilde{\psi}_i(\psi^*)$ is a monotonic increasing function of ψ but has a jump discontinuity.[6] The jump discontinuity could be attributed to the advantage of sourcing from both domestic and foreign markets over sourcing exclusively from the domestic market.[7]

In country j, combining equation (1.5) with (1.7), the available price of variety produced by firm ψ located in country i can be expressed as:

$$p_{ij}^m(\psi) = \tau_{ij} d_{ij} \mu \frac{\sigma}{\sigma-1} \frac{w_i^{\alpha}\gamma^{1-\alpha}}{[\Phi_i^m(\psi)]^{\frac{1-\alpha}{\theta}}\psi} \qquad m = 1, 2 \tag{1.8}$$

where $\tau_{ij} = \tau_{E,i}\tau_{I,j}$ represents the interaction term between the export tax by country i and the import tariff by country j on final goods. So the variable profit from country j for firm ψ located in country i is

$$\pi_{ij}^m(\psi) = \frac{p_{ij}^m(\psi) q_{ij}(\psi)}{\tau_{ij}\sigma} = \mu^{1-\sigma} B_j \tau_{ij}^{-\sigma} \left(\frac{[\Phi_i^m(\psi)]^{\frac{1-\alpha}{\theta}}\psi}{d_{ij} w_i^{\alpha}\gamma^{1-\alpha}}\right)^{\sigma-1} \qquad m = 1, 2 \tag{1.9}$$

where $B_j = \frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}} E_j P_j^{\sigma-1}$ is the market demand size in country j. Equation (1.9) shows that the variable profit for a specific final good producer also depends on its input sourcing strategy.

Following Melitz (2003), firms in country i should pay f_i^D (f_i^X) units of domestic labor as entry costs to sell final goods in the domestic (foreign) market.

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[5] The calculations are consistent with that by Eaton and Kortum (2002) to solve for the aggregate price index. Following Antras et al. (2018), I assume $\theta > \epsilon - 1$ to guarantee a reasonable marginal cost index. In addition to satisfying this restriction, the value of ϵ is absorbed into a constant and does not matter for any results of interest.

[6] At the discontinuous jump point, the net profits for firm ψ, if it sourced inputs exclusively from the domestic market, are the same as that if it sourced inputs from multi-market.

[7] Taking differential respect to ψ^*, $\widetilde{\psi_i}(\psi^*)$ could also be proved as a monotonic increasing function of ψ^*. The construction of $\widetilde{\psi_i}(\psi^*)$ is similar to the aggregate productivity level over $[\psi^*, +\infty)$, $\widetilde{\psi^*} = \left(\int_{\psi^*}^{\infty} \frac{\psi^{\sigma-1}}{1-G(\psi^*)} dG(\psi)\right)^{\frac{1}{\sigma-1}}$ defined in Melitz(2003), which also increases with ψ^*, but differs in the weight of sourcing capability compared with with $\widetilde{\psi_i}(\psi^*)$ In this chapter.

Assume $f_i^D \ll f_i^X$.[8] So the net profit of firm ψ located in country i, conditional on its sourcing and exporting strategy, are

$$\pi_i(\psi) = \begin{cases} 0 & \text{if firm exits market} \\ \pi_{ii}^1(\psi) - w_i f_i^D & \text{only domestic} \\ \pi_{ii}^2(\psi) - w_i(f_i^D + f_i^S) & \text{imported intermediates} \\ \sum\limits_{j=H,F} \pi_{ij}^1(\psi) - w_i(f_i^D + f_i^X) & \text{exported final goods} \\ \sum\limits_{j=H,F} \pi_{ij}^2(\psi) - w_i(f_i^D + f_i^X + f_i^S) & \text{imp'ed inter's \& exp'ed final} \end{cases} \tag{1.10}$$

Each firm chooses the sourcing and exporting strategy to maximize profits according to its productivity. Therefore, only high productivity firms benefit from accessing the foreign market, which is large enough to cover the fixed costs of sourcing and exporting, as Antras et al. (2018) and Melitz (2003) developed. It means that these fixed costs cause the selection effect among heterogeneous firms. Because of the selection effect, the effects of trade policies on firms with heterogeneous productivity are different.

1.3.3 Equilibrium

In the equilibrium, because of the selection effect induced by fixed costs f_i^D, f_i^S and f_i^X, there exist cutoff productivities ψ_i^D, ψ_i^S and ψ_i^X for country i, respectively. Here I assume the initial free-trade equilibrium satisfy $\psi_i^D < \psi_i^S < \psi_i^X$, $i = H, F$.[9] In country i, firm $\psi \in (\underline{\psi}, \psi_i^D)$ exits the market immediately once it knows its productivity; firm $\psi \in (\psi_i^D, \psi_i^S)$ is only active in domestic intermediate-input and final-good sectors; firm $\psi \in (\psi_i^S, \psi_i^X)$ sources from both domestic and foreign markets but still not exports to the foreign market; firm $\psi \in (\psi_i^X, \infty)$ sources from both domestic and foreign market and also exports to the foreign market.

If firms source intermediate inputs from both domestic and foreign markets in the equilibrium, according to the Frechet distribution's characteristic, the market share of country j in the purchasing of intermediate inputs by firms located in i is

$$\beta_{ji} = \frac{T_j(w_j \tau_{ji}^M d_{ji}^M)^{-\theta}}{\sum\limits_{n=H,F} T_n(w_n \tau_{ni}^M d_{ji}^M)^{-\theta}} \qquad i, j = H, F \tag{1.11}$$

So the market share is proportional to country j's contribution to the sourcing capability of firms in country i. Given trade policy τ_{ji}^M, if country j has lower trade costs of exporting intermediate inputs to country i, d_{ji}^M, lower wage w_j

[8] Given the variable trade costs, the assumption about the fixed trade costs guarantees that the exporting cutoff productivity is larger than the existing cutoff productivity. Moreover, it implies that no existing firms only export products to the foreign market without selling in the domestic market.

[9] There exit another three possible equilibriums (1) $\psi_i^D < \psi_i^X < \psi_i^S$ $i = H, F$; (2) $\psi_H^D < \psi_H^X < \psi_H^S$, $\psi_F^D < \psi_F^S < \psi_H^X$; (3) $\psi_H^D < \psi_H^S < \psi_H^X$, $\psi_F^D < \psi_F^X < \psi_F^S$. As the policymaker change policy instruments, the economic equilibrium would switch among these possible equilibriums.

and more advanced production technology T_j, its market share β_{ji} would be higher.

For the final good producers, the expenditure of purchasing intermediate inputs is equal to the fraction $(1-\alpha)(1-\sigma)$ of variable profits. According to zero profit conditions for firms with productivity ψ_i^z, $z = D, S, X$, the expenses of sourcing intermediate inputs from the domestic market in country i can be solved out as:[10]

$$X_{ii}^M = \lambda(1-\alpha)(\sigma-1)w_i \left[N_i^D f_i^D + \frac{\beta_{ii}\phi_i - 1}{\phi_i - 1} N_i^S f_i^S + \beta_{ii} N_i^X f_i^X \right] \tag{1.12}$$

where $\lambda = \frac{k}{k+1-\sigma} > 0$. $N_i^z = N_i^E(1 - G(\psi_i^z))$, $z = D, S, X$, denotes the amount of firms with productivity $\psi > \psi_i^z$ in country i. $\phi_i = \left(\frac{\Phi_i^2}{\Phi_i^1}\right)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}$ captures the comparative advantage of sourcing from both domestic and foreign markets over sourcing only from the domestic market. Similarly, the expenses of sourcing intermediate inputs from the foreign market in country i can be solved out as:

$$X_{ji}^M = \beta_{ji}\lambda(1-\alpha)(\sigma-1)w_i [\frac{\phi_i}{\phi_i - 1} N_i^S f_i^S + N_i^X f_i^X] \tag{1.13}$$

In the decentralized equilibrium given policy tools, households choose their consumption bundle to maximize their utility under the budget constraint; final-good producers choose the output level to maximize their profit given the consumption demand; final-good producers enter the market until the expected profits are zero; goods and labor market clear; and trade is balanced. So the equilibrium should satisfy the following conditions:[11]

$$\left[\frac{\psi_i^D}{\psi_i^S}\right]^{\sigma-1} = \frac{f_i^D}{f_i^S}(\phi_i - 1) \quad i = H, F \tag{1.14}$$

$$\left[\frac{\psi_j^X}{\psi_i^D}\right]^{\sigma-1} = \tau_{ji}^{\sigma} d^{\sigma-1} \frac{f_j^X}{f_i^D} \left[\frac{w_j}{w_i}\right]^{\alpha(\sigma-1)+1} \left[\frac{\Phi_i^1}{\Phi_j^2}\right]^{\frac{(1-\alpha)(\sigma-1)}{\theta}} \quad i \neq j \tag{1.15}$$

$$\sum_{z=D,X} f_i^z (1 - G(\psi_i^z)) \frac{\widetilde{\psi}_i(\psi_i^z)}{[\Phi_i^m(\psi_i^z)]^{\frac{1-\alpha}{\theta}} \psi_i^z} = f_i^E + \sum_{z=D,S,X} (1 - G(\psi_i^z)) f_i^z \quad i = H, F \tag{1.16}$$

$$P_{ij}^{1-\sigma} = \nu N_i^E (1 - G(\psi_{ij}))[\frac{\widetilde{\psi}_i(\psi_{ij})}{\tau_{ij} d_{ij} w_i^{\alpha} \gamma^{1-\alpha}}]^{\sigma-1} \quad i, j = H, F^{[12]} \tag{1.17}$$

[10] Details about the zero profit conditions for firms with productivity ψ_i^z, $z = D, S, X$, in the equilibrium are shown in the Appendix A.

[11] The derivation about these following equilibrium conditions are available in the Appendix.

[12] In the denotation of equations (1.17) and (1.18), $\nu = \left[\frac{\sigma}{\sigma-1} \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right]^{1-\sigma}$. Besides, $\psi_{ij} = \psi_i^D$ and $f_{ij} = f_i^D$ if $i = j$, whereas $\psi_{ij} = \psi_i^X$ and $f_{ij} = f_i^X$ if $i \neq j$.

$$Q_{ij} = \frac{\sigma w_i f_{ij} \tau_{ij}^{\sigma}}{\nu} \left[\frac{d_{ij} w_i^{\alpha} \gamma^{1-\alpha}}{[\Phi_i^2]^{\frac{1-\alpha}{\theta}} \psi_{ij}} \right]^{\sigma-1} P_{ij}^{-\sigma} \qquad i,j = H,F \tag{1.18}$$

$$w_i(L_i - L_i^M) = (\frac{1}{\sigma} + \alpha \frac{\sigma - 1}{\sigma}) \sum_{j=H,F} \frac{P_{ij} Q_{ij}}{\tau_{ij}} \qquad i = H,F \tag{1.19}$$

$$w_i L_i^M = \sum_{j=H,F} \frac{X_{ij}^M}{\tau_{ij}^M} \qquad i = H,F \tag{1.20}$$

$$\frac{P_{HF} Q_{HF}}{\tau_{IF}} + \frac{X_{HF}^M}{\tau_{IF}^M} = \frac{P_{FH} Q_{FH}}{\tau_{IH}} + \frac{X_{FH}^M}{\tau_{IH}^M} \tag{1.21}$$

Equations (1.14) and (1.15) are the ratio of zero profit condition about ψ_i^D to that about ψ_i^S and ψ_j^X, respectively. ψ_i^S decreases with Φ_i because the increasing sourcing capability makes it more likely for a specific firm to cover the fixed costs of sourcing from the foreign market. Equation (1.15) shows the dependence of $\frac{\psi_j^X}{\psi_i^D}$ on both the relative wage $\frac{w_j}{w_i}$ (direct labor input) and the relative sourcing capability $\frac{\Phi_j^2}{\Phi_i^2}$ (intermediate-input). It also captures how trade in intermediates affects the ratio of the exporting cutoff productivity to the survival cutoff productivity through the sourcing capability Φ_j^2.

Equation (1.16) is the free entry condition in the equilibrium for the final-good sector in which the expected profits of firms (left-hand side) should be equal to all the fixed costs (right-hand side). In equations (1.17) and (1.18), P_{ij} and Q_{ij} are the aggregate index of price and quantity of varieties produced in country i and sold in country j, respectively.[13]

Equations (1.19) and (1.20) are the labor market clearing conditions for the final-good and intermediate-input markets, respectively, which determine the equilibrium number of entry firms N_i^E and the labor force devoted to the intermediate-input sector L_i^M,$i = H,F$. In equation (1.19), the left-hand side is the total labor income from the final-good sector, whereas the right-hand side is the direct labor input costs of final-good producers. To see this, note that a fraction $\frac{1}{\sigma}$ and a fraction of $\alpha\frac{\sigma-1}{\sigma}$ of firm-level revenues are used to cover the fixed and variable labor input costs, respectively. Equation (1.20) shows that the total labor income from the intermediate goods sector (left-hand side) is equal to the total revenue from domestic and foreign intermediate input markets (right-hand side) because the intermediate goods market is under perfect competition.

Equation (1.21) is the trade balanced condition, which also implies households' budget constraint. It refers the net value of exported intermediate inputs and final goods by Home (left-hand side) should be equal to that of imported intermediate and final goods by Home (right-hand side). Both sides are measured at international prices before import tariffs are applied.

[13] Note the aggregate index of price and quantity demand shown in equations (1.17) and (1.18) are also applied to the case in which $\psi_i^X < \psi_i^S$, $i = H,F$.

With $w_F = 1$ by normalization, the equilibrium given specific domestic and trade policies can be described by the 19 endogenous variables ψ_i^z, P_{ij}, Q_{ij}, N_i^E, L_i^M, $z = D, S, X$, $i, j = H, F$ and w_H which satisfy the 19 equilibrium conditions (1.14)-(1.21).

1.4 Welfare optimization problem and policy incentives

1.4.1 Home's welfare optimization problem

Home's policymaker uses trade policy instruments in order to maximize domestic welfare, given the level of the Foreign trade policy instruments. For the unilateral optimal trade policy, Home doesn't need to consider the retaliation from Foreign and I assume $\tau_{XF} = \tau_{XF}^M = 1, X = I, E$. So the welfare optimization problem for Home is given by

$$\begin{aligned} &\max_{\tau_{XH}, \tau_{XH}^M, X=I,E} \quad \frac{E_H}{P_H} \\ &st \quad \text{Equations} \quad (1.14) - (1.21) \end{aligned}$$

The objective function is the real income of households in Home, $\frac{E_H}{P_H}$, where $E_H = w_H L_H + R_H$ measures the total nominal income for households and $P_H = \left(\sum_{j=H,F} P_{jH}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$ is the price index in Home.[14] Here R_H denotes the total transferred income from the Home government.[15] It consists of import tax revenues charged on imports of inputs and final goods gross of transport costs and foreign export taxes, and export tax revenues charged on exports of inputs and final goods gross of transport costs:

$$\begin{aligned} R_H = (\tau_{IH} - 1)\frac{P_{FH}Q_{FH}}{\tau_{IH}} + (\tau_{EH} - 1)\frac{P_{HF}Q_{HF}}{\tau_{EH}\tau_{IF}} \\ + (\tau_{IH}^M - 1)\frac{X_{FH}^M}{\tau_{IH}^M} + (\tau_{EH}^M - 1)\frac{X_{HF}^M}{\tau_{EF}^M} \end{aligned} \tag{1.22}$$

The constraints, equations (1.14)-(1.21), are the equilibrium conditions for the equilibrium which satisfies $\psi_i^D < \psi_i^S < \psi_i^X$, $i = H, F$. Note that the order of ψ_i^D, ψ_i^S, and ψ_i^X, $i = H, F$, in the initial free trade equilibrium state depends on the initial values of parameters. Besides, the equilibrium state is endogenous and responds to changes in trade policies. For example, given the initial equilibrium state $\psi_i^D < \psi_i^S < \psi_i^X$, $i = H, F$, if Home raised the import

[14]The household income is equal to its total expenditure in equilibrium, so I use the denotation of expenditure E_H to measure Home's nominal income in the objective function.

[15]R_H would be negative if the money taken by the government from the household for subsidy policy exceeds the revenue of tax and tariff. In this case, the trade policies are at the costs of the domestic market size in Home.

tariff on intermediate inputs τ_{IH}^M, ψ_i^S would increase correspondingly. Once τ_{IH}^M rises to a specific degree, the order of cutoff productivity values for Home in the equilibrium becomes $\psi_H^D < \psi_H^X < \psi_H^S$. Furthermore, when the equilibrium switches to another state as policy instruments change, the constraints in the welfare maximization problem would also change correspondingly.

1.4.2 Policymakers' incentives

In this part, I would take Home, for example, to discuss policymakers' incentives. There exist four kinds of policy incentives in the model: terms-of-trade for final goods, terms-of-trade for intermediate goods, monopolistic distortion correction, and production efficiency. The following discussions concentrate on the case $\tau_{XH} > 1$ and $\tau_{XH}^M > 1$, $X = I, E$ separately. The results about $\tau_{XH} < 1$, and $\tau_{XH}^M < 1$, $X = I, E$ would be opposite.

Terms-of-trade for final goods

According to equation (1.17), Home's terms-of-trade for final goods is given by:

$$ToT_H = \frac{\tau_{EH}}{\tau_{EF}} \left(\frac{w_H}{w_F}\right)^{\alpha} \left(\frac{N_H^D * m_{HF}}{N_F^D * m_{FH}}\right)^{\frac{1}{1-\sigma}} \left(\frac{\widetilde{\psi}_H(\psi_H^X)}{\widetilde{\psi}_F(\psi_F^X)}\right)^{-1} \tag{1.23}$$

where $m_{ij} = \frac{1-G(\psi_i^X)}{1-G(\psi_i^D)}$ denotes the exporting participation rate in country i. Equation (1.23) shows that the export tax on final goods directly affects Home's terms-of-trade for final goods. Besides, the change in ToT_H can be attributed to variations in the relative wage, the relative number of exporters, and the relative aggregate sourcing-capability-weighted productivity among exporters. To better illustrate the impact of trade in intermediates on ToT_H, I take log-differential in both sides of equation (1.23) and decompose the sourcing capability $\Phi_i^m(\psi)$, $i = H, F$, into wages and import and export tariffs on intermediate inputs. Details about the log-differential decomposition are shown in Appendix C.[16] Without losing generality, the log-differential decomposition concentrates on the cases of symmetric equilibrium, either $\psi_i^X > \psi_i^S$ or $\psi_i^X < \psi_i^S$, $i = H, F$.[17]

Case (I) $\quad \psi_i^X > \psi_i^S$, $i = H, F$

If $\psi_i^X > \psi_i^S$, it means that all the final-good exporters source intermediate inputs from the domestic and foreign markets simultaneously, which implies $\Phi_i^m(\psi) = \sum_{j=H,F} T_j(\tau_{ji}^M d_{ji}^M w_j)^{-\theta}$, $i = H, F$, in equation (1.23). In this case, the change in ToT_H can be decomposed as follows:

[16] The log-differential decomposition only holds if the policy instrument value is small because of the Taylor expansion's limitation. However, even if the policy instrument value is large, the variation of ToT_H is still as a function of terms in equation (23) but not linear.

[17] The log-differential decomposition of terms-of-trade for final goods under the asymmetric equilibrium, either $\psi_H^X > \psi_H^S$, $\psi_F^X < \psi_F^S$ or $\psi_H^X < \psi_H^S$, $\psi_F^X > \psi_F^S$, could be regarded as the mixture of the decomposition under the two symmetric cases.

$$
\begin{aligned}
\frac{\Delta ToT_H}{ToT_H} &= \frac{\Delta \tau_{EH}}{\tau_{EH}} + (1-\alpha)\beta_{FH}\left(\frac{\Delta \tau_{IH}^M}{\tau_{IH}^M} - \frac{\Delta \tau_{EH}^M}{\tau_{EH}^M}\right) \\
&\quad + (\alpha + (1-\alpha)(\beta_{HH} - \beta_{FH}))(\underbrace{\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}}_{(i)}) \\
&\quad + \frac{1}{1-\sigma}(\underbrace{\frac{\Delta N_H^D}{N_H^D} - \frac{\Delta N_F^D}{N_F^D}}_{(ii)} + \underbrace{\frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}}}_{(iii)}) - (\underbrace{\frac{\Delta \psi_i^X}{\psi_i^X} - \frac{\Delta \psi_j^X}{\psi_j^X}}_{(iv)})
\end{aligned}
\tag{1.24}
$$

The first line on the right-hand side of equation (1.24) captures the direct effects of Home's trade policies on ToT_H. Notably, the first term denotes the variations of export tax on final goods, and the second term refers to the difference between Home's export tax and import tariff on intermediate inputs. The coefficient of the second term is the interaction term of the fraction of intermediate input in the final-good production, $(1-\alpha)$, and the fraction of intermediate inputs sourcing from Foreign, β_{FH}.

For other terms in equation (1.24), (i) corresponds to an individual variety's change in ex-factory price. In contrast, (ii) and (iii) refer to the extensive measure of exportable and importable varieties. The last term (iv) affects both the average price of exporting varieties and the number of exporters in Home and Foreign. For the coefficient of (i), the difference between the fraction of intermediate inputs sourcing from Home and Foreign, $\beta_{HH} - \beta_{FH}$, captures how trade in intermediates affects ToT_H through the price of individual variety. Here I assume $\beta_{HH} > \beta_{FH}$ in the initial free trade equilibrium.[18] As the dependence of sourcing intermediate inputs from Foreign for firms in Home increases, $\beta_{HH} - \beta_{FH}$ decreases, and the impact of trade in intermediates on ToT_H rises. If there no exists trade in intermediates, $\beta_{FH} = 0$ and $\beta_{HH} = 1$. In this way, the coefficient of (i) reduces to 1 as the standard Melitz model, and the terms about τ_{IH}^M and τ_{EH}^M also disappear. Since all the final-good exporters source inputs from domestic and foreign markets together, there no exists the selecting term capturing the effect of sourcing inputs on ToT_H at the extensive margin.

Case (II) $\quad \psi_i^X < \psi_i^S$, $i = H, F$

If $\psi_i^X < \psi_i^S$, it means that final-good exporters within country i have heterogeneous sourcing strategies. Exporters with $\psi \in (\psi_i^X, \psi_i^S)$ source intermediate inputs exclusively from the domestic market, whereas exporters with $\psi > \psi_i^S$ take advantage of sourcing inputs from the foreign market. In this case,

[18]The assumption implies that for the final-good producers, the dependence on domestic intermediate input suppliers is larger than that on foreign input suppliers.

I decompose the variation of ToT_H as follows:

$$\begin{aligned}\frac{\Delta ToT_H}{ToT_H} = &\frac{\Delta\tau_{EH}}{\tau_{EH}} + (1-\alpha)\lambda_{FH}\frac{\phi_i}{\phi_i - 1}\left(\frac{\Delta\tau^M_{IH}}{\tau^M_{IH}} - \frac{\Delta\tau^M_{EH}}{\tau^M_{EH}}\right) \\ &+ (\alpha + (1-\alpha)(\lambda_{HH} - \lambda_{HF}))(\underbrace{\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}}_{(i)}) \\ &+ \frac{1}{1-\sigma}(\underbrace{\frac{\Delta N^D_H}{N^D_H} - \frac{\Delta N^D_F}{N^D_F}}_{(ii)} + \underbrace{\frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}}}_{(iii)}) \\ &+ \frac{(\sigma - k - 1)\lambda_{HH} + k}{1-\sigma}(\underbrace{\frac{\Delta\psi^X_H}{\psi^X_H} - \frac{\Delta\psi^X_F}{\psi^X_F}}_{(iv)}) \\ &+ \frac{(\sigma - k - 1)\lambda_{FH}}{1-\sigma}(\underbrace{\frac{\Delta\psi^S_H}{\psi^S_H} - \frac{\Delta\psi^S_F}{\psi^S_F}}_{(v)})\end{aligned} \quad (1.25)$$

where $\lambda_{ii} = \frac{\int_{\psi^X_i}^{\infty} \Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}} \psi^{\sigma-1} dG(\psi)}{\int_{\psi^X_i}^{\infty} \Phi_i^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}} \psi^{\sigma-1} dG(\psi)}$, $i = H, F$, denotes the contribution of domestic intermediate input suppliers to exporters' aggregate weighted productivity, whereas $\lambda_{ji} = 1 - \lambda_{ii}$, $j \neq i$ represents that of foreign input suppliers.[19] Following the assumption $\beta_{HH} > \beta_{FH}$ in equation (1.24), I assume $\lambda_{HH} > \lambda_{FH}$, which implies that the dependence on domestic input suppliers is larger than that on foreign ones.

On the right-hand side of equation (1.25), due to the differences in sourcing strategies among Home's final-good exporters, the effects of Home's policy tools and terms (i)-(iv) on ΔToT_H change correspondingly. Firstly, the coefficient of the relative changes of Home's import tariff and export tax on inputs, $\frac{\Delta\tau^M_{IH}}{\tau^M_{IH}} - \frac{\Delta\tau^M_{EH}}{\tau^M_{EH}}$, has an additional mark-up, $\frac{\phi_i}{\phi_i - 1}$, in comparison with that in equation (1.24).[20] Furthermore, for the indirect effect of relative wage on ToT_H through intermediate inputs, the relevant coefficient becomes $(1-\alpha)(\lambda_{HH} - \lambda_{HF})$, capturing the effect of sourcing inputs on ToT_H at the intensive margin. Moreover,

[19] The numerator of λ_{ii} can be regarded as the aggregate weighted productivity of exporters in country i if all the exporters only source intermediate inputs from the domestic market. According to the expression of λ_{ii}, $\lambda_{ji} = \frac{\int_{\psi^S_i}^{\infty} (\Phi_i^{2\,\frac{(1-\alpha)(\sigma-1)}{\theta}} - \Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}}) \psi^{\sigma-1} dG(\psi)}{\int_{\psi^X_i}^{\infty} \Phi_i^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}} \psi^{\sigma-1} dG(\psi)}$. The term $\Phi_i^{2\,\frac{(1-\alpha)(\sigma-1)}{\theta}} - \Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}}$ in the numerator denotes the gap in sourcing capability between sourcing exclusively from the domestic market and sourcing from domestic and foreign markets simultaneously.

[20] Note that the fraction $\frac{\phi_i}{\phi_i - 1}$ is equal to $\frac{\Phi_i^{2\,\frac{(1-\alpha)(\sigma-1)}{\theta}}}{\Phi_i^{2\,\frac{(1-\alpha)(\sigma-1)}{\theta}} - \Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}}}$, measuring the relative size of the capability of sourcing from domestic and foreign markets simultaneously to that exclusively from the domestic market.

since $0 < \lambda_{HH} < 1$ and $k+1 > \sigma$, $-1 < \frac{(\sigma-k-1)\lambda_{HH}+k}{1-\sigma} < 0$. It implies that the negative effect of relative exporting cutoff productivity on ToT_H remains but with a smaller magnitude under the heterogeneous sourcing strategies. Finally, the selecting term (v) denotes the effect of sourcing intermediate inputs on ToT_H at the extensive margin. Its negative coefficient implies that the rising relative sourcing capability due to trade in intermediates reduces ToT_H.

The impact of a specific policy instrument on ToT_H is uncertain and depends on calibrated parameters and policy values, so I would analyze how a specific policy affects (i)-(v) separately. Firstly, the export tax on final goods $\tau_{EH} > 1$ makes Foreign households transfer their consumption demand to domestically produced varieties. So Home's wage decreases relative to that of Foreign, implying that (i) is negative. Besides, the change in relative wage reduces the sourcing capability of Home relative to Foreign, so (v) is positive. Furthermore, as the export tax reduces the profits in the exporting market, ψ_H^X increases. In contrast, Foreign exporting cutoff productivity ψ_F^X decreases because the increasing sourcing capability reduces the production costs of Foreign exporters. So (iv) is positive. Regarding the effects of $\tau_{EH} > 1$ on the number of active domestic firms, on the one hand, N_F^D (ψ_F^D) increases (decreases) because Home's export tax on final goods transfer Foreign's consumption demand to domestically produced goods. On the other hand, N_H^D (ψ_H^D) also increases (decreases) because of the reducing domestic wage and the increasing market demand size induced by the export tax revenue. Therefore, (ii) and (iii) are uncertain given $\tau_{EH} > 1$.

Secondly, considering the import tariff on final goods $\tau_{IH} > 1$, it protects domestic firms from import competition and transfers domestic consumption demand to domestically produced varieties. So the increasing labor demand drives up the wage in Home relative to that in Foreign, making (i) be positive. The rising relative wage strengthens the sourcing capability of Home relative to Foreign, resulting in the reduction in ψ_H^S relative to ψ_F^S, so (v) is negative. Besides, ψ_F^X obviously increases relative to ψ_H^X due to the import tax, implying that (iv) is negative. For the effects of import tariff on the number of active domestic firms, on the one hand, the protection from import tariff makes ψ_H^D decrease and N_H^D increase. On the other hand, for low-productivity firms in Foreign, the domestic market demand for their products increases because of the rising price of imported varieties and the weakened sourcing capability of high-productivity firms in Foreign. So ψ_F^D reduces and N_F^D rises. In summary, (ii) is uncertain. Since both the relative productivity $\frac{\psi_H^D}{\psi_H^X}$ and $\frac{\psi_F^D}{\psi_F^X}$ decrease, changes in the relative exporting participation rate, (iii), is also uncertain.

Thirdly, for the export tax on inputs $\tau_{EH}^M > 1$, it raises the export price of domestically produced inputs and weakens the sourcing capability of Foreign. So ψ_F^S increases relative to ψ_H^S and (v) is negative. Since Foreign's import demand of inputs decreases, the labor demand and corresponding wage in Home reduce relative to that in Foreign, and (i) is negative. Besides, the weakened sourcing capability raises the production costs of Foreign exporters, so the exporting cutoff productivity ψ_F^X increases with $\tau_{EH}^M > 1$. In contrast, ψ_H^X decreases due to the reducing wage and the expanding foreign market demand. In summary, (iv) is negative if $\tau_{EH}^M > 1$. Furthermore, because of the reduction in relative wage and the weakened sourcing capability of Foreign, the domestic market demand for low-productivity firms in Home and Foreign increases. So both N_H^D and N_F^D (ψ_H^D and ψ_F^D) increase (decrease). As a result, terms (ii) and (iii) are uncertain.

Finally, regarding the import tariff on intermediate goods $\tau_{IH}^M > 1$, it raises the available price of imported inputs and weakens the sourcing capability of Home. So ψ_H^S increases relative to ψ_F^S, making (v) be negative. Besides, the import tariff on inputs drives up the domestic factor price in Home, so the relative wage increases and (i) is positive. As Home's firms suffer from the tariff on imported inputs and the rising factor prices, the exporting cutoff productivity in Home ψ_H^X increases relative to that in Foreign ψ_F^X. So (iv) is positive. Furthermore, the market expansion in Home makes ψ_H^D decrease and N_H^D increase. However, N_F^D also rises because of the increasing available price of imported varieties in Foreign and the reducing sourcing capability of Foreign high-productivity firms. So (ii) is unclear. In addition, Home's exporting participation rate m_{HF} decreases because of the increasing ψ_H^X and the reducing ψ_H^D. However, the change in Foreign's exporting participation rate m_{FH} is unclear because both ψ_F^D and ψ_F^X decrease under $\tau_{IH}^M > 1$. In summary, the change in (iii) is undetermined.

Terms-of-trade for intermediate goods

Home's terms-of-trade for intermediate goods can be measured by

$$ToT_H^M = \frac{P_{HF}^M/\tau_{IF}^M}{P_{FH}^M/\tau_{IH}^M} = \frac{\tau_{EH}^M}{\tau_{EF}^M}\frac{w_H}{w_F}\left(\frac{T_F}{T_H}\right)^{\frac{1}{\theta}} \tag{1.26}$$

where P_{ij}^M is the aggregate price at which firms in country j obtained intermediate inputs imported from country i.

If the technology of producing intermediate inputs is symmetric, $T_H = T_F$, ToT_H^M is equal to the interaction term between the relative wage, $\frac{w_H}{w_F}$, and the relative export tax on intermediate inputs, $\frac{\tau_{EH}^M}{\tau_{EF}^M}$. If Home has a relative advantage over Foreign in producing intermediate goods, $T_H > T_F$, given the change of relative wage $\frac{w_H}{w_F}$, the variation of ToT_H^M is weakened by the comparative advantage. It can be attributed to the reason that given the higher production technology T_H, the unit cost of producing a specific intermediate input is lower for Home than Foreign, which induces lower exporting prices of intermediate inputs.

The rising ToT_H^M implies that Home's firms benefit from sourcing relatively cheaper intermediate inputs from Foreign. The reduction in production costs due to trade in intermediates would increase firms' profits. To improve ToT_H^M, Home can directly use the export tax on intermediate goods, although the induced decreasing wage weakens its effects on ToT_H. Besides, Home can also implement the policies which raise the relative wage indirectly, including import tariff on intermediate goods, import tariff, and export subsidy on final goods, to drive up ToT_H^M correspondingly.

1.4.2.1 Correction of monopolistic distortions

This final-good sector has monopolistic distortion since this sector is characterized by monopolistic competition. Because of the monopolistic distortion, prices of individual varieties are too high. Thus there is too little demand for the differential varieties, resulting in too little entry into the final goods sector. Therefore, to increase the number of domestic active final-good producers, Home can use the following policy tools: the production subsidy; the import tariff, which protects domestic firms from the imported competition; export tax on final goods, which raises the domestic market size and reduces domestic wage; import tariff on intermediate inputs, which increases the market demand of varieties produced by firms with low productivity; export tax on intermediate inputs, which rises the importing price of varieties.

As Dixit (1985) shows, the monopolistic distortion is best countered with the production tax that works directly on the marginal and fixed costs. In contrast, the trade policies are implemented to deal with other incentives for policy intervention: the terms-of-trade for final goods, the terms-of-trade for intermediate goods, and the production relocation incentive. Campolmi et al. (2014) show that when production subsidies are not available, the import or export subsidies can improve the free trade allocation to a second-best level. These subsidies can partially eliminate the monopolistic distortions, but they can't achieve the first-best allocation. The reason is that these trade policy instruments cannot eliminate the markups on the goods produced and consumed in the same region. So I would study the unilateral optimal trade policies in the absence of domestic production policy, which are the second-best level.

1.4.2.2 Production efficiency

Since the final-good market is under monopolistic competition whereas the intermediate-input market is under perfect competition, the marginal values of workers devoted to these two sectors are different. Therefore, if too few workers are allocated to the final goods sector, the misallocation of the labor force across sectors results in welfare distortion. Suppose the number of workers devoted to the intermediate goods sector decreases, and firms source more inputs from the foreign market. In this case, Home improves its domestic production efficiency at the cost of Foreign welfare. This neighbor beggar effect is consistent with the production relocation incentive (home market effect) emphasized in Venables (1987), Ossa (2011), and Campolmi et al. (2014). The production relocation incentive works through changes in N_H^D and N_F^D that reduce the domestic price level by increasing the fraction of varieties produced domestically because domestic households don't need to incur transport costs on domestically produced varieties. To reduce the fraction of workers devoted to the intermediate input sector, Home can implement the following policies: import subsidy, and export tax on inputs, which reduce the importing price and raise the exporting prices of inputs, respectively; import subsidy and export tax on final goods, which drive up the factor price and reduce the demand for domestically produced inputs.

1.5 Unilateral second-best trade policy

In this section, I explore how Home uses unilateral trade policies to maximize domestic welfare given Foreign policy instruments. Here I assume $\tau_{IF} = \tau_{EF} = \tau_{IF}^M = \tau_{IF}^M = 1$ for Foreign. I start with the constrained trade policies in which Home can only carry out one or several trade policies instead of using all of them simultaneously. Then I turn to the unconstrained trade policies in which Home is allowed to use all trade policies simultaneously. In the absence of the domestic production subsidy, the solutions to the welfare maximization problem are the second-best trade policies.

Following Ossa (2016), I solve the welfare optimization problem with a two-stage numerical approach.[21] Firstly, I define Home's real income as a function of policy instruments and solve the equilibrium conditions given the values of policy tools. Then, I take the optimization routine over Home's real income to determine the policy instrument values that maximize Home's welfare.[22]

1.5.1 Calibration

I calibrate the model to quantify the importance of trade in intermediates for the optimal trade policy and simulate the trade policy's welfare effect. Besides, the calibration is to replicate essential facts about the US's trade data instead of calibrating two specific countries in the real world.

Since there no exists physical capital in the model, I assume that the weights of labor and intermediate input in the final-good production are equal, $\alpha = 0.5$. Following Melitz and Redding(2015), I set the elasticity of substitution σ equal to 4. Besides, for the Pareto distribution of productivity, I set the shape parameter k and the lower bound $\underline{\psi}$ equal to 4.25 and 1.31, respectively. Note the calibration satisfies the assumption in the model, $k+1 > \sigma$. Given the chosen values of σ, k, and $\underline{\psi}$, I calibrate the trade costs for final goods d to be 1.65 for matching the fraction of exports over GDP, 0.1. Furthermore, I set the relative fixed trade costs $\frac{f_i^X}{f_i^D}$ equal to 1.3 for matching the export participation rate of US manufacturing firms, 0.18.[23] For the technology of intermediate

[21] Ossa(2016) uses the "exact hat algebra" method to rewrite the equilibrium conditions in levels into that in changes. This method avoids the difficulty of recovering some parameters from the real world. But the model in Ossa (2016) is homogeneous and only includes trade in final goods. Using the "exact hat algebra" to the equilibrium conditions in my model will result in very complex calculations, so I still use the equilibrium conditions in levels in the welfare maximization problem and obtain parameters from other literature.

[22] In MATLAB, for the first stage, I use the 'fsolve' function to solve the optimization problem given a specific set of parameters and policy instruments. In the second stage, I use the 'fminunc" function to implement the optimization routine.

[23] Both the data on the fraction of exports over GDP and the exporting participation rate

inputs, following Antras et al.(2018), I calibrate the average state T and the productivity variation θ to be 1.1 and 1.79, respectively. For the variable trade costs for intermediate inputs, I set it to be the same as that for final goods, $d^M = d = 1.65$, making the fraction of intermediate inputs sourcing from foreign over total used intermediate inputs be 21%. In the comparative statics analysis later, I will change d^M to explore how trade in intermediate goods affects optimal trade policy. Finally, I calibrate $\frac{f_i^D}{f_i^S} = 1.5$ to make firm's source participation rate be 29%. These calibrations make the cutoff productivity in the free trade equilibrium satisfy $\psi_i^D < \psi_i^S < \psi_i^X \; i = H, F$.

1.5.2 Constrained trade policy on final goods

In Column (1) of Table 1.1, when Home only implements import tariff/subsidy on final goods, the tariff at $\tau_{IH} = 1.37$ maximizes Home's welfare. By restricting imports from Foreign, the tariff encourages households to transfer their consumption demand to domestically produced varieties, expanding the market demand for domestic firms and raising the labor demand. So the wage in Home (also ToT_H^M) increases by 10.73%, which weakens the sourcing capability of firms in Foreign. Besides, the amount of active domestic firms rises by 2.52%, whereas the fraction of the labor force devoted to the intermediate goods sector decreases by 8.44%. However, ToT_H reduces slightly by 0.57% under $\tau_{IH} = 1.37$, which results from the 42.08% increase in the relative amount of exporters.[24] In summary, terms-of-trade for intermediate goods, correction of domestic distortion and production relocation motives dominates over terms-of-trade for final goods, thus leading to the import tariff on final goods.

When Home is constrained to use export tax on final goods, it's optimal to set $\tau_{EH} = 0.97$ as Column (2) shows. This export subsidy directly makes ToT_H decrease by 3%, whereas the aggregate effect of other factors on ToT_H is slight -0.03%. The decreasing ToT_H raises the imported demand for Home's product from Foreign, driving the labor demand and wage in Home (also ToT_H^M) to rise by 1.36%. But Home's ascending wage and reducing market size results in the 1.47% reduction in N_H^D accordingly. Besides, the import demand for intermediate inputs from Foreign also decreases, leading to the reallocation of the labor force from the input sector to the final-good sector in Home. In summary, although both ToT_H and N_H^D decrease with the export subsidy on final goods, the rising ToT_H^M and labor force reallocated to the final-good sector make up for these welfare losses.

The comparison between Columns (1) and (2) shows that both the second-best import tariff and the export subsidy on final goods worsen the terms-of-trade for final goods, but improve the terms-of-trade for inputs. The rising terms-of-trade for inputs reallocates the labor force from the input sector to

are obtained from the 2000-2010 US Census of Manufacture.

[24] The change in the relative amount of exporters $\frac{N_H^X}{N_F^X}$ can induced from the changes in $\frac{N_H^D}{N_F^D}$ and $\frac{m_{HF}}{m_{FH}}$ as $\Delta \frac{N_H^X}{N_F^X} = (\frac{\Delta N_H^D}{N_H^D} - \frac{\Delta N_F^D}{N_F^D}) + (\frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}})$

Table 1.1: Unilateral optimal trade policy on final goods by Home

			(1) $\tau_{IH}=1.37$ $\tau_{EH}=1$	(2) $\tau_{IH}=1$ $\tau_{EH}=0.97$	(3) $\tau_{IH}=1.4$ $\tau_{EH}=0.90$
$\frac{\Delta TOT_H}{TOT_H}$			-0.57%	-2.97%	-10.17%
	(i) $\frac{\Delta w_H}{w_H}-\frac{\Delta w_F}{w_F}$	(+)	10.73%	1.36%	16.63%
	(ii) $\frac{\Delta N_H^D}{N_H^D}-\frac{\Delta N_F^D}{N_F^D}$	(−)	-5.27%	-0.94%	-8.52%
	(iii) $\frac{\Delta m_{HF}}{m_{HF}}-\frac{\Delta m_{FH}}{m_{FH}}$	(−)	47.35%	10.16%	84.84%
	(iv) $\frac{\Delta \psi_H^X}{\psi_H^X}-\frac{\Delta \psi_F^X}{\psi_F^X}$	(−)	-25.75%	-1.58%	-31.89%
$\frac{\Delta TOT_H^M}{TOT_H^M}$			10.73%	1.36%	16.63%
$\frac{\Delta N_H^D}{N_H^D}$			2.52%	-1.47%	-2.3%
$\frac{\Delta (L_H^M/L_H)}{(L_H^M/L_H)}$			-8.44%	-1.16%	-12.47%
$\frac{\Delta W_H}{W_H}$			1.9%	0.03%	2.16%
$\frac{\Delta W_F}{W_F}$			-3.16%	-0.05%	-3.64%

[1] The sign in the brackets is the sign of the terms in the log-differentiation of ToT_H in equation (1.24)

[2] Term (v) in equation (1.25) is not shown in this Table because the cutoff productivities ψ_i^S and ψ_i^X, $i=H,F$, remain satisfying $\psi_i^S<\psi_i^X$ in the second-best solution of unilateral optimal trade policies on final goods.

the final-good sector, thus leading to the expansion of the final-good sector. However, the effects of the second-best import tariff and export subsidy on final goods on monopolistic distortion are different. The import tariff protects domestic low-productivity firms from import competition, increasing the amount of active domestic firms. In contrast, the export subsidy raises high-productivity exporters' profits in the export market. Still, it reduces the domestic market size because of the induced fiscal burden, expelling low-productivity firms from the market. So the welfare improvement under the second-best import tariff on final goods is more significant than under the second-best export subsidy.

In Column (3), if Home uses the export and import trade policy on final goods simultaneously, the second-best trade policies are import tariff $\tau_{IH}^M=1.40$ and export subsidy $\tau_{EH}^M=0.90$. According to Columns (1) and (2), the change in ToT_H would be almost equal to the export subsidy, around a 10% decrease. Both the second-best import tariff and the export subsidy drive up the domestic labor demand in Home, making w_H (also ToT_H^M) increase by 16.63% consequentially. Besides, workers are reallocated from the input sector to the final-good sector as $\frac{L_H^M}{L_H}$ reduces 12.47%. Although the import tariff $\tau_{IH}=1.40$ protects domestic firms from import competition, the number of active firms in Home decreases by 2.3% in total because of the export subsidy $\tau_{EH}^M=0.90$.

1.5.3 Constrained trade policy on intermediate goods

Table 1.2: Unilateral optimal trade policy on intermediate goods by Home

			(1) $\tau_{IH}^M = 0.95$ $\tau_{EH}^M = 1$	(2) $\tau_{IH}^M = 1$ $\tau_{EH}^M = 1.67$	(3) $\tau_{IH}^M = 0.96$ $\tau_{EH}^M = 1.67$
$\frac{\Delta TOT_H}{TOT_H}$			-2.34%	-12.14%	-14.07%
	(i) $\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}$	(+)	-0.49%	-0.42%	-0.85%
	(ii) $\frac{\Delta N_H^D}{N_H^D} - \frac{\Delta N_F^D}{N_F^D}$	(−)	-1.43%	-0.94%	-11.33%
	(iii) $\frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}}$	(−)	15.86%	10.16%	86.2%
	(iv) $\frac{\Delta \psi_H^X}{\psi_H^X} - \frac{\Delta \psi_F^X}{\psi_F^X}$	(−)	-2.78%	-12.35%	-14.93%
$\frac{\Delta TOT_H^M}{TOT_H^M}$			-0.49%	66.23%	65.52%
$\frac{\Delta N_H^D}{N_H^D}$			-2.5%	5.64%	3.02%
$\frac{\Delta (L_H^M/L_H)}{(L_H^M/L_H)}$			-1.4%	-14.14%	-15.48%
$\frac{\Delta W_H}{W_H}$			0.05%	2.82%	2.87%
$\frac{\Delta W_F}{W_F}$			-0.09%	-5.09%	-5.17%

[1] The sign in the brackets is the sign of the terms in the log-differentiation of ToT_H in equation (1.24)

[2] Term (v) in equation (1.25) is not shown in this Table because the cutoff productivities ψ_i^S and ψ_i^X, $i = H, F$, remain satisfying $\psi_i^S < \psi_i^X$ in the second-best solution of unilateral optimal trade policies on final goods.

As Column (1) in Table 1.2 shows, when Home is restricted to use import tariff/subsidy on intermediate inputs, the second-best import subsidy is $\tau_{IH}^M = 0.95$. Since $\frac{L_H^M}{L_H}$ and N_H^D decrease by 1.4% and 2.5%, respectively, this import subsidy improves production efficiency by reallocating Home's labor force from the input sector to the final-good sector, at the cost of the number of active domestic firms. So it identifies that high-productivity firms benefit from the subsidy on imported inputs for reducing production costs, whereas low-productivity firms suffer from the reduced market demand due to the fiscal burden of import subsidy. However, ToT_H^M and ToT_H reduce by 0.49% and 2.34%, respectively, due to the slight reduction in the relative wage and the significant increase in the relative exporting participation rate. So the Home's welfare only increases 0.05% under the second-best import subsidy on inputs.

In Column (2), when Home accesses exclusively to export tax on inputs, the second-best export tax is $\tau_{EH}^M = 1.67$. The export tax directly contributes to the 66.23% increase of ToT_H^M and weakens the sourcing capability of Foreign firms. As Foreign import demand for inputs decreases, $\frac{L_H^M}{L_H}$ decreases by 14.14%. The rising price of imported inputs drives up production costs and export prices of Foreign firms, leading to the 12.14% reduction in ToT_H.[25] So the market demand in Home for domestically produced varieties rises, resulting in a 5.64% increase of N_H^D. Indeed, as the import tariff on final goods, the export tax on intermediate goods protects domestic firms from import competition by raising the available prices of imported varieties. In summary, the export tax on inputs improves terms-of-trade for inputs at the cost of terms-of-trade for final goods. Besides, it corrects the domestic monopolistic distortion and production efficiency, resulting in a significant increase in Home welfare.

The comparison between Columns (1) and (2) shows that the 12.14% reduction in ToT_H under the second-best export tax on inputs ${\tau_{EH}^M}^* = 1.67$ is much larger than the 2.34% reduction under the second-best import subsidy ${\tau_{IH}^M}^* = 0.95$. However, this export tax makes ToT_H^M increase by 66.23%, which is in contrast to the 0.49% reduction under the second-best import subsidy. So the production efficiency improvement under ${\tau_{EH}^M}^* = 1.67$ is as many as ten times that under ${\tau_{IH}^M}^* = 0.95$. Furthermore, N_H^D increases by 5.64% under ${\tau_{EH}^M}^* = 1.67$ as it raises the production costs and export price of Foreign firms. In contrast, the fiscal burden due to the import subsidy reduces the domestic market demand size, worsening the monopolistic distortion with a 2.5% reduction in N_H^D. In summary, the welfare improvement under the second-best export tax on inputs is more significant than under the second-best import subsidy on inputs. Finally, when Home manipulates import and export policy on inputs simultaneously, it is optimal to set ${\tau_{IH}^M}^* = 0.96$ and ${\tau_{EH}^M}^* = 1.67$, which is almost the same as using these two trade policies separately.

Regarding the results about constrained second-best trade policies, the welfare improvement under either the export subsidy on final goods or the import subsidy on inputs is significantly smaller than that under the import tariff on final goods or export tax on inputs. It can be attributed to the fiscal burden due to the subsidies, which reduces the domestic market demand size. The reducing domestic market demand expels low-productivity firms from the market and raises the market concentration, thus worsening the monopolistic distortion. Furthermore, the welfare improvement under the second-best import tariff on final goods is relatively minor than under the export tax on inputs. The export tax on inputs directly improves terms-of-trade for inputs and raises the production costs of Foreign firms, thus reallocating the labor force across sectors. However, the import tariff on final goods indirectly affects terms-of-trade for inputs through the domestic wage induced by the rising demand for domestically produced varieties.

[25]The relative export cutoff productivity $\frac{\psi_H^X}{\psi_F^X}$ decreases 12.35%, but its effect on ToT_H is dominated by the negative effect of $\frac{m_{HF}}{m_{FH}}$ which increase 10.16%. Although the coefficient of $\frac{\psi_H^X}{\psi_F^X}$ in equation (1.24) is larger than that of $\frac{m_{HF}}{m_{FH}}$, I can't use it to approximate their marginal contributions to ToT_H at $\Delta\tau_{EH}^M = 0.65$ because equation (1.24) is only hold when $\Delta\tau_{EH}^M$ is extreme small.

1.5.4 Unconstrained trade policies

Table 1.3: Unilateral optimal unconstrained policy by Home

			$\tau_{IH} = 1.06, \tau_{EH} = 1.18$ $\tau^M_{IH} = 0.87, \tau^M_{EH} = 1.82$
$\frac{\Delta TOT_H}{TOT_H}$			-9.61%
	(i) $\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}$	(+)	-9.58%
	(ii) $\frac{\Delta N_{HH}}{N_{HH}} - \frac{\Delta N_{FF}}{N_{FF}}$	(−)	-11.27%
	(iii) $\frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}}$	(−)	71.21%
	(iv) $\frac{\Delta \psi^X_H}{\psi^X_H} - \frac{\Delta \psi^X_F}{\psi^X_F}$	(−)	-28.95%
$\frac{\Delta TOT^M_H}{TOT^M_H}$			64.24%
$\frac{\Delta N^D_H}{N_{HH}}$			8.04%
$\frac{\Delta(L^M_H/L_H)}{(L^M_H/L_H)}$			-15.4%
$\frac{\Delta W_H}{W_H}$			3.45%
$\frac{\Delta W_F}{W_F}$			-6.11%

[1] The sign in the brackets is the sign of the terms in the log-differentiation of ToT_H in equation (1.24)

[2] Term (v) in equation (1.25) is not shown in this Table because the cutoff productivities ψ^S_i and ψ^X_i, $i = H, F$, remain satisfying $\psi^S_i < \psi^X_i$ in the second-best solution of unilateral optimal trade policies on final goods.

Table 1.3 displays that if all trade policies are implemented simultaneously, the second-best trade policies include import tariff on final goods $\tau_{IH} = 1.06$, export tax on final goods $\tau_{EH} = 1.18$, import subsidy on inputs $\tau^M_{IH} = 0.87$, and export tax on inputs $\tau^M_{EH} = 1.82$. Although $\tau_{EH} = 1.18$ directly drives up ToT_H by 18%, ToT_H decreases by 9.61% in aggregate due to the negative effects of other trade policies on ToT_H. Because of the 9.58% reduction in Home wage w_H and the direct export tax on inputs $\tau^M_{EH} = 1.82$, ToT^M_H increases by 64.24%. The rising ToT^M_H transfers the labor force from the input sector to the final-good sector, resulting in the expansion of the final-good sector. Finally, although low-productivity firms suffer from the import subsidy on inputs $\tau^M_{IH} = 0.87$, the second-best import tariff on final goods $\tau_{IH} = 1.06$ and export tax on inputs $\tau^M_{EH} = 1.82$ protects domestic firms from import competition, thus leading to 8.04% increase in N^D_H. So the second-best trade policies improve terms-of-trade for inputs and production efficiency and correct monopolistic distortion at the cost of terms-of-trade for final goods, resulting in a 3.45% increase in domestic welfare.

In comparing constrained and unconstrained second-best trade policies, the constrained second-best import tariff on final goods ($\tau_{IH} = 1.37$) is significantly larger than the unconstrained one ($\tau_{IH} = 1.06$). In contrast, the constrained second-best export tax on inputs ($\tau^M_{EH} = 1.67$) is smaller than the unconstrained one ($\tau^M_{EH} = 1.82$). The difference implies that Home prefers to use the export tax on inputs to protect domestic firms and correct monopolistic distortion rather than the import tariff on final goods when these two policies are available simultaneously. Furthermore, the constrained second-best subsidy on inputs ($\tau_{IH}^M = 0.95$) is smaller than the unconstrained second-best one ($\tau_{IH}^M = 0.87$). The reason is that when Home implements all the unconstrained second-best trade policies, the protection for domestic firms from import competition because of export tax on inputs and import tariffs on final goods counteracts the negative effect of import subsidy on the market demand size. Finally, unlike the used export subsidy on final goods in the constrained case, Home implements export tax on final goods in the unconstrained case. The export tax on final goods partly offsets the significant negative effects of the import subsidy and export tax on inputs on terms-of-trade for final goods.

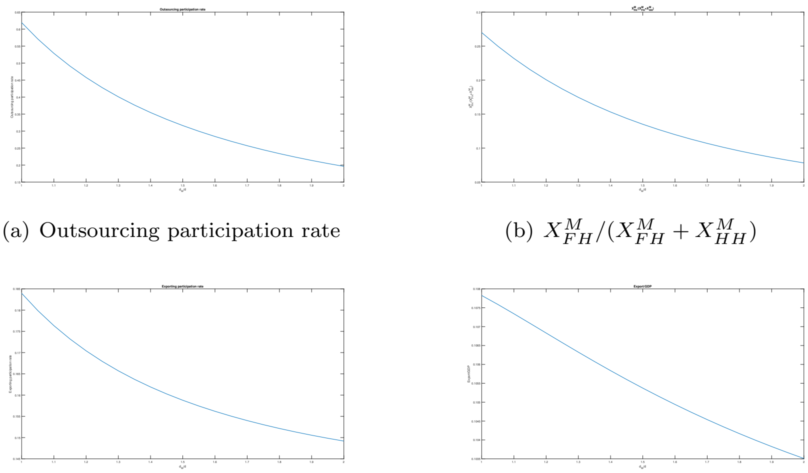
The above results show that the changes in ToT_H in all constrained and unconstrained second-best trade policies are negative, whereas ToT_H^M, N_H^D and $\frac{L_H^M}{L_H}$ are improved in almost all second-best trade policies. When Home chooses its unilateral optimal trade policies in the absence of the domestic production policy, the above results infer that terms-of-trade for intermediate inputs, correction of monopolistic distortion, and production efficiency motives dominate terms-of-trade for final goods. Trade in intermediates makes it more complex for Home to manipulate international prices of final goods in its favor by implementing trade policies. For example, if Home imposed an export tax on final goods, the induced reducing wage strengthens the sourcing capability of Foreign firms. It increases their import demand for inputs, thus reallocating the Home domestic labor force from the final-good sector to the input sector. In this way, improving terms-of-trade for final goods is at the cost of worsening monopolistic distortion and production efficiency. In contrast, manipulating terms-of-trade for inputs enables Home to efficiently improve production efficiency and correct monopolistic distortion without domestic production subsidy. So the policymaker prefers to manipulate terms-of-trade for inputs instead of terms-of-trade for final goods in the absence of domestic production subsidy.

1.6 Comparative statics

In this part, I explore how the unilateral optimal trade policies change with the trade costs of intermediate goods d^M through comparative statics. Here I focus on the cases in which Home uses the constrained trade policies separately.

Figure 1.1 illustrates the effects of trade costs of intermediate inputs on the initial free trade equilibrium. The horizontal axis is the trade costs of intermediate inputs relative to final goods.[26] In the free trade equilibrium, the sourcing capability decreases with the trade costs of intermediate inputs, thus reducing the outsourcing participation rate and the fraction of inputs sourcing from the foreign market, as Figure 1.1 (a) and (b) show. Besides, Figure 1.1 (c) and (d) show that the weakened sourcing capability raises the production costs of exporters, thus making the initial exporting participation rate and the ratio

[26]Since d is unchanged, the rising $\frac{d^M}{d}$ implies the increase of d^M.



(a) Outsourcing participation rate

(b) $X^M_{FH}/(X^M_{FH}+X^M_{HH})$

(c) Exporting participation rate

(d) Export/GDP

Figure 1.1: The effects of trade costs of inputs on the free trade equilibrium

of exports to GDP decrease. Intuitively, the dependence on foreign intermediate input supplies decreases with d^M, so the relative contribution of terms-of-trade for inputs to welfare improvement decreases. Besides, since the fraction $(1-\alpha)$ of intermediate inputs in the final-good production is fixed, it's more difficult for the policymaker to improve production efficiency by manipulating terms-of-trade for inputs after d^M increases.

Given the corresponding second-best trade policies under different trade costs of inputs, Figure 1.2 illustrates the changes in terms-of-trade for final goods, terms-of-trade for inputs, the number of active domestic firms, and the fraction of the labor force devoted to the input sector. It shows that the improvement of Home production efficiency (the reduction in $\frac{L^M_H}{L_H}$) given the corresponding second-best trade policies decreases with d^M. In contrast, the improvement of terms-of-trade for final goods increases significantly with d^M.

In Figure 1.3, the horizontal axis is still the relative trade costs of inputs to final goods; the vertical axis is the second-best trade policy when Home implements the corresponding trade policy individually. Figure 1.3 (a) shows that the second-best import tariff on final goods decreases with d^M. It can be attributed to the following reasons. On the one hand, the rising d^M weakens the sourcing capability of Foreign firms and increase the production costs of Foreign exporter, so the import competition faced by Home domestic firms diminishes. On the other hand, the increasing d^M makes it difficult for Home to improve the production efficiency by manipulating terms-of-trade for inputs, so Home adjusts the trade policy to improve terms-of-trade for final goods as d^M increases.

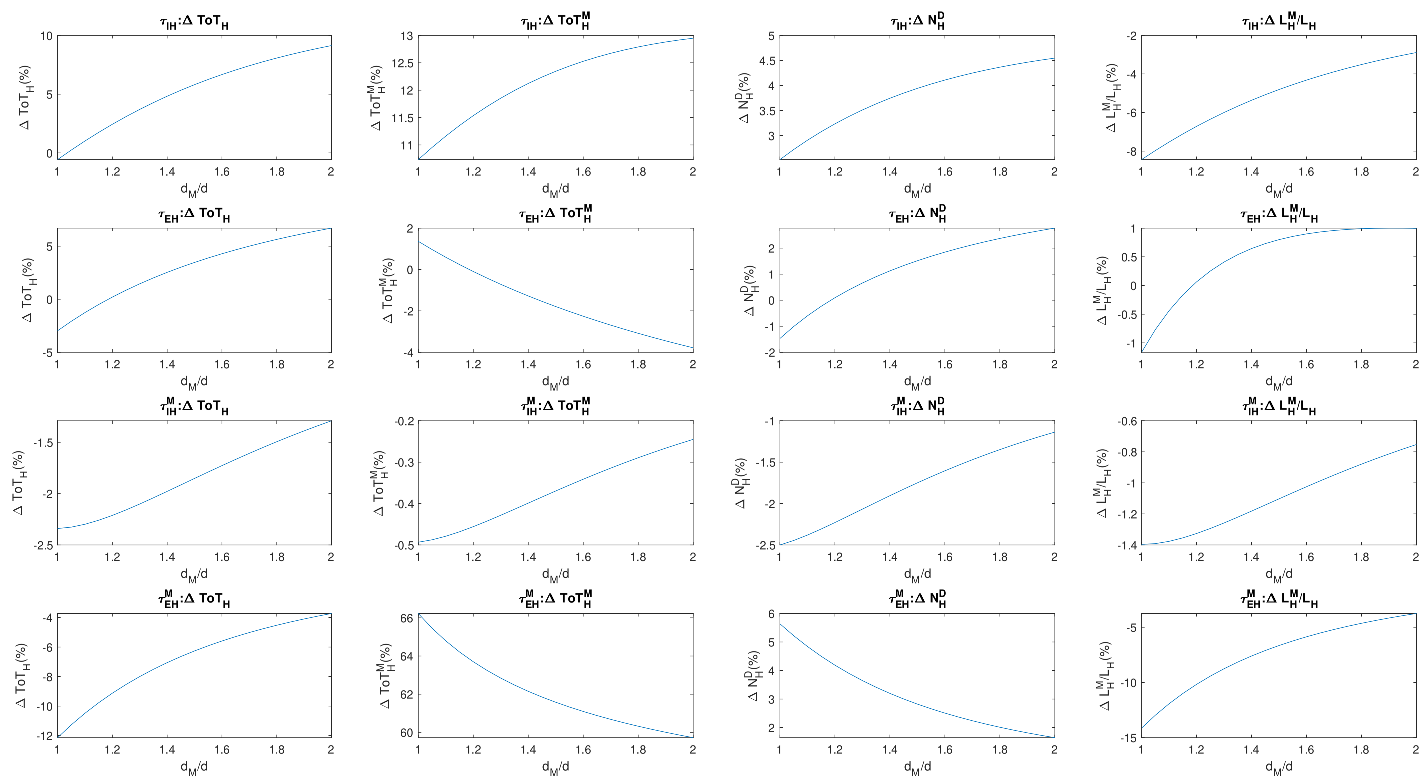
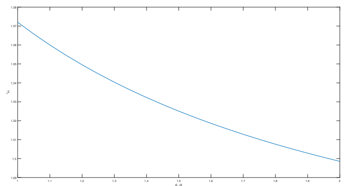
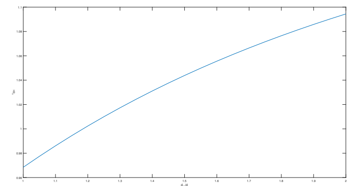


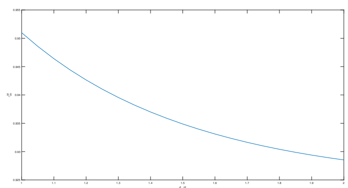
Figure 1.2: The policy incentives given the corresponding second-best trade policies [27]



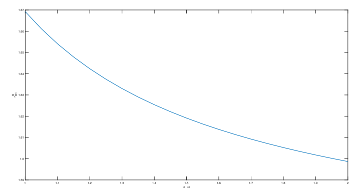
(a) Import tariff/subsidy on final goods



(b) Export tax/subsidy on final goods



(c) Import tariff/subsidy on inputs



(d) Export tax/subsidy on inputs

Figure 1.3: The effects of trade costs of inputs on second-best trade policies

Analogously, Figure 1.3 (b) shows that the second-best export subsidy on final goods decreases with d^M and switches to be export tax after the relative trade cost $\frac{d^M}{d}$ exceeds 1.2. As Figure 1.2 shows, the second-best export tax on final goods improves the terms-of-trade for final goods and corrects the monopolistic distortion at the cost of terms-of-trade for inputs and production efficiency. The result also implies that if the relative trade cost of inputs to final goods is low, the second-best trade policy on final goods is the export subsidy. In this way, terms-of-trade for inputs and the production efficiency incentive dominate terms-of-trade for final goods and monopolistic distortion correction. On the other hand, if the relative trade cost is high, the policymaker prefers the second-best export tax on final goods, at which terms-of-trade for final goods and monopolistic distortion correction dominate terms-of-trade for inputs and production efficiency incentive.

Finally, regarding the second-best trade policy on inputs, Figure 1.3 (c) and (d) show that as d^M increases, the second-best import subsidy on inputs τ_{IH}^M increases, whereas the second-best export tax on inputs τ_{EH}^M decreases. Intuitively, the rising d^M implies the physical transportation cost increases, so the policymaker directly adjusts the second-best trade policy on inputs to offset the rising d^M.

[27] The rows sequentially corresponds to the second best import and export policy on final goods, and import and export policy on inputs. The columns sequentially corresponds to the changes in terms-of-trade for final goods ToT_H, terms-of-trade for input ToT_H^M, the amount of active domestic firms N_H^D, and the fraction of labor force devoted to the input sector $\frac{L_H^M}{L_H}$.

1.7 Conclusion

In this chapter, I construct a two-country trade model with monopolistic competition, heterogeneous firms, and trade in intermediates and final goods. Because of the fixed costs of sourcing and exporting, only high productivity firms afford to access the foreign intermediate inputs and final goods market. Then I figure out the policymaker's incentives for trade policy, including terms-of-trade for final goods, terms-of-trade for intermediate inputs, correction of monopoly distortion, and production efficiency. Finally, I numerically solve the unilateral optimal trade policies and do the comparative statics analysis regarding trade costs of intermediate inputs.

My main findings include that in the absence of the domestic production policy, if Home uses the individual trade policy separately, it's optimal to implement import tariff and export subsidy on final goods and import subsidy and export tax on intermediate inputs, respectively. However, if Home implements all the trade policies simultaneously, Home will implement an export tax instead of an export subsidy on final goods. The results also imply that high-productivity firms benefit from the import subsidy on inputs, whereas low-productivity firms suffer from the fiscal burden of subsidy. Besides, the export tax on inputs protects domestic firms from the import competition as the import tariff on final goods, but is more efficient in improving the domestic welfare. In summary, trade in intermediates makes the change in domestic factor prices affect the production activities of foreign firms, resulting in the difficulty of manipulating terms-of-trade for final goods. In contrast, the policymaker can manipulate terms-of-trade for intermediate inputs to improve domestic monopolistic distortions and production efficiency.

I conclude by mentioning two limitations of the current analysis that could be relaxed in future research. The first one is the perfect competition assumption for the intermediate goods market. Given this assumption, intermediate suppliers have constant return technology, and they don't have the bargaining power in the deal with final good producers. However, intermediate suppliers in the real world, especially those producing high skill-intensive intermediate inputs, could have monopolistic market power in the bargaining with final good producers. It would be significant to study how the monopolistic market power in the intermediate input market affects optimal trade policies.

The second one is the absence of a domestic production policy. According to Dixit (1985), the monopolistic distortion is best countered with the production subsidy that works directly on the appropriate margin. In the absence of a domestic production subsidy, the trade policies can improve the free trade allocation to a second-best level (Campolmi et al. (2014)). So it would be interesting to research the first-best trade policies after introducing the domestic production subsidy. Notably, because of the selection effect of fixed costs of sourcing, firms with high productivity benefit from the production subsidy on the imported inputs, whereas firms with low productivity suffer from the fiscal burden of subsidy on imported inputs. So it's meaningful to study how to set up the production subsidy for the imported intermediate inputs, given the existence of heterogeneous firms.

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Appendices

A Equilibrium $\psi_i^D < \psi_i^S < \psi_i^X \quad i, j = H, F$

According to equation (1.2) and (1.8), the revenue from country j for firm ψ located in country i is

$$r_{ij}(\psi) = \frac{p_{ij}(\psi) q_{ij}(\psi)}{\tau_{ij}} \tag{A1}$$

where $p_{ij}(\psi) = \tau_{Ei}\tau_{Ij}d_{ij}p_i(\psi)$ is the price at which consumers in country j obtain variety produced by firm ψ in country i.

Since the final goods market is under monopolistic competition, the variable profit from market j for firm ψ settled in country i is

$$\pi_{ij}(\psi) = \frac{r_{ij}(\psi)}{\sigma} = \mu B_j \tau_{ij}^{-\sigma} \left(\frac{\psi \Phi_i^m(\psi)^{\frac{1-\alpha}{\theta}}}{d_{ij} w_i^\alpha \gamma^{1-\alpha}} \right)^{\sigma-1} \tag{A2}$$

where $B_j = \frac{(\sigma-1)^{\sigma-1}}{\sigma^\sigma} E_j P_j^{\sigma-1}$ is the market demand size and $\mu = \left(\frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \right)^{1-\sigma}$.

In this equilibrium, there exist cutoff productivity ψ_i^D,ψ_i^S and ψ_i^X for country i in the equilibrium. In country i, firm $\psi \in (\underline{\psi}, \psi_i^D)$ exits the market immediately once it knows its productivity; firm $\psi \in (\psi_i^D, \psi_i^S)$ is active in domestic market with sourcing only from the domestic market; firm $\psi \in (\psi_i^S, \psi_i^X)$ source from both domestic and foreign markets but still not export to the foreign market; firm $\psi \in (\psi_i^X, \infty)$ exports to foreign with sourcing from both domestic and foreign markets.

Using $\pi_i^1(\psi)$ denotes the total profit of firm ψ when it only sources from the domestic market, whereas $\pi_i^2(\psi)$ denotes its total profit if it sources from both domestic and foreign markets. If firm ψ only sourced from and sell in the domestic market, its total profit is

$$\pi_i^1(\psi) = \mu B_i \left(\frac{\psi {\Phi_i^1}^{\frac{1-\alpha}{\theta}}}{w_i^\alpha \gamma^{1-\alpha}} \right)^{\sigma-1} - w_i f_i^D$$

Since firm ψ_i^D is indifferent between existing the market and staying in the domestic market restrictively, so the zero profit condition is $\pi_i^1(\psi_i^D) = 0$. It implies

$$\psi_i^D = \left(\frac{w_i f_i^D}{\mu B_i} \right)^{\frac{1}{\sigma-1}} \frac{\gamma^{1-\alpha}}{{\Phi_i^1}^{\frac{1-\alpha}{\theta}}} w_i^\alpha = \left(\frac{w_i f_i^D}{\mu B_i} \right)^{\frac{1}{\sigma-1}} \frac{\gamma^{1-\alpha}}{T_i^{\frac{1-\alpha}{\theta}}} w_i \tag{A3}$$

If firms ψ sourced from both home and foreign markets but still not export, the sourcing strategy decreases marginal costs and its total profit is

$$\pi_i^2(\psi) = \mu B_i \left(\frac{\psi {\Phi_i^2}^{\frac{1-\alpha}{\theta}}}{w_i^\alpha \gamma^{1-\alpha}} \right)^{\sigma-1} - w_i f_i^D - w_i f_i^S$$

Since firm ψ_i^S is indifferent between sourcing exclusively from the domestic market and sourcing from both domestic and foreign markets when it chooses not to export, the zero profit condition is $\pi_i^2(\psi_i^S) - \pi_i^1(\psi_i^S) = 0$. It implies

$$\psi_i^S = \left[\frac{w_i f_i^S}{\mu B_i(\Phi_i^{2\,\frac{(1-\alpha)(\sigma-1)}{\theta}} - \Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}})}\right]^{\frac{1}{\sigma-1}} \gamma^{1-\alpha}(w_i)^\alpha \tag{A4}$$

Since firm ψ_i^X in country i is indifferent between exporting or not when it sources from both domestic and foreign markets, the zero profit condition about ψ_i^X is its profits from exporting market is zero. It means

$$\mu B_j \tau_{ij}^{-\sigma}\left(\frac{\psi \Phi_i^{2\,\frac{1-\alpha}{\theta}}}{d_{ij} w_i^\alpha \gamma^{1-\alpha}}\right)^{\sigma-1} - w_i f_i^X = 0$$

it implies that

$$\psi_i^X = \left(\frac{w_i f_i^X}{\mu B_j \tau_{ij}^{-\sigma}}\right)^{\frac{1}{\sigma-1}} \frac{d_{ij}(w_i)^\alpha \gamma^{1-\alpha}}{\Phi_i^{2\,\frac{1-\alpha}{\theta}}} \tag{A5}$$

Taking the ratio of equation (A2) to (A3) and (A4), respectively, I can obtain (1.14) and (1.15) in the equilibrium conditions.

Since the final goods market is free entry, the economy achieve to the equilibrium when the expected profit of firms is equal to fixed costs of entry in the final goods sector. The free entry condition in country i is

$$\int_{\psi_i^D}^{\infty} \pi_i(\psi) dG(\psi) = w_i f_i^E \tag{A6}$$

Substituting Equation (A3),(A4) and (A5) into the free entry condition above, we can obtain the equilibrium condition (1.16).

From the price distribution over $(\psi_i^X, +\infty)$, the aggregate price of goods from country i in country j,P_{ij}, satisfies $P_{ij}^{1-\sigma} = N_{ij}\int_{\psi_i^X}^{+\infty} \frac{p_{ij}(\psi)^{1-\sigma}}{1-G(\psi_i^X)} dG(\psi)$. Substituting equation (1.8) into it, I can obtain

$$P_{ij} = (\nu N_{ij})^{\frac{1}{1-\sigma}}[\frac{\widetilde{\psi}_i(\psi_i^X)}{d_{ij}\tau_{ij} w_i^\alpha \gamma^{1-\alpha}}]^{-1} \tag{A7}$$

where $N_{ij} = N_i^E(1 - G(\psi_i^X))$ and $\nu = \left[\frac{\sigma}{\sigma-1}\frac{1}{\alpha^\alpha(1-\alpha)^{1-\alpha}}\right]^{1-\sigma}$.

Similarly, the aggregate quantity of final goods exporting from country i to country j is $Q_{ji} = \left[\int_{\omega\in\Omega_{ji}} q_{ji}^{\frac{\sigma-1}{\sigma}}(\omega) d\omega\right]^{\frac{\sigma}{\sigma-1}}$. Substituting equations (1.2) and (1.8) into it, I can obtain

$$Q_{ij} = \frac{\sigma w_i f_i^X \tau_{ij}^\sigma}{\nu}\left[\frac{d_{ij} w_i^\alpha \gamma^{1-\alpha}}{[\Phi_i^{2\,\frac{1-\alpha}{\theta}} \psi_i^X]}\right]^{\sigma-1} P_{ij}^{-\sigma} \tag{A8}$$

Here equations (A7) and (A8) are corresponding equations (1.17) and (1.18) in the equilibrium conditions.

For the final good producers, the expenditure of purchasing intermediate inputs is equal to $(1-\alpha)\frac{\sigma-1}{\sigma}$ fraction of revenue. So the total trade flow of intermediate inputs from country j to i ($i \neq j$) is:

$$\begin{aligned} X_{ji}^M &= \beta_{ji}(1-\alpha)(\frac{\sigma-1}{\sigma})N_i^e \int_{\psi_i^S}^{\infty} r_i(\psi)dG(\psi) \\ &= \beta_{ji}(1-\alpha)(\sigma-1)N_i^E w_i \left[(1-G(\psi_i^S))f_i^D \frac{\widetilde{\psi}_i(\psi_i^S)^{\sigma-1}}{[\Phi_i^1{}^{\frac{1-\alpha}{\theta}}\psi_i^S]^{\sigma-1}} + (1-G(\psi_i^X))f_i^X \frac{\widetilde{\psi}_i(\psi_i^X)^{\sigma-1}}{[\Phi_i^2{}^{\frac{1-\alpha}{\theta}}\psi_i^X]^{\sigma-1}}\right] \end{aligned}$$

where $r_i(\psi)$ is the revenue obtained by firm ψ in country i.

The total purchase of intermediate inputs from the domestic market in country i is

$$\begin{aligned} X_{ii}^M &= (1-\alpha)\frac{\sigma-1}{\sigma}\sum_{j=H,F}\frac{P_{ij}Q_{ij}}{\tau_{ij}} - X_{ji}^M \\ &= (1-\alpha)(\sigma-1)N_i^E w_i \left[(1-G(\psi_i^D))f_i^D \frac{\widetilde{\psi}_i(\psi_i^D)^{\sigma-1}}{[\Phi_i^1{}^{\frac{1-\alpha}{\theta}}\psi_i^D]^{\sigma-1}} + (1-G(\psi_i^X))f_i^X \frac{\widetilde{\psi}_i(\psi_i^X)^{\sigma-1}}{[\Phi_i^2{}^{\frac{1-\alpha}{\theta}}\psi_i^X]^{\sigma-1}}\right] - X_{ji}^M \end{aligned}$$

For the final good producers, the proportion $\frac{1}{\sigma}$ of firm's revenue covers fixed costs and the proportion $\alpha\frac{\sigma-1}{\sigma}$ of revenue covers operating costs of labor inputs. For the intermediate good producers, the total revenue is equal to costs of labor input. So the labor market clear condition for the final goods sector is

$$w_i(L_i - L_i^M) = (\frac{1}{\sigma} + \alpha\frac{\sigma-1}{\sigma})\sum_{j=H,F}\frac{P_{ij}Q_{ij}}{\tau_{ij}} \qquad (A9)$$

and the labor market clear condition for the intermediate input sector is

$$w_i L_i^M = \sum_{j=H,F}\frac{X_{ij}^M}{\tau_{ij}^M} \qquad (A10)$$

where L_i^M is the amount of labor force supplied to the sector of intermediates in equilibrium. Here I obtain equations (1.19) and (1.20) in the equilibrium conditions.

In equilibrium, the trade between Home and Foreign should be balanced. It means that the value of exporting final and intermediate goods from Home to Foreign is equal to that of imported final and intermediate goods from Foreign to Home.(both the export and import value are measured at international price.) So I obtain the following equation

$$\frac{P_{HF}Q_{HF}}{\tau_{IF}} + \frac{X_{HF}^M}{\tau_{IF}^M} = \frac{P_{FH}Q_{FH}}{\tau_{IH}} + \frac{X_{FH}^M}{\tau_{IH}^M} \qquad (A11)$$

as the equation (1.21).

B Equilibrium conditions for other possible equilibrium

When the trade policy change, there exists other possible equilibrium: (1) $\psi_i^D < \psi_i^X < \psi_i^S$ $i = H, F$;(2) $\psi_H^D < \psi_H^X < \psi_H^S$,$\psi_F^D < \psi_F^S < \psi_H^X$; (3) $\psi_H^D < \psi_H^S < \psi_H^X$,$\psi_F^D < \psi_F^X < \psi_F^S$. The equilibrium conditions corresponding to these equilibrium can be solved similarly as that in the equilibrium $\psi_i^D < \psi_i^M < \psi_i^X$ $i \neq j$ $i, j = H, F$.

C Decomposition of $\Delta ln(ToT_H)$

According to equation (1.17), Home's terms-of-trade for final goods can be expressed as:

$$
\begin{aligned}
ToT_H &= \frac{P_{HF}/\tau_{IF}}{P_{FH}/\tau_{IH}} \\
&= \frac{\tau_{EH}}{\tau_{EF}}\left(\frac{w_H}{w_F}\right)^{\alpha}\left(\frac{N_H^E(1-G(\psi_H^X))}{N_F^E(1-G(\psi_F^X))}\right)^{\frac{1}{1-\sigma}}\left(\frac{\int_{\psi_H^X}^{\infty}\frac{SC(\psi)^{\sigma-1}}{1-G(\psi_H^X)}dG(\psi)}{\int_{\psi_F^X}^{\infty}\frac{SC(\psi)^{\sigma-1}}{1-G(\psi_F^X)}dG(\psi)}\right)^{\frac{1}{1-\sigma}} \\
&= \frac{\tau_{EH}}{\tau_{EF}}\left(\frac{w_H}{w_F}\right)^{\alpha}\left(\frac{N_H^D * m_{HF}}{N_F^D * m_{FH}}\right)^{\frac{1}{1-\sigma}}\left(\frac{{\psi_H^X}^k\int_{\psi_H^X}^{\infty}\Phi_H^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-k-2}d\psi}{{\psi_F^X}^k\int_{\psi_F^X}^{\infty}\Phi_F^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-k-2}d\psi}\right)^{\frac{1}{1-\sigma}} \qquad (C1)
\end{aligned}
$$

Case (I) $\quad \psi_i^X > \psi_i^S$, $i = H, F$

If $\psi_i^X > \psi_i^S$, then $\Phi_i^2 = \sum_{j=H,F} T_j(\tau_{ji}^M d_{ji}^M w_j)^{-\theta}$ for all $\psi > \psi_i^X$, and I take log-differential in both sides of equation (C1) as follows

$$
\begin{aligned}
\frac{\Delta ToT_H}{ToT_H} &= \frac{\Delta\tau_{EH}}{\tau_{EH}} + \alpha(\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}) + \frac{1}{1-\sigma}(\frac{\Delta N_H^D}{N_H^D} - \frac{\Delta N_F^D}{N_F^D} + \frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}}) \\
&\quad + \frac{\alpha-1}{\theta}(\frac{\Delta\Phi_H^2}{\Phi_H^2} - \frac{\Delta\Phi_F^2}{\Phi_F^2}) - (\frac{\Delta\psi_H^X}{\psi_H^X} - \frac{\Delta\psi_F^X}{\psi_F^X}) \quad (C2)
\end{aligned}
$$

Since $\Phi_i^2 = \sum_{j=H,F} T_j(\tau_{ji}^M d_{ji}^M w_j)^{-\theta}$, then taking log-differential in both sides, I can obtain

$$
\frac{\Delta\Phi_i^2}{\Phi_i^2} = -\theta\beta_{ii}\frac{\Delta w_i}{w_i} - \theta\beta_{ji}\left(\frac{\Delta w_j}{w_j} + \frac{\Delta\tau_{Ej}^M}{\tau_{Ej}^M} + \frac{\Delta\tau_{Ii}^M}{\tau_{Ii}^M}\right) \qquad (C3)
$$

where $\beta_{ji} = \frac{T_j(\tau_{ji}^M d_{ji}^M w_j)^{-\theta}}{\sum_{n=H,F} T_j(\tau_{ni}^M d_{ni}^M w_n)^{-\theta}}$. So

$$
\begin{aligned}
&\frac{\Delta\Phi_H^2}{\Phi_H^2} - \frac{\Delta\Phi_F^2}{\Phi_F^2} \\
&= -\theta(\beta_{HH} - \beta_{HF})\left(\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}\right) - \theta\beta_{FH}\left[\left(\frac{\Delta\tau_{EF}^M}{\tau_{EF}^M} - \frac{\Delta\tau_{EH}^M}{\tau_{EH}^M}\right) + \left(\frac{\Delta\tau_{IH}^M}{\tau_{IH}^M} - \frac{\Delta\tau_{IF}^M}{\tau_{IF}^M}\right)\right] \qquad (C4)
\end{aligned}
$$

where the second line comes from $\beta_{HH}=\beta_{FF}$ and $\beta_{HF}=\beta_{FH}$ because the initial equilibrium is symmetric. Substituting (C3) into (C1), I can obtain Equation (22) as below:

$$\begin{aligned}\frac{\Delta ToT_H}{ToT_H} &= \frac{\Delta\tau_{EH}}{\tau_{EH}} + (1-\alpha)\beta_{FH}\left(\frac{\Delta\tau_{IH}^M}{\tau_{IH}^M} - \frac{\Delta\tau_{EH}^M}{\tau_{EH}^M}\right)\\ &+ (\alpha + (1-\alpha)(\beta_{HH}-\beta_{HF}))\left(\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}\right)\\ &+ \frac{1}{1-\sigma}\left[\frac{\Delta N_H^D}{N_H^D} - \frac{\Delta N_F^D}{N_F^D} + \frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}}\right] - \left(\frac{\Delta\psi_H^X}{\psi_H^X} - \frac{\Delta\psi_F^X}{\psi_F^X}\right) \qquad (C5)\end{aligned}$$

Case (II) $\psi_i^X < \psi_i^S$, $i = H, F$

If $\psi_i^X < \psi_i^S$, then $\Phi_i^m = \sum_{j=H,F} T_j(\tau_{ji}^M d_{ji}^M w_j)^{-\theta}$ for $\psi > \psi_i^S$, and $\Phi_i^m = T_i(\tau_{ii}^M d_{ii}^M w_i)^{-\theta}$ for all $\psi_i^X < \psi < \psi_i^S$.Then

$$\begin{aligned}&\int_{\psi_i^X}^{\infty} \Phi_i^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-1}dG(\psi)\\ &= \frac{k\psi_{min}^k}{k+1-\sigma}\Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi_i^{X\,\sigma-k-1} + \frac{k\psi_{min}^k}{k+1-\sigma}\left(\Phi_i^{2\,\frac{(1-\alpha)(\sigma-1)}{\theta}} - \Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}}\right)\psi_i^{S\,\sigma-k-1}\end{aligned}$$

Taking log-differential on both sides of the equation above, I can obtain:

$$\begin{aligned}&dln\left(\int_{\psi_i^X}^{\infty} \Phi_i^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-1}dG(\psi)\right)\\ &= \lambda_{ii}\left[\frac{(1-\alpha)(\sigma-1)}{\theta}\frac{\Delta\Phi_i^1}{\Phi_i^1} + (\sigma-k-1)\frac{\Delta\psi_i^X}{\psi_i^X}\right]\\ &+ \lambda_{ji}\left[\frac{\phi}{\phi-1}\frac{(1-\alpha)(\sigma-1)}{\theta}\frac{\Delta\Phi_i^2}{\Phi_i^2} - \frac{1}{\phi-1}\frac{(1-\alpha)(\sigma-1)}{\theta}\frac{\Delta\Phi_i^1}{\Phi_i^1} + (\sigma-k-1)\frac{\Delta\psi_i^S}{\psi_i^S}\right]\\ &= \frac{(1-\alpha)(\sigma-1)}{\theta}\left(\lambda_{ii} - \frac{\lambda_{ji}}{\phi-1}\right)(-\theta)\left(\frac{\Delta w_i}{w_i}\right) + (\sigma-k-1)\left(\lambda_{ii}\frac{\Delta\psi_i^X}{\psi_i^X} + \lambda_{ji}\frac{\Delta\psi_i^S}{\psi_i^S}\right)\\ &+ \lambda_{ji}\frac{\phi}{\phi-1}\frac{(1-\alpha)(\sigma-1)}{\theta}\left(-\theta\beta_{ii}\frac{\Delta w_i}{w_i} - \theta\beta_{ji}\left(\frac{\Delta w_j}{w_j} + \frac{\Delta\tau_{Ej}^M}{\tau_{Ej}^M} + \frac{\Delta\tau_{Ii}^M}{\tau_{Ii}^M}\right)\right)\\ &= (1-\alpha)(1-\sigma)\left(\lambda_{ii} - \frac{\lambda_{ji}}{\phi-1} + \lambda_{ji}\beta_{ii}\frac{\phi}{\phi-1}\right)\frac{\Delta w_i}{w_i} + (\sigma-k-1)\left(\lambda_{ii}\frac{\Delta\psi_i^X}{\psi_i^X} + \lambda_{ji}\frac{\Delta\psi_i^S}{\psi_i^S}\right)\\ &+ \lambda_{ji}\beta_{ji}\frac{\phi}{\phi-1}(1-\alpha)(1-\sigma)\left(\frac{\Delta w_j}{w_j} + \frac{\Delta\tau_{Ej}^M}{\tau_{Ej}^M} + \frac{\Delta\tau_{Ii}^M}{\tau_{Ii}^M}\right)\end{aligned}$$

where $\phi = \left(\frac{\Phi_i^2}{\Phi_i^1}\right)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}$ represents the relative advantage of sourcing from domestic and foreign markets; $\lambda_{ii} = \frac{\int_{\psi_i^X}^{\infty}\Phi_i^{1\,\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-1}dG(\psi)}{\int_{\psi_i^X}^{\infty}\Phi_i^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-1}dG(\psi)}$ denotes the contribution of weighted productivity by domestic intermediate suppliers to exporters' total weighted productivity; $\lambda_{ji} = 1-\lambda_{ii} = \frac{\int_{\psi_i^S}^{\infty}(\Phi_i^2{}^{\frac{(1-\alpha)(\sigma-1)}{\theta}} - \Phi_i^1{}^{\frac{(1-\alpha)(\sigma-1)}{\theta}})\psi^{\sigma-1}dG(\psi)}{\int_{\psi_i^X}^{\infty}\Phi_i^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-1}dG(\psi)}$ denotes the fraction of weighted productivity by foreign intermediate suppliers to total weighted productivity.

then

$$
\begin{aligned}
& dln(\int_{\psi_H^X}^{\infty}\Phi_H^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-1}dG(\psi)) - dln(\int_{\psi_F^X}^{\infty}\Phi_F^m(\psi)^{\frac{(1-\alpha)(\sigma-1)}{\theta}}\psi^{\sigma-1}dG(\psi)) \\
& = (1-\alpha)(1-\sigma)(\lambda_{HH} - \frac{\lambda_{FH}}{\phi-1} + \lambda_{FH}\beta_{HH}\frac{\phi}{\phi-1})(\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}) \\
& + (\sigma-k-1)\left[\lambda_{HH}\left(\frac{\Delta\psi_H^X}{\psi_H^X} - \frac{\Delta\psi_F^X}{\psi_F^X}\right) + \lambda_{FH}\left(\frac{\Delta\psi_H^S}{\psi_H^S} - \frac{\Delta\psi_F^S}{\psi_F^S}\right)\right] \\
& + \lambda_{FH}\beta_{FH}\frac{\phi}{\phi-1}(1-\alpha)(1-\sigma)\left[\left(\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}\right) + \frac{\Delta\tau_{IH}^M}{\tau_{IH}^M} - \frac{\Delta\tau_{EF}^M}{\tau_{EF}^M}\right] \\
& = (1-\alpha)(1-\sigma)(\lambda_{HH} - \lambda_{FH})(\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}) \\
& + (\sigma-k-1)\left[\lambda_{HH}\left(\frac{\Delta\psi_H^X}{\psi_H^X} - \frac{\Delta\psi_F^X}{\psi_F^X}\right) + \lambda_{FH}\left(\frac{\Delta\psi_H^S}{\psi_H^S} - \frac{\Delta\psi_F^S}{\psi_F^S}\right)\right] \\
& + \lambda_{FH}\beta_{FH}\frac{\phi}{\phi-1}(1-\alpha)(1-\sigma)\left[\frac{\Delta\tau_{IH}^M}{\tau_{IH}^M} - \frac{\Delta\tau_{EF}^M}{\tau_{EF}^M}\right]
\end{aligned}
$$

As a result, taking the log differential of Home's terms-of-trade for final goods when $\psi_i^S >$, I can obtain:

$$
\begin{aligned}
\frac{\Delta ToT_H}{ToT_H} = & \frac{\Delta\tau_{EH}}{\tau_{EH}} + (1-\alpha)\lambda_{FH}\beta_{FH}\frac{\phi}{\phi-1}\left(\frac{\Delta\tau_{IH}^M}{\tau_{IH}^M} - \frac{\Delta\tau_{EH}^M}{\tau_{EH}^M}\right) \\
& + (\alpha + (1-\alpha)(\lambda_{HH} - \lambda_{HF}))\left(\frac{\Delta w_H}{w_H} - \frac{\Delta w_F}{w_F}\right) + \frac{1}{1-\sigma}\left[\frac{\Delta N_H^D}{N_H^D} - \frac{\Delta N_F^D}{N_F^D} + \frac{\Delta m_{HF}}{m_{HF}} - \frac{\Delta m_{FH}}{m_{FH}}\right] \\
& + \frac{(\sigma-k-1)\lambda_{HH}+k}{1-\sigma}\left(\frac{\Delta\psi_H^X}{\psi_H^X} - \frac{\Delta\psi_F^X}{\psi_F^X}\right) + \frac{(\sigma-k-1)\lambda_{FH}}{1-\sigma}\left(\frac{\Delta\psi_H^S}{\psi_H^S} - \frac{\Delta\psi_F^S}{\psi_F^S}\right) \quad (C6)
\end{aligned}
$$

D Terms-of-trade for intermediate goods

According to the general definition of terms-of-trade, Home's terms-of-trade for intermediates goods ToT_H^M is the ratio of Home's intermediate export price to Home's intermediate import price. So

$$ToT_H^M = \frac{P_{HF}^M/\tau_{IF}^M}{P_{FH}^M/\tau_{IH}^M} \qquad (B1)$$

where $P_{ij}^M = (\int_0^1 p_{ij}^{1-\epsilon}(v)dv)^{1/(1-\epsilon)} = (\int_0^{\infty} p^{1-\epsilon}dG(P_{ij}))^{1/(1-\epsilon)}$ is the aggregate price index of intermediates produced in country i and sold in country j, and $p_{ij}(v)$ is the price of intermediate v among them.

since

$$G(P_{ij}) = \int_0^{\infty} (T_i(w_i\tau_{ij}^M)^{-\theta}\theta p^{\theta-1})e^{-T_i(w_i d_{ij}^M)^{-\theta}p^{\theta}}dp \qquad (B2)$$

then

$$P_{ij}^M = \gamma(\Phi_{ij})^{-\frac{1}{\theta}} \qquad (B3)$$

where $\Phi_{ij} = T_i(w_i\tau_{ij}^M d_{ij}^M)^{-\theta}$

$$TOT_H^M = \left(\frac{T_F}{T_H}\right)^{\frac{1}{\theta}} \frac{w_H}{w_F}\frac{\tau_{EH}^M}{\tau_{EF}^M} \qquad (B4)$$

Chapter 2

Skill-upgrading offshoring and skill premium

In this chapter, I examines the impact of skill-upgrading processing export expansion on regional skill premium across China before and after China's accession to the World Trade Organization(WTO). I firstly develop a two-country, two-factor(high- and low-skill workers) Heckscher-Ohlin model of offshoring and skill premium. Then I prove that reducing offshoring costs raises the skill premium in the developing country. Next, in the empirical part, I construct regional measures of high- and low-skill processing export demand shocks by employing the variation in skill intensities across cities and industries. Finally, using Chinese Urban Household Survey data from 2000 to 2006, I identify empirically that high-skill processing export shocks raise the regional skill premium, whereas low-skill processing export shocks depress it.

2.1 Introduction

The importance of offshoring has increased significantly in international trade during the past decades. Because of its popularity, around two-thirds of world trade volume is in the form of trade in intermediate goods (Johnson and Noguera, 2012). Meanwhile, skill premium, the wage gap between skilled and unskilled workers, has often risen across developing countries integrated into the world market (Goldberg and Pavcnik 2004, 2007). So what have been the effects of offshoring on skill premium? The seminal work of Feenstra and Hanson (1996) showed that as the developed country outsources more relatively skill-intensive production stages to the developing country, the skill premium in the developing country rises. The subsequent research, including Feenstra and Hanson (1997, 1999), Hsieh and Woo (2005), and Zhu and Trefler (2005), obtained consistent empirical results across countries. Although China served as the world's factory and had rapid growth in processing trade since the 1990s, very few researchers pay attention to how offshoring affects skill wage premium in China.[1]

The wage premium for skilled workers in China has risen dramatically since the 1980s, and there are differences in regional trends of skill premium. Note that the changes in skill premium between trade high-exposure and low-exposure regions are significantly different.[2] The classification of high-exposure and low-exposure regions is based on cities' distance to the coast because regional openness in China is significantly related to a region's geographical distance to the coast(Han et al., 2012). Figure 2.1 (a) illustrates the rising tendency of skill premium in high-exposure and low-exposure regions between 1992 and 2006. The change in skill premium is much more significant in high-exposure regions than in low-exposure regions. For example, before and after China's accession to the World Trade Organization (WTO) in 2001, the average skill premium in high-exposure regions during 2000-2006 achieved 0.47, whereas that in low-exposure regions was 0.36.

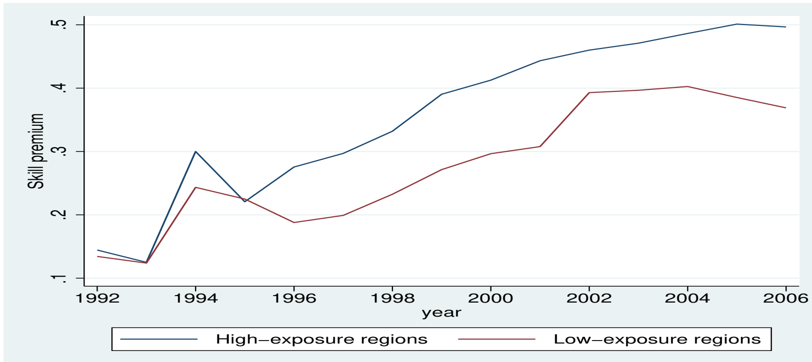
As China integrated into the world market further by joining in processing trade since the 1980s, developed countries have outsourced different production activities to China during the past decades. In processing trade, domestic firms import raw materials and intermediate inputs from foreign countries and export the value-added final products after local processing. To promote the growth of processing trade, China implemented a series of incentive policies, including duty-free import inputs, the absence of import and export quotas, and low land rents for processing exporters. As a result, as Figure 2.1 (b) shows, China's processing exports increased dramatically since the 1990s and accounted for 56% of the total exports between 2000 and 2006.

After China acceded to the WTO in 2001, its processing exports experienced significant skill-upgrading expansion. On the one hand, as the offshoring costs decreased further, developed countries outsourced more relatively skill-intensive production tasks to China. On the other hand, China carried out a skill-upgrading industrial policy to increase the fraction of high-skill intensive

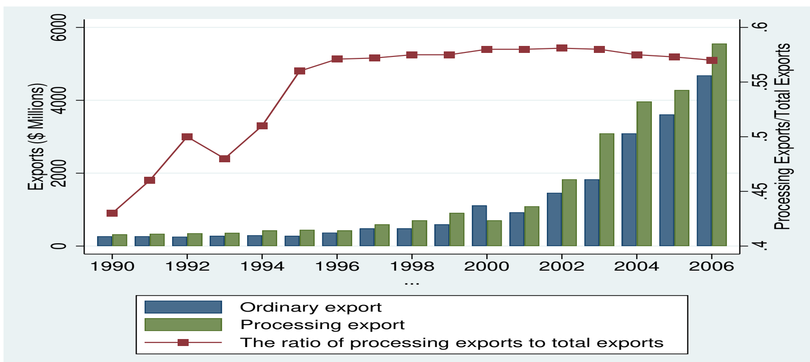
[1]To the best of my knowledge, Han et al. (2012), Li (2018), and Sheng and Yang (2019) are the only papers exploring the wage effects of export expansion across regions within China. Using the geographic distance to the coast to measure export exposure, Han et al. (2012) identify that China's accession to the WTO leads to the rising wage inequality and skill premium in high-exposure regions. Li (2018) studies the effects of China's export expansion because of the reducing tariffs faced by exporters on regional human capital accumulation. She finds that high-skill export shocks raise both high school and college enrollments, while low-skill export shocks depress both. Correspondingly, the high- and low-skill demand shocks affect the regional skill premium. Sheng and Yang (2019) add the incomplete contract theory into the classical offshoring and wage premium model by Feenstra and Hanson (1996). They find that FDI offshoring is more skill-intensive than arm's length offshoring and has relatively more substantial effects on skill premium.

[2]I obtain the skill wage premium information from the Chinese Urban Household Survey(CUHS). In the dataset, I classify Liaoning, Shandong, Beijing, Shanghai, Jiangsu, Zhejiang, and Guangdong as high-exposure regions, and Heilongjiang, Shanxi, Henan, Anhui, Hubei, Jiangxi, Shaanxi, Chongqing, Sichuan, Yunnan, and Gansu as low-exposure regions.

[3]Notes: (a) High-skill workers are defined as workers with college degree or above. Using the Chinese Urban Household Survey 1992-2006, I obtained the skill premium according to the Mincer regression after controlling individual characteristics. (b) The trade data from China Customs



(a) Skill premium in high-exposure and low-exposure regions



(b) China's ordinary export and Processing export (1990-2006)

Figure 2.1: Skill premium, ordinary export and processing export in China [3]

industries in China's processing trade. For example, in the revisions of Catalogs of Industries for Guiding Foreign Investment (CGFII) in 2002 and 2004, the fraction of high-skill intensive industries in the catalog of encouraged industries for foreign investment increased vastly.[4] As a result, the processing exports of high-skill intensive industries during 2000-2005 accounted for 41.4% of total processing exports, 4.5 times larger than that during 1995-2000, and achieved 543.8 million dollars.[5] This skill-upgrading processing export expansion resulted in the rising skill demand and corresponding regional skill premium after 2000.

In this chapter, I develop a two-country, two-factor Heckscher-Ohlin model of offshoring and skill premium in developing countries. By introducing ordinary exports into the offshoring framework by Feenstra and Hanson (1996), the model emphasizes the role of comparative advantage in shaping the pattern of

[4]CGFII is officially published by the China Ministry of Commerce and contains the catalogues of encouraged and restricted industries for foreign investment. The government departments and financial institutions will possibly provide encouraged industries with fiscal, tax, land, and credit support.

[5]The data is obtained from the statement by Ministry of Commerce of China in 2006.

global sourcing. Besides, it illustrates the Feenstra-Hanson channel through which the relatively more skill-intensive production stages are outsourced to the developing country. The propositions imply that the reduction in offshoring costs contributes to the developing country's increasing supply of intermediate inputs. The transfer of production activities will raise the developing country's skill demand and corresponding skill premium if its ordinary exporting goods are low-skill intensive.

In the empirical part, I use a two-stage identification strategy to test the empirical prediction of my model. In the first stage, I explore the determinants of China's processing exports, especially import tariffs introduced by trading partners, offshoring costs, and foreign investments. In the second stage, to identify the effects of processing exports on skill premium, I construct the corresponding high- and low-skill demand shocks at the city level. In the construction of demand shocks, the changes in processing exports are attributed to high-skill (low-skill) workers according to corresponding sectoral factor intensities and divided by the regional endowment of high-skill (low-skill) workers. Therefore, the high-skill (low-skill) processing export shock can be regarded as processing export exposure in dollars per high-skill (low-skill) worker. To address the potential endogeneity concerns in estimating the effects of offshoring on skill premium, I use the predicted value of processing exports in the first stage to construct the instrumental variables for the second stage.

My empirical work uses the comprehensive dataset, Chinese Urban Household Survey (CUHS) data, between 2000 and 2006 to obtain the city-level skill premium in China. Besides, I exploit the micro-level data, the China 2000 Population Census and the China 2004 Economic Census, for the employment share of high- and low-skill workers at the industry-city-specific level in 2000 and 2004. Finally, combining the employment skill distribution with data on processing exports, I construct the corresponding high- and low-skill demand shocks for 2000-2004 and 2004-2006. In this chapter, I focus on the processing exports from China to developed countries by non-trading companies. To explore the determinants of China's processing exports in the first stage, I use the number of economic policy zones and the density of highways to approximate offshoring costs. Besides, I construct the encouragement and restriction policy indicator for foreign investment in China according to the CGFII.

The regression results show that the reduction in import tariffs and offshoring costs, and the increase in foreign investment contribute significantly to the skill-upgrading expansion of China's processing exports between 2000 and 2006. Compared with high skill-intensive industries, the low-skill intensive industries are more sensitive to the change in import tariffs by trading partners but benefit less from the economic policy zones, infrastructure investment, and foreign investment. For the impact of offshoring on skill premium, the processing export high-skill (low-skill) demand shock has a statistically significant and positive (negative) effect on skill premium in China. Quantitatively, an interquartile range increase in high-skill processing export shock raises skill premium by 1.66 percentage points. Conversely, an interquartile range increase in low-skill processing export shock reduces skill premium by 1.47 percentage points. These interquartile differences account for 6.74% and 5.88% of the interquartile change of regional skill premium, respectively. It implies that skill premium is affected by the export exposure of high-skill workers relative to that of low-skill workers instead of the overall processing export shock.[6]

To substantiate the robustness of the empirical results, I consider alternative measures of demand shocks, skill premium, and processing exports. Firstly, by either dropping one/two provinces or excluding specific regions, I examine the robustness of results given different geographical samples. Secondly, I test the baseline results with alternative measures of skill premium and processing exports, including skill premium estimated without containing individual characteristics, processing exports to the whole world, and processing exports containing the trading companies, respectively. The estimation results remain stable under these robustness tests. Finally, I combine processing and ordinary exports and construct the skill demand shock embodied in total exports. The estimated effects of total export skill demand shocks are also statistically significant.

I structure the chapter as follows. Section 2.2 describes the literature relevant to my research. Section 2.3 illustrates the theoretical model and corresponding propositions. Section 2.4 and 2.5 introduce the identification strategy and the data, respectively. Section 2.6 reports the empirical results. Section 2.7 presents the results of robustness tests. Section 2.8 concludes.

2.2 Literature

Firstly, my work is related to the literature on the wage effects of offshoring. The seminal work of Feenstra and Hanson (1996, 1997) showed that sourcing intermediate inputs from foreign suppliers instead of domestic ones would cause displacement and lower wages. Besides, the offshoring activity raises skill premium in both developed and developing countries. However, the work of Grossman and Rossi-Hansberg (2007, 2008), Amiti and Konings (2007), and Goldberg et al. (2010) find that taking advantage of foreign inputs may lower firms' production costs and raise their productivity, which would expand their output and increase employment and wage. In addition, the literature also explores the impact of offshoring on skill premium. Following Feenstra and Hanson (1996, 1997), Feenstra and Hanson (1999) and Hsieh and Woo (2005) empirically prove that offshoring increases skill premium in both developed and developing countries. Specifically, Carluccio et al. (2019) extend the homogeneous offshoring model of Feenstra and Hanson (1996) to the heterogeneous-firm

[6] Following Feenstra and Hanson (1996), I also use the ratio of processing exports to industrial output to approximate the role of processing exports in determining skill premium. Then I take the regression of changes in regional skill premium on changes in the processing exports to industrial output ratio. Although the estimated coefficient is positive and significant, the interquartile variation of the processing exports to output ratio could only account for 0.81 percent of that of skill premium. The reason is that the fraction of processing exports to industrial output rarely changed, making their quantitative contributions to the rising college premium insignificant.

case, including fixed offshoring costs. Then they use the French manufacturing firm-level data to identify that reductions in offshoring costs to labor-abundant countries have substantially raised firm-level skill intensities of French manufacturers. The model in my paper is consistent with Feenstra and Hanson (1996). Besides, my empirical results also prove that the skill demand in China increases as developed countries outsource more relative skill-intensive production tasks to China.

Secondly, my work is also related to the literature on the differential local labor market effects of trade within a specific country by using the initial regional differences in industry composition. Some of these studies concentrate on import shocks, including Edmonds et al.(2010), Topalova (2010), Hakobyan and McLaren (2010), Autor et al.(2013), Dix-Carneiro and Kovak (2015), and Greenland and Lopresti (2016). In contrast, other studies pay attention to exploring the effects of export demand shocks. The relevant works include McCaig (2011), Cheng and Potlogea (2015), Costa et al. (2016), Bombardini and Li (2016), and Li (2018). Specifically, in the context of China, Bombardini, and Li (2016) study the effects of export expansion and the embodied pollution on the environment and health outcomes across cities in China. Li (2018) constructs the skill demand embodied in China's export shocks and empirically connects them to schooling decisions in China. The construction method of skill demand shock in my paper shares similarities with Li (2018).

Thirdly, my work also contributes to the literature about wage premium in China. The researchers regard China's trade expansion as an important role in explaining the rising wage inequality in China since the 1980s. Han et al. (2012) use two China trade liberalization shocks, Deng Xiaoping's Southern Tour in 1992 and China's accession to WTO in 2001, to identify the impact of globalization on wage premium in China. They prove that regions with more exposure to globalization have more considerable changes in wage premium than less-exposed regions. Chen et al. (2017), Li et al. (2020), and Sheng and Yang (2019) attribute the rise in skill demand and skill premium in China to the intermediate input imports, capital imports, and ownership liberalization, respectively. In this chapter, I will explore the effects of offshoring on skill premium in the context of processing export.

Besides the effects of trade expansion on wage premium, other literature also considers the role of the institution and individual characteristics in determining China's wage premium. For example, Zhang et al. (2005) identify that the rise in the skill premium after 1992 was affected strongly by institutional reforms, which raised the demand for high-skill workers. Xia et al.(2013) found that the average wage of the state sector compared with the non-state sector increased significantly during 1988-2007, which enlarged the wage premium in China's urban area. Appleton et al. (2007) and Wang et al. (2019) identify the positive effects of Communist Party Membership on wage premium because the membership is treated as political capital, which brings monetary reward. So I would also consider these institutional and individual factors in estimating skill premium with the Mincer equation.

Finally, my work also fits into the literature on China's processing export.

According to Xu and Lu (2009), Jarreau and Poncet (2011), and Dai et al. (2016), processing trade mainly contributes to the upgrading of China's export. The increasing popularity of processing trade in China since the 1980s can be attributed to different reasons. Manova and Yu (2016) find that firms in China choose to conduct more processing trade and pure assembly because of credit constraints. The financial friction precludes them from high value-added activities. Besides, Feenstra et al. (2013) find that processing export relies significantly on the contract environment, and the institution matters more for processing trade than ordinary trade. Sheng and Yang (2019) identify the positive effects of encouragement policy and the negative effects of restriction policy on processing export. They attribute the rapid growth of processing trade in China to the encouragement policy (especially the economic policy zones) and the infrastructure investment. So I would take these institution and policy factors into account in estimating the processing exports.

2.3 Model and equilibrium

2.3.1 Model setup

There are two countries in the open economy, the North (N) and the South (S), endowed with low-skill workers L_i and high-skill workers H_i in country i, $i = N, S$. Workers are supplied inelastically and are immobile across the border. Assume the North is relatively more skill abundant than the South, so $\frac{H_N}{L_N} > \frac{H_S}{L_S}$. Countries are identical in preferences, technologies, and parameter values.

Each country has a representative consumer with utility function $U_j = C_{Nj}^{\alpha} C_{Sj}^{1-\alpha}$, $\alpha \in (0, 1)$. C_{ij} represents country j's consumption of the final good produced in country i. Assume there exist no trade costs for final goods across the border. Thus, the available prices of final goods in these two countries are indifferent.[7]

The final good produced in the South, subject to perfect competition and free trade, follows the blueprint: $Y_S = H_{SS}^{\beta} L_{SS}^{1-\beta}$, $\beta \in (0, 1)$, where H_{SS} and L_{SS}, respectively, denote the amount of high- and low-skill workers allocated to produce final goods in the South. Assume $\beta \ll 1/2$ and the final good producers in the South can't transfer their production activities to the North.

The final good industry in the North is also perfectly competitive, and there exists a group of final good producers with the same production technology. The final good produced in the North is assembled from a series of sequential stages $z \in [0, 1]$ as:

$$Y_N = exp\left[\int_0^1 I(z)\eta(z)ln(Y_N(z))dz\right] \quad \text{with} \quad \int_0^1 \eta(z)dz = 1 \tag{2.1}$$

[7] The assumption regards the whole world as an integrated market with price difference for final goods across countries. In this way, it can make use of the characteristics of Cobb-Douglas utility function and simplify the mathematics proof for the following propositions without losing the generality.

where $Y_N(z)$ denotes the quantity of intermediate inputs that the supplier of stage z delivers to the final good producer. Here a larger z corresponds to a stage further upstream. $I(z)$ is an indicator function such that $I(z) = 1$ if stage z is completed after all $z' > z$ upstream inputs have been assembled, otherwise $I(z) = 0$.[8] Since skill intensities across stages increase with z along the value chain, z also denotes the skill intensity of the corresponding production stage.

The intermediate input z for use in the North can be produced in country j according to

$$y_{jN}(z) = \frac{1}{z^z(1-z)^{1-z}} h_{jN}(z)^z l_{jN}(z)^{1-z} \tag{2.2}$$

where $h_{jN}(z)$ and $l_{jN}(z)$, respectively, represent the high- and low-skill workers devoted to its production. The intermediate input is fully customized to the final good producer, which means the supplier's outside option is 0.[9] Assume trade in intermediate goods is subject to the ice-berg trade cost τ_{jN}, which describes the final good producer's sourcing pattern. If $j = N$, then $\tau_{jN} = 1$ and the intermediate input z is produced domestically in the North; if $j \neq N$, then $\tau_{jN} = \tau > 1$ and the intermediate input is offshored to foreign suppliers.

The final good producer in the North is assumed to have full control over input services at all stages.[10] In this case, the firm makes a contract offer $[Y_N(z), s(z)]$ for every intermediate input $z \in [0,1]$, under which a supplier is obliged to supply $Y_N(z)$ units of intermediate inputs as stipulated in the contract in exchange for the payment $s(z)$. So the profit maximization problem for the final good producer in the North is

$$\begin{aligned} \max_{[s(z),Y_N(z)],z\in(0,1)} \quad & P_N * exp\left[\int_0^1 I(z)\eta(z)ln(Y_N(z))dz\right] - \int_0^1 s(z)dz \\ st \quad & s(z) - c_{jN}(z)Y_N(z) \geq 0 \qquad \forall z \in (0,1) \end{aligned} \tag{2.3}$$

where P_N is the retailing price of the final good produced in the North; $c_{jN}(z)$ is the available price of intermediate input z produced in country j.

2.3.2 Equilibrium

Given domestic factor prices, to minimize production costs, the optimal factor demands for producing a specific intermediate input z in country j should

[8] The final good production secured up to stage z could be denoted by $exp\left[\int_z^1 \eta(z)ln(Y_N(z))dz\right]$.

[9] The fully compatible assumption for intermediate inputs implies that the values of intermediate inputs for other buyers are zero, so the outside option for an input supplier is zero.

[10] It is equal to the assumption that the contract between the final good producer and intermediate input suppliers is complete. In contrast to the complete contract, Antras and Chor (2013) explore the sequential production model with the incomplete contract assumption. Under the incomplete contract, the final good producer negotiates with the supplier over the supplier's incremental contribution to total revenue at the current stage.

satisfy:

$$\frac{h_{jN}(z)}{l_{jN}(z)} = \frac{z}{1-z}\frac{w_j^L}{w_j^H} \tag{2.4}$$

where w_j^H and w_j^L are, respectively, the wages of high- and low-skill workers in country j. So the optimal relative skill demand increases with the skill intensity of the current stage, but decreases with the local skill premium. Then, combining the production function of inputs with the first-order condition, I can solve out the optimal factor demand for producing one unit of intermediate input z as:

$$h^*_{jN}(z) = \left(\frac{w_j^H}{w_j^L}\right)^{z-1} z \quad \text{and} \quad l^*_{jN}(z) = \left(\frac{w_j^H}{w_j^L}\right)^{z} (1-z) \tag{2.5}$$

Since the intermediate input market is subject to perfect competition, the available price of input z produced in country j is:

$$c_{jN}(w_j^L, w_j^H, z) = \tau_{jN}\left[w_j^H h^*_{jN}(z) + w_j^L l^*_{jN}(z)\right] = \tau_{jN} w_j^{L\,1-z} w_j^{H\,z} \tag{2.6}$$

Given w_j^H and w_j^L, $c_{jN}(w_j^L, w_j^H, z)$ is a continuous and monotonic function of z. So the final good producer's offshoring decision responds to the comparative advantage: the most low-skill intensive stages are offshored to the South. There exists the intermediate input z^* which is indifferent between being outsourced to the North and the South. Thus, it means that

$$c_{NN}(w_N^L, w_N^H, z^*) = c_{SN}(w_S^L, w_S^H, z^*, \tau) \tag{2.7}$$

To characterize the offshoring patterns of the final good producers in the North, I make the following assumption:

Assumption 1 $\quad \frac{w_N^H}{w_S^H} < \tau < \frac{w_N^L}{w_S^L}$

The assumption actually excludes the extreme cases in which all the intermediate inputs are produced in the same location. The inequality $\tau > \frac{w_N^H}{w_S^H}$ identifies that the most high-skill intensive intermediate $z = 1$ is produced in the North, whereas the inequality $\tau < \frac{w_N^L}{w_S^L}$ guarantees that the most low-skill intensive intermediate input $z = 0$ is outsourced to the South. Since the skill intensity increases with z across stages, the final good producer in the North outsources inputs $z \in [0, z^*)$ to the South and purchases input $z \in (z^*, 1]$ from the domestic market, respectively. Given the optimal offshoring strategy, the available price of the final good assembled in the North is:

$$P_N = A * exp\left(\int_0^{z_i^*} \eta(z) ln\left(c_{SN}(z)\right) dz + \int_{z_i^*}^{1} \eta(z) ln\left(c_{NN}(z)\right) dz\right) \tag{2.8}$$

where $A = exp(-\int_0^1 \eta(z) ln(\eta(z)) dz)$. In the complete contract, the final good producer intends to follow the natural sequencing of production, which means

$I(z) = 1$ for all $z \in [0, 1]$. Besides, the incentive condition in the optimization problem (2.3) should be binding to maximize profits, so $s(z) = c_{jN}(z)Y_{jN}(z)$ for any $z \in [0, 1]$. Given the optimal outsourcing strategy, the profit maximization problem becomes

$$\max_{[Y_{jN}(z), z\in[0,1]]} \quad exp\left[\int_0^1 \eta(z)ln(Y_{jN}(z))dz\right] P_N - \sum_{j=N,S}\int_{z\in\Lambda_j} c_{jN}(z)Y_{jN}(z)dz \tag{2.9}$$

where Λ_j, $j = N, S$, denotes the set of intermediate inputs produced in country j: $\Lambda_S = [0, z^*)$ and $\Lambda_N = (z^*, 1]$. Taking the first-order condition respect to $Y_{jN}(z)$, the optimal demand of intermediate input z can be solved out as:

$$Y_{jN}(z) = \frac{\eta(z)Y_N P_N}{c_{jN}(z)} \qquad j = N, S \tag{2.10}$$

According to the characteristic of Cobb-Douglas utility function, $Y_N P_N = \alpha E$, where $E = \sum_{j=N,S}(w_j^L L_j + w_j^H H_j)$ denotes the total expenditure of consumers in these two countries. Similarly, the market demand for the final good produced in the South is $Y_S = \frac{(1-\alpha)E}{P_S}$, where $P_S = w_S^{L\,1-\beta} w_S^{H\,\beta}$, following equation (2.6), denotes its market price. Being analogous to equation (2.5), the corresponding high- and low-skill workers, respectively, devoted to produce final goods in the South are:

$$H_{SS} = \beta Y_S \left(\frac{w_S^H}{w_S^L}\right)^{\beta-1} \quad \text{and} \quad L_{SS} = (1-\beta)Y_S\left(\frac{w_S^H}{w_S^L}\right)^{\beta} \tag{2.11}$$

According to final good producers' production strategies, the labor market clearing conditions for high- and low-skill workers in the South are:

$$\int_0^{z^*} \frac{\eta(z)Y_N P_N}{c_{SN}(z)}\left(\frac{w_S^H}{w_S^L}\right)^z (1-z)dz + (1-\beta)Y_S\left(\frac{w_S^H}{w_S^L}\right)^{\beta} = L_S \tag{2.12}$$

and

$$\int_0^{z^*} \frac{\eta(z)Y_N P_N}{c_{SN}(z)}\left(\frac{w_S^H}{w_S^L}\right)^{z-1} zdz + \beta Y_S\left(\frac{w_S^H}{w_S^L}\right)^{\beta-1} = H_S \tag{2.13}$$

Correspondingly, suppliers in the North concentrate on producing the high-skill intensive intermediate inputs, so the labor market clearing conditions for the North are:

$$\int_{z^*}^1 \frac{\eta(z)Y_N P_N}{c_{NN}(z)}\left(\frac{w_N^H}{w_N^L}\right)^z (1-z)dz = L_N \tag{2.14}$$

and

$$\int_{z^*}^1 \frac{\eta(z)Y_N P_N}{c_{NN}(z)}\left(\frac{w_N^H}{w_N^L}\right)^{z-1} zdz = H_N \tag{2.15}$$

In summary, the competitive equilibrium of the model can be defined by the six endogenous variables E, w_j^L,w_j^H, and z^*, $j = N, S$, which satisfy equations (2.7), (2.12), (2.13), (2.14), (2.15), and the budget constraint condition for the world.[11] According to Walras' law, I would normalize the world expenditure at unity, $E = 1$, to drop one equilibrium condition. In this way, the factor prices are measured as shares of world factor income in the industries.

2.3.3 Effects of the reduction in offshoring costs

According to the comparative advantage, the low-skill intensive intermediate inputs are offshored from the North to the South in the equilibrium. Now suppose that the trade cost of intermediate inputs decreases. What will be its effect on the skill premium in both countries?

Based on equation (2.7), I can obtain the cutoff stage z^* as a function of the offshoring cost and factor prices in both countries:

$$z^* = \frac{ln\left(\frac{w_N^L}{w_S^L}\right) - ln(\tau)}{ln\left(\frac{w_S^H}{w_S^L}\right) - ln\left(\frac{w_N^H}{w_N^L}\right)} \tag{2.16}$$

Since $\frac{H_N}{L_N} > \frac{H_S}{L_S}$, the skill premium in both countries satisfy $\frac{w_N^H}{w_N^L} < \frac{w_S^H}{w_S^L}$ in the equilibrium. Given the factor prices, z^* increases with a decreasing offshoring cost. It means that the reduction in offshoring costs makes firms in the North shift more skill-intensive production activities to the South. This conclusion still holds even if the factor prices change endogenously in the equilibrium.

Proposition 1 The cutoff offshoring stage z^* decreases with the trade cost of intermediate inputs. The change in z^* due to the change in the trade cost of intermediate inputs satisfies:

$$\frac{dz^*}{d\tau} = (\tau * B)^{-1}\left(\frac{\alpha \int_0^{z^*} \eta(z)dz}{\tau E_S} - 1\right) < 0 \quad \text{with} \quad B > 0 \tag{2.17}$$

The proofs are shown in Appendix A. Proposition 1 implies that the extensive margin in which the reduction in offshoring costs makes more intermediate inputs with higher z be outsourced to the South. The transfer of production activities results in changes in relative skill demand in these two countries. For a specific intermediate input z, according to equation (2.4), the relative demand for high-skill workers increases with the skill intensity z, but decreases with the local skill premium. Then I define the aggregate relative skill demand for producing intermediate inputs in country j as:

$$D_j = \frac{H_{jN}}{L_{jN}} = \frac{\int_{\Lambda_j} \frac{\eta(z)Y_N P_N}{c_{jN}(z)} h_{jN}(z)dz}{\int_{\Lambda_j} \frac{\eta(z)Y_N P_N}{c_{jN}(z)} l_{jN}(z)dz} = \frac{\int_{\Lambda_j} \frac{\eta(z)}{c_{jN}(z)} h_{jN}(z)dz}{\int_{\Lambda_j} \frac{\eta(z)}{c_{jN}(z)} l_{jN}(z)dz} \tag{2.18}$$

[11] The budget constraint for the world is binding in the equilibrium, which means that the world expenditure E is equal to the sum of factor payments in both countries, $E = \sum_{j=N,S}(w_j^L L_j + w_j^H H_j)$.

To illustrate the effects of the change in z^* on relative skill demand and skill premium in the North and South, I make the following assumption:

Assumption 2 $\quad \beta < z^* + \frac{\alpha \int_0^{z^*} \eta(z)(z^*-z)}{(1-\alpha)\tau}$

If $\beta \leq z^*$, it implies that the skill intensity of the final goods produced in the South is not higher than that of intermediate inputs offshored to the South; If $z^* < \beta < z^* + \frac{\alpha \int_0^{z^*} \eta(z)(z^*-z)dz}{(1-\alpha)\tau}$, it implies that although the final good produced by the South is relative more high-skill intensive than inputs produced in the South, its fraction in total consumption expenditure, $1-\alpha$, is smaller than $\frac{\int_0^{z^*} \eta(z)(z^*-z)dz}{\int_0^{z^*} \eta(z)(z^*-z)dz+(\beta-z^*)\tau}$. Based on Assumption 2, I can derive the following proposition:

Proposition 2 (a) A rising in the offshoring cutoff stage between North-South production increases the aggregate relative skill demand for producing intermediate inputs in both countries:

$$\frac{\partial ln(D_j)}{\partial z^*} > 0 \quad j = N, S \tag{2.19}$$

(b) The skill premium in the North and South increase with the offshoring cutoff stage z^* between the North and South. Furthermore,

$$\frac{\partial \frac{w_S^H}{w_S^L}}{\partial z^*} = \frac{L_S}{H_S} \frac{\tau(1-\alpha)(z^*-\beta) + \alpha(\int_0^{z^*}(z^*-z)\eta(z)dz)}{\left(\alpha \int_0^{z^*} \eta(z)(1-z)dz + (1-\beta)(1-\alpha)\tau\right)^2} > 0 \tag{2.20}$$

and

$$\frac{\partial \frac{w_N^H}{w_N^L}}{\partial z^*} = \frac{L_N}{H_N} \frac{\eta(z^*) \int_{z^*}^1 \eta(z)(z-z^*)dz}{\left(\int_{z^*}^1 \eta(z)(1-z)dz\right)^2} > 0 \tag{2.21}$$

The proofs are shown in Appendix B. Proposition 2 (a) confirms the Feenstra-Hanson channel through which the relative skill demand embodied in producing intermediate inputs increases as more relative skill-intensive production activities are transferred from the North to the South. Given Assumption 2, the shifting production activities raise the skill premium in both countries. So Proposition 2 (b) follows.

If Assumption 2 doesn't hold, however, the final good produced in the South is relative more skill-intensive than inputs offshored to the South, and its fraction in total consumption expenditure, $1-\alpha$, is significant.[12] In this

[12]If Assumption 2 doesn't hold, which means $\beta > z^* + \frac{\alpha \int_0^{z^*} \eta(z)(z^*-z)}{(1-\alpha)\tau}$, the fraction of the final good produced by the South in total consumption expenditure is larger than $\frac{\int_0^{z^*} \eta(z)(z^*-z)dz}{\int_0^{z^*} \eta(z)(z^*-z)dz+(\beta-z^*)\tau}$.

case, although the rising z^* drives the skill demand for producing inputs up, the market demand for the final good produced in the South decreases, which results in the reduction in skill demand and corresponding skill premium. In summary, the effects of the rising z^* on skill premium in the South depend on the market demand structure, the relative skill intensity of final goods to intermediate inputs produced in the South. In this chapter, I concentrate on the case in which the final good produced in the South is low-skill intensive, which is consistent with China's exporting structure before and after joining the WTO in 2001.

According to Propositions 1 and 2, a reduction in offshoring cost raises the cutoff stage between North-South production, which in turn increases the skill premium in these two countries. However, the changes in skill demand and skill premium are not dependent on the reduction in offshoring cost, but also result from changes in other factors which raise the South's intermediate input supplies. These shocks include the relative growth of productivity, capital stock, and foreign direct investment in the South.

As the relative skill demand increases, if the factor supplies are fixed in the equilibrium, the variance of relative skill demand across intermediate inputs offshored to the South increases. If the supplies of high- and low-skill workers are unchanged, the labor market clearing conditions can be held if employment at the lowest skill production tasks also increases, with less employment in the middle of the range $[0, z*)$. In this case, for the ordinary exporting good produced in the South, whether its production expands or not depends on its skill intensity. So the production activities using the highest and lowest ratios of high-skill/low-skill workers will expand, implying the rising variance of the ratio in the South. But the implication doesn't apply to the case in which the factor supplies in the South increase. For example, China released the restriction of immigration across regions and enlarged the college enrollment at the end of the 1990s, which raised the supplies of high- and low-skill workers after 2000. Later the expansion of China's processing exports took place in all the low-, medium- and high-skill intensive industries.

2.4 Practical strategy

To examine the impact of offshoring on skill premium in China between 2000 and 2006, I divide my empirical strategy into two stages: (1) identifying determinants of China's processing exports, (2) exploring the effects of processing export demand shocks on skill premium. In this chapter, I use processing exports to approximate offshoring in the context of China as Feenstra and Hanson (2005) and Fernandes and Tang (2012). Then, to eliminate the endogenous concerns in the second stage, I use the estimated values of processing exports from the first stage to construct relevant instrumental variables for the second stage.

2.4.1 Processing exports

Firstly, I analyze determinants of China's processing exports across cities and industries, especially import tariffs by China's trading partners, offshoring costs, and foreign investment. The regression model is as follows:

$$\begin{aligned} ln(PE_{kit}) = {} & \theta_1 ln(1+\tau_{kit}) + \theta_2 N^{epz}_{i,t-1} + \theta_3 H_{i,t-1} \\ & + \theta_4 EP_{kt} + \theta_5 RP_{kt} + \theta_6 S^{FIE}_{ikt} \\ & + \eta * F + \nu_k + \nu_i + \nu_t + \epsilon_{ikt} \end{aligned} \tag{2.22}$$

where $ln(PE_{kit})$ is the log value of processing exports for industry k in city i and period t. The key independent variables include the import tariff by trading partners (τ_{kit}), the number of economic policy zones ($N^{epz}_{i,t-1}$), the regional density of highways ($H_{i,t-1}$), the encouragement policy (EP_{kt}), the restriction policy (RP_{kt}), and the share of foreign-invested firms in city-industry-specific processing exports (S^{FIE}_{ikt}). F contains the interaction terms between factor intensities and factor endowments. Here I take one-period lagged values of economic policy zones, highway density, and factor endowments to eliminate the possible contemporaneous problem between them and the error term. Besides, ν_k, ν_i and ν_t represent the fixed effects of industry k, city i, and period t, respectively. Alternatively, I also use the city-year fixed effect instead of separate fixed effects for city and year to account for other unobserved city-year changing factors. In this way, the control for city-year effects would eliminate the city-level variables measuring offshoring costs from the regression model. Consequentially, the regression model will take city-year cluster robust standard errors for controlling sample dependence.

For the import tariff imposed by trading partners on the manufacturing sector k in city i and period t, I construct it as:

$$\tau_{kit} = \sum_n \frac{PE_{k,in,0}}{PE_{k,i,0}} \tau_{k,in,t} \quad \text{with} \quad \tau_{k,in,t} = \sum_{g \in k} \frac{PE_{g,in,0}}{PE_{k,in,0}} \tau_{g,n,t} \tag{2.23}$$

where $\tau_{g,n,t}$ denotes the import tariff imposed by country n on China's exporting good g in period t. $PE_{k,in,0}$ ($PE_{g,in,0}$) is the value of industry k (good g) in city i's processing export to country n in period 0, whereas $PE_{k,i,0} = \sum_n PE_{k,in,0}$ represents the corresponding total processing export value. Firstly, the product-level tariffs, $\tau_{g,n,t}$, are weighted by goods' shares in the processing export value of industry k. In this way, I obtain the import tariff imposed by country n on industry k in city i during period t, $\tau_{k,in,t}$. Then the tariffs are weighted by countries' shares in city i's export values of industry k in period 0 and aggregated to the industry level. Because of the log value transformation, the coefficient θ_1 represents the trade elasticity of processing exports with respect to import tariffs by trading partners.

In the regression model, I use two variables to measure the reduction in offshoring costs. The first variable is the accumulative amount of economic policy zones, $N^{epz}_{i,t-1}$.[13] The economic policy zones provide firms with different ad-

[13]The establishment of economic policy zones in China started in the early 1980s. These

vantages, including low land rents and corporate tax rates, duty-free imported inputs, and free of property tax at the beginning years.[14] Both Wang (2013) and Sheng and Yang (2019) identify the positive effects of economic policy zones on China's exports since the 1980s. The second variable is the regional density of highways, $H_{i,t-1}$. The rising density of highways implies the improvement of infrastructure and the reduction in transport costs, contributing to the development of processing exports.

To measure the impact of foreign investment on China's processing exports, the regression model incorporates the foreign investment encouragement and restriction policy indicators, EP_{kt} and RP_{kt}, respectively. The constructions of $EP_{k,t}$ and $RP_{k,t}$ are based on Catalogue for the Guidance of Foreign Investment Industries (CGFII 1995, 2002, 2004).[15] According to CGFII, foreign investors in encouraged industries are supplied with several advantages, including freely choosing ownership structures, low land rent, and preferential corporate tax rates. In contrast, high entry costs and strict regulations on ownership structures exist in restricted industries for foreign investors. Following Sheng and Yang (2016), I set $EP_{kt} = 1$ ($RP_{kt} = 1$) for a specific industry k if at least one product in this industry belongs to the encouragement (restriction) list in CGFII; otherwise, $EP_{kt} = 0$ ($RP_{kt} = 0$). Industries without any policy interventions are regarded as the reference group. Furthermore, I add the share of foreign-invested firms in city-industry-specific processing exports, S_{ikt}^{FIE}, to capture the role of foreign-invested enterprises at the city-industry-specific level. According to Hsieh and Klenow (2009) and Yu (2014), foreign-invested companies have an advantage in productivity and management efficiency over state-owned and private-owned enterprises in China.

Following Romalis (2004), I take into account the role of comparative advantage in processing exports. The comparative advantage means that cities concentrate on producing and exporting skill-intensive (capital-intensive) products if they are abundant with skill (capital) endowment. So the control variables in F include the intersection terms of the city-level factor endowments, high-skill workers and physical capital, and the corresponding city-industry-specific factor intensities.

According to the implication of Proposition 1, the reduction in offshoring costs encourages developed countries to shift more relative high-skill intensive production activities to China, which results in the expansion of China's pro-

economic policy zones include Export Processing Zone, High-tech Development Area, Bonded Area, and Economic and Technological Development Zone. The number of economic policy zones is obtained from the China Development Zone Review Announcement Catalogue (DZRAC, 2006).

[14] One possible concern about using the number of economic policy zones to measure the reduction in offshoring costs is the lack of considering their differences in area. For example, the Shanghai Jinqiao Export Processing Zone is 27.43 million square meters and is as large as the sum of several export processing zones in its neighboring province Jiangsu. Although DZRAC(2006) recorded the areas of all the policy zones in 2006, the dynamic changes of zone areas can't be observed.

[15] The CGFII was first published in 1995 and revised in 2002 and 2004. I assume that no policy is changed until a formal revision is announced in the published catalogue.

cessing exports. This channel also applies to reducing import tariffs faced by China's processing exporters and increasing foreign investment. In summary, I would expect $\theta_1 < 0$, $\theta_2 > 0$, $\theta_3 > 0$, $\theta_4 > 0$, $\theta_5 < 0$, and $\theta_6 > 0$ in the regression model (2.22). Because of the comparative advantage, the coefficients of independent variables contained in F are positive: $\eta > 0$.

2.4.2 Skill premium

To obtain the city-level skill premium, I estimate the following Mincer wage equation separately for each city and year:

$$ln(w_{jit}) = \alpha_{it} E_j + \delta_{it} + \gamma * X_j + \epsilon_{jit} \tag{2.24}$$

where w_{jit} is the wage of individual j in city i and year t. E_j is a dummy variable for college graduates ($E_j = 1$ if the individual obtains a college degree or above, and 0 otherwise). δ_{it} is the city and year fixed effect. X_j is a set of other individual characteristics affecting wage, including working experience, gender, and the employer's ownership type (state, collective or private).[16] The coefficient of the dummy variable for education level represents the college wage premium in city i and year t in percentage terms. That is, $\alpha_{it} = E(ln(w_{jit})|E_j = 1, \delta_{it}, X_j) - E(ln(w_{jit})|E_j = 0, \delta_{it}, X_j)$.

2.4.3 The effects of processing export on skill premium

To identify the impact of processing exports on skill premium, I take the regression of changes in skill premium on the processing export demand shocks as:

$$\Delta\alpha_{it} = \beta_1 \Delta PE_{it}^H + \beta_2 \Delta PE_{it}^L + \beta_3 \alpha_{i0} + \delta \Delta Z_{it} + \phi_{pt} + \epsilon_{it} \tag{2.25}$$

where $\Delta\alpha_{it}$ is the change in skill premium in city i between period $t-1$ and t. ΔPE_{it}^H and ΔPE_{it}^L denote the high- and low-skill processing export demand shocks in city i and period t, respectively. α_{i0} is the skill premium for city i at the initial period and captures the city-specific trends relating to the initial skill premium. ΔZ_{it} is a set of other independent economic shocks that also affect skill premium. ϕ_{pt} controls the province-year fixed effect, so the identification comes from within-province variation in processing exports. The econometric model takes the first differences for the two periods, 2000 to 2004 and 2004 to 2006. Besides, the standard errors are clustered at the province level to account for potential serial correlation over time and across cities within the same province. Moreover, each regression is weighted by the city population in the base period.

For ΔPE_{it}^H and ΔPE_{it}^L, I construct the demand shock as the interaction of the initial city-industry-specific factor intensity and changes in processing

[16] To eliminate the effects of individual characteristics on skill premium, I also regress the log wage on the education dummy variable and city-year dummy variable directly. Then I use it as the alternative measure of skill premium in the robustness test of the empirical part.

exports at the city-industry level, normalized by regional factor endowments:

$$\Delta PE_{it}^{H} = \sum_k \frac{H_{ik0}}{E_{ik0}} \frac{\Delta PE_{ikt}}{H_{i0}} \text{and} \qquad \Delta PE_{it}^{L,I} = \sum_k \frac{L_{ik0}}{E_{ik0}} \frac{\Delta PE_{ikt}}{L_{i0}} \tag{2.26}$$

where H_{ik0} and L_{ik0}, respectively, denote the initial amount of high- and low-skill employees in industry k and city i, and $E_{ik0} = H_{ik0} + L_{ik0}$ represents the corresponding total employment. ΔPE_{ikt} is the change in processing export values for industry k in city i between period $t-1$ and t. H_{i0} and L_{i0} are the initial endowment of high- and low-skill workers in city i, respectively. According to its construction, the high-skill (low-skill) demand shock denotes the processing export exposure in dollar per high-skill (low-skill) worker.

This construction of processing export demand shock is similar to the method of Li (2018), but Li (2018) uses the national-level changes in industry export instead of city-level ones. With the national industry-specific export shocks, Li (2018) distributes them across regions according to the ratio of regional industry-specific employment to national corresponding industry employment. It relies on the assumption that regional industry employment can fully approximate the distribution of industrial output across cities.[17] To avoid the possible errors from using national export shock, I use the city-level changes in industry export to construct the export demand shock directly.

Cities are different in industrial specialization patterns because of their differences in production technology, capital endowments, and relative skill supply. So the skill demand shocks and the induced effects on skill premium vary across cities. The higher the skill intensity of industries in which a city specializes, the larger the relative skill demand caused by the processing export shock that it undergoes. The corresponding change in relative skill demand affects local skill premium. The increasing demand for high-skill (low-skill) workers contributes to a higher (lower) skill premium, so β_1 (β_2) in (2.25) is predicted to be positive (negative).

ΔZ_{it} in the regression model (2.25) includes other coexistent economic shocks that might independently affect skill premium. Firstly, I consider the ordinary exports and use the change in the ratio of ordinary exports to industrial output to capture its effect on skill premium. Secondly, I regard the complementarity between capital and skill and add changes in the capital-to-output ratio into the regression model. Krusell et al.(2000) find that the capital-skill complement effect plays an essential role in explaining the variations in the skill premium. Besides, Li et al.(2019) find that cities in China with more capital imports tend to have higher skill premium. The last shock is the variation in total factor productivity (TFP), measuring the growth of productivity efficiency.[18] The relative growth of China's TFP encourages developed countries

[17] Li (2018) uses the 2000 data to test the approximation and regresses a region's export share on its employment share. Although the estimated coefficient is 0.965 and not significantly different from one, the linear approximation doesn't consider increasing return and regional differences in capitals. In this way, it undermines the assumption that regional industry employment can fully approximate the distribution of industrial output across cities.

[18] The regional TFP is calculated as the Solow residual, the portion of an economy's output

to outsource more skill-intensive production tasks to China, as Feenstra and Hanson (1996) imply.

2.4.4 Instrumental variable strategy

Potential endogenous problems exist in using the regression model (2.25). Firstly, the causality may be in the inverse direction. For example, if the skill premium decreases and high-skill workers become relatively cheaper, firms participating in processing exports intend to produce and export high-skill intensive products. In this case, the principal regression model (2.25) will overstate the actual effect of processing exports on skill premium. Secondly, other variables may affect the domestic skill premium and process exports simultaneously, making the estimated effect of processing exports on skill premium overestimated or underestimated. Take, for example, research and development (R&D). On the one hand, the rise of R&D expenses raises the demand for high-skill workers and skill premium correspondingly; on the other hand, R&D activities increase firms' productivity and processing export values. In this way, the estimated coefficient in equation (2.25) overestimates the positive effect of processing exports on skill premium.

To address the potential endogenous problem, I use the estimated value of processing exports to construct the instrumental variable (IV). Then, based on the predicted value $\widehat{PE_{ikt}}$ from the first stage, I construct the estimated demand shocks as follows:

$$\Delta\widehat{PE_{it}^{H}} = \sum_{k} \frac{H_{ik0}}{E_{ik0}} \frac{\Delta\widehat{PE_{ikt}}}{H_{i0}} \qquad \Delta\widehat{PE_{it}^{L}} = \sum_{k} \frac{L_{ik0}}{E_{ik0}} \frac{\Delta\widehat{PE_{ikt}}}{L_{i0}} \tag{2.27}$$

These estimated values would serve as the instrumental variables for ΔPE_{it}^{H} and ΔPE_{it}^{L} in the main regression, respectively. Using the component of exports predicted by equation (2.22), I can isolate the processing export demand shocks from other factors related to export expansion, including contract environment and productivity.

The validity of these estimated values as instrumental variables would be promising because the corresponding determinants of processing exports are exogenous to the skill premium. Firstly, the import tariffs imposed by trading partners are obviously exogenous to China's regional differences in the skill premium. Secondly, the encouragement and restriction policy for foreign investment are at the industry level instead of the city level. Before and after China joined the WTO in 2001, the revisions of FDI regulation resulted from China's compliance with the WTO agreement on Trade-Related Investment Measures (TRIMs). No direct evidence shows that these policy changes are associated with the regional skill premium.[19]

growth that cannot be attributed to the accumulation of capital and labor. The city-level output, capital, and labor data is obtained from China City Statistical Yearbook.

[19]Lu et al. (2017) studied the spillover effect of horizontal FDI and regarded the change in FDI regulations around 2001 as a plausibly exogenous event. Furthermore, they empirically

One possible concern about the effectiveness of the IV strategy is that the economic policy zones and infrastructure targeted high skill premium growth in selected regions. It means that these variables may affect regional skill premium through channels other than processing exports. The establishment of economic policy zones corresponds to two significant shocks of trade liberalization to the Chinese economy. The first trade liberalization shock was Deng Xiaoping's Southern Tour in 1992, in which he delivered a series of speeches to underscore the significance of "opening up". As a result, most of the High-tech Development Areas, Bonded Areas, and Economic and Technological Development Zones were built in 1992-1996.[20] The second trade liberalization shock was China's accession to the WTO in 2001. Before and after China's accession to the WTO, the amount of Processing Export Zone established by the government of China in 2000-2004 achieved 40 (DZRAC, 2006). So I regress changes in skill premium on the initial economic policy zones and infrastructure projects for different time periods: 1992-2000, 1996-2000, 2000-2006, and 2004-2006. The regression results are shown in Table C.1 in Appendix C. In all these regressions, the estimated coefficients of economic policy zones and infrastructure in the initial period are not statistically different from zero, indicating no evidence of policy targeting. Moreover, this baseline result is robust to the addition of other control variables, including export-output ratio, capital-output ratio, and TFP.

2.5 Data

2.5.1 Data on skill premium

To obtain the city-level skill premium, I draw the data on jobs and wages from the Chinese Urban Household Survey (CUHS 2000-2006). The survey is conducted by the National Bureau of Statistics of China (NBSC). The CUHS is representative because it covers 192 prefectures in 18 provinces, including developed and underdeveloped cities located in China's inland and coastal areas.[21] Besides, it contains individual information on geographic residence (prefecture and province), demographic characteristics (age, gender, and marital status), and employment (wage, education level, working experience, occupation, and sector).[22] In this chapter, I will focus on individuals who are between 16 and

identified that the industries benefiting from the encouragement policies are unrelated to labor force characteristics, such as working experience and the employment sector.

[20]According to DZRAC (2006), the aggregate number of economic policy zones, including High-tech Development Areas, Bonded Areas, and Economic and Technological Development Zones, established in 1992-1996 achieved 70.

[21]These provinces include Heilongjiang, Liaoning, Peking, Shandong, Shanghai, Jiangsu, Zhejiang, Guangdong, Yunnan, Chongqing, Sichuan, Jiangxi, Hubei, Anhui, Henan, Gansu, Shanxi, and Shangxi.

[22]According to Han et al. (2012), although the UHS data is the most comprehensive to examine income inequality in China, it has one limitation that the floating population is not covered in the survey. Here the floating population refers to migrants who are not listed in the urban household registry, known in Chinese as Hu Kou. The exclusion of migrants in

60 years old and have labor income.

2.5.2 Data on industry employment

To construct the processing export shocks, I obtain the data on industry employment from the 1% subsample of the 2000 China Population Census and the 2004 China Economic Census. The 1% subsample of the 2000 China Population Census contains more than 11.8 million respondents and records their individual information, including postcode of residence, education level, employment status, occupation, and industry. The 2004 China Economic Census records the firm-level data on employees' education background and classifies firms into different manufacturing sectors. For a specific city, these censuses enable me to obtain the fractions of high- and low-skill workers in employment for different manufacturing sectors in 2000 and 2004, respectively. In the empirical part, I define workers with a college degree or above as high-skill workers and those without college education as low-skill workers.

However, an inconsistency exists between the China Industrial Classification (CIC) used in the 2000 Population Census and the 2004 Economic Census. The old version of CIC (CIC-02) was used until 2002, whereas the new version (CIC-03) was used from 2003 onwards. To fix the inconsistency, I convert them to the consistent industrial classification (CIC-adjusted) constructed by Brandt et al. (2017).[23]

2.5.3 Data on processing exports

I receive China processing trade data from China customs (2000-2006). The data includes information on the trade values at 6-digit HS product level, the exporting (importing) city in China, the importing (exporting) country, the ownership of firms, and the trade regime. The recorded trade regimes between 2000 and 2006 contain 16 kinds of trade regimes, including ordinary trade, process and assembling, process with imported materials, and others.[24] However, the classification of trade regime after 2006 in the trade data by China customs only contains ordinary trade and processing trade. Therefore, to make the statistic consistent, I choose 2000-2006 as the sample period and focus on two specific types: (1) process and assembling; (2)process with imported materials.[25]

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the UHS data may underestimate the wage inequality in China because the wages of these migrants are often concentrated at the lower tail of the wage distribution.

[23]Brandt (2017) provides the concordance among CIC-adjusted, CIC-02, and CIC-03 at 4-digit manufacturing sector level.

[24]The other trade regime forms include: international aid; donation by overseas Chinese; compensation trade; process assembling; process with imported materials; goods on consignment; border trade; equipment for processing trade; contracting projects; goods on lease; equipment/materials investment by foreign-invested enterprise; outward processing; barter trade; duty-free commodity and warehousing trade; entrepot trade by bonded area.

[25]In processing with assembly, the domestic firms locally process raw materials and intermediate inputs receiving freely from foreign trading partners and resell final products to the same trading partners for obtaining assembly fees. In contrast, firms in processing with inputs pay for imported inputs by themselves and export final goods to any trading partners after

To be consistent with the data on industry employment, I divide processing export goods into different manufacturing sectors according to CIC-adjusted. According to the concordance table between 6-digit HS product and CIC-adjusted by Brandt et al. (2017), most of the 6-digit HS China processing exporting goods can be classified into corresponding manufacturing sectors. For the rest which can't be identified according to Brandt (2017), I classify them according to International Standard Industrial Classification (ISIC) 3.0 firstly and convert them to CIC-adjusted based on the concordance between ISIC 3.0 and CIC-adjusted. [26]

The China customs data includes the trading companies which don't produce their products but only export goods collected from other domestic producers. I exclude such trading companies from the sample because the origin of their processing export goods can't be identified.[27] So the sample used in the empirical analysis doesn't include the companies whose names contain Chinese characters for Importing and Exporting Company or Trading Company.[28]

Besides, I focus on the processing exports between China and developed countries defined by OECD between 2000 and 2006.[29] In the global value chain, developed countries initially outsource low skill-intensive tasks to China and upgrade the skill-intensive level of offshoring tasks as the offshoring cost decreases.

2.5.4 Data on industry capital intensity

To obtain the industry capital intensity, I use the data on fixed capital stock and depreciation from the Annual Survey of Industrial Production (ASIP 1999-2006) which is also conducted by NBSC. The ASIP records the annual accounting statement and production activities for manufacturing firms with annual sales above 5 million RMB. According to Brandt, Biesebroeck, and Zhang (2012), firms in the ASIP account for 70%, 91%, 97%, and 90% of the employment, sales, export, and gross asset, respectively, in the manufacturing sector.[30]

The fixed-asset investment by industry k in city i and year t is the sum of

local processing.

[26]Since the National Bureau of Statistics of China publishes the concordance table between ISIC 3.0 and CIC-03, I combine it with the concordance between CIC-03 and CIC-adjusted by Brandt (2017) to construct the mapping between ISIC 3.0 and CIC-adjusted.

[27]In the robustness test, I would include these trading companies in the sample under the assumption that they collect their processing export goods from firms located in the same city as the trading company.

[28]The China Ministry of Commerce requires trading companies to register with a name including Chinese characters for 'Importing and Exporting Company' or 'Trading Company'.

[29]There are 16 countries and regions on the list of developed countries by OECD, including Hong Kong, Taiwan, Japan, South Korea, Singapore, Australia, New Zealand, Liechtenstein, Iceland, Israel, Switzerland, Norway, European Union, United States, Canada, and Bermuda. In the robustness test, I would eliminate the restriction and take all the trading partners, either developed or developing countries, into account.

[30]The number of firms recorded in the ASIP increases continuously from 0.16 million to 0.30 million between 2000 and 2006.

fixed asset investment by the local firms belonging to this industry:

$$I_{kit} = \sum_{j \in k} (FA_{jit} - FA_{ji,t-1} + D_{jit}) \tag{2.28}$$

where FA_{jit} and D_{jit} denote firm j's fixed asset stock and depreciation in period t, respectively. Since ASIP doesn't include the data on disposal gains, I don't take into account firm-specific disposal gains and assume that the total industry-specific disposal gains are zero.

The measurement of capital intensity is the ratio of fixed-asset investment to output for the industry, so the city-industry-specific capital intensity obtained from ASIP is:

$$\frac{I_{kit}}{Y_{kit}} = \frac{I_{kit}}{\sum_{j \in k} Y_{jit}} \tag{2.29}$$

where Y_{kit} and Y_{jit} are the output of industry k and firm j in city i and year t, respectively. The city-industry-specific capital intensity will be used to explore the role of comparative advantage in the determinants of processing exports.

2.5.5 Macro data

For other macro data used in the empirical part, I collect the import tariff on China exporting goods imposed by trading partners from Trade Analysis Information System (TRAINS). Besides, I obtain the China city-level gross domestic product, city capital stock, consumer price index, local government expenditures, highway miles from China Statistical Yearbooks, China Regional Economics Yearbooks, and China City Statistical Yearbooks (2000-2006). Furthermore, the number of different economic policy special zones and their established time are available in China Development Zone List published by China National Development and Reform Commission. Moreover, I collect information about the encouragement and restriction policy from the Catalogue for the Guidance of Foreign Investment Industries (CGFII 1997, 2002, 2004).

2.6 Empirical results

2.6.1 Skill content and demand shocks

Table 2.1: Summary statistics of China's processing exports

Year	Processing exports		Share in Processing Exports		
	Values	Share in Total Exports	Low-skill Industries	Medium-skill Industries	High-skill Industries
2000	93	0.762	0.349	0.22	0.431
2001	118	0.767	0.329	0.214	0.457
2002	124	0.744	0.293	0.202	0.505
2003	183	0.757	0.247	0.181	0.572
2004	220	0.732	0.221	0.172	0.607
2005	301	0.755	0.196	0.167	0.637
2006	368	0.722	0.178	0.158	0.664

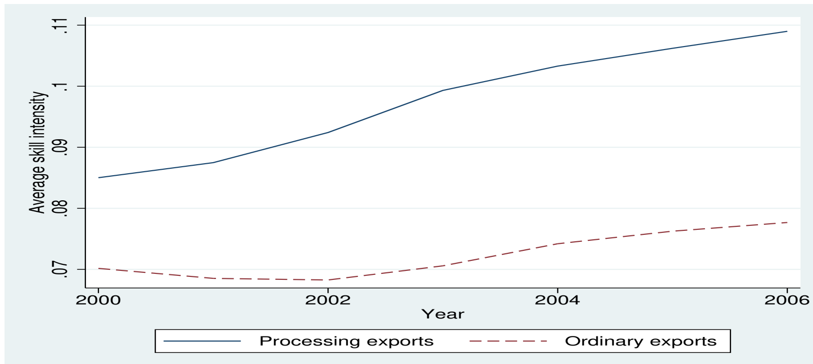
Notes: The number of sample city is 192. The unit of processing export values is 1 billion USD.

I begin this section by analyzing the skill content of China's processing exports and corresponding skill demand shocks. According to the China Industrial Classification (CIC), there are 30 manufacturing sectors at the 2-digit level in China, which are consistently defined between 2000 and 2006.[31] In Table C.2 in Appendix C, I classify these manufacturing sectors into low-, medium- and high-skill groups according to their skill intensity. Here I define the skill intensity for a specific industry as the ratio of employees with college degrees or above to the total industrial employment. The classification is based on the industrial employment information from the China 2000 Population Census and 2004 Economic Census. Table C.2 shows that all manufacturing sectors, especially those belonging to low- and medium-skill groups in 2000, have a significant skill upgrading between 2000 and 2004.[32]

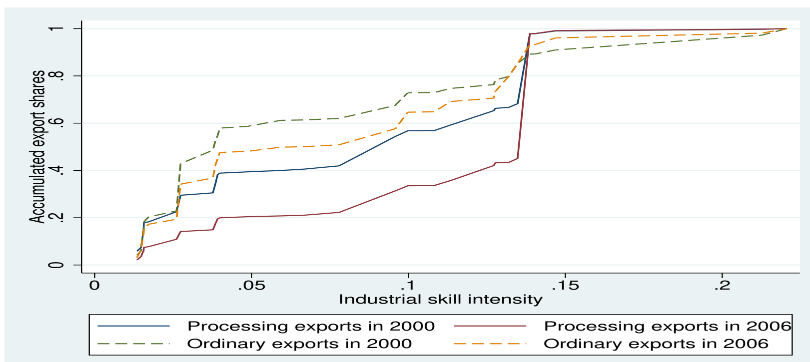
In the aggregate, processing exports account for 57.3% of China's total exports between 2000 and 2006. For cities in the sample, processing exports comprise as high as 74.4% of their total exports. Besides, their processing exports increase continuously from $93 billion to $368 billion in this period, as shown in Table 2.1. It means that the majority of cities in the sample are more exposed to processing exports than other cities in China. Table 2.1 also reveals that both the shares of low- and medium-skill industries in processing exports persist declination, whereas that of high-skill industry increases incessantly.

[31] Although there exist differences between CIC-02 and CIC-03 at the 4-digit level, their classifications at the 2-digit level are almost unchanged across years. One slight difference between CIC-02 and CIC-03 at the 2-digit level is that the military industry included in CIC-02 is excluded from CIC-03. However, the difference lacks influences on the statistic of China's processing exports because the military industry is forbidden to involve in China's processing trade.

[32] The industrial skill upgrading can be partly attributed to the increasing amount of college graduates since 2003. The China government has carried out the education reform policy and enlarged college enrollment constantly since 1999. So the amount of college graduates in China achieves to 1.88 million in 2003, a 121% increase compared with that in 1999.



(a) Average skill intensity



(b)Accumulated export shares

Figure 2.2: Skill content of China's processing exports and ordinary exports

To explore the skill content of China's processing exports, Figure 2.2 (a) plots the trends of the average skill intensities of processing exports and ordinary exports from 2000 to 2006. Here the average skill intensity is the weighted average of industrial skill intensity, with the industrial shares of relevant exports as the weights. The figure reveals that both processing exports and ordinary exports have a significant skill upgrading in this period, and the former is more skill-intensive than the latter. Besides, the contribution of processing exports to the skill content in total exports remains around 80% between 2000 and 2006.[33]

Figure 2.2 (b) additionally plots the accumulative distribution function of skill intensity for processing exports and ordinary exports, respectively.[34] The

[33]The contribution of processing exports to the skill content in total exports is measured by the ratio of the skill content in processing exports to that of total export. That is $S_t^{PE} = \frac{\sum_k s_k * PE_{k,t}}{\sum_k s_k * PE_{k,t} + \sum_k s_k * OE_{k,t}}$, where s_k is the skill intensity of the manufacture industry k; $PE_{k,t}$ and $OE_{k,t}$ denote the export values of processing exports and ordinary exports, respectively, for industry k in period t.

[34]To calculate the accumulative distribution function of skill intensity, I sort the manufacture industries according to their skill intensities from low to high as Column 2 in Table 1. So s_m, $m = 1, 2...30$, denotes the skill intensity of the m-th industry in this rank. The

Table 2.2: Summary statistics of skill premium and demand shocks

	10th	25th	50th	75th	90th	Mean	Std
Panel A: Change in Skill Premium							
00-04	-0.106	0	0.122	0.21	0.277	0.108	0.162
04-06	-0.186	-0.11	-0.027	0.056	0.171	0.019	0.134
00-06	-0.174	-0.046	0.105	0.204	0.306	0.082	0.176
Panel B: High-skill Processing Export Shocks-ΔPE^H							
00-04	-0.002	0	0.006	0.057	0.430	0.246	1.045
04-06	-0.012	0	0.003	0.084	0.450	0.258	1.01
00-06	-0.003	0	0.010	0.117	0.762	0.499	2.086
Panel C: Low-skill Processing Export Shocks-ΔPE^L							
00-04	-0.001	0	0.003	0.014	0.122	0.073	0.323
04-06	-0.002	0	0.001	0.014	0.094	0.052	0.209
00-06	-0.006	0	0.003	0.031	0.281	0.153	0.647

Notes: The number of city in the sample is 192. Unit of high- and low-skill demand shocks is 1000 USD.

shape of the accumulative distribution functions implies that exports, especially processing exports, have a significant skill upgrading because the distributions shift in the right direction from 2000 to 2006. Besides, the distribution of processing exports is more skewed to skill-intensive manufacturing sectors than that of ordinary exports. For example, the electronic and telecommunication equipment manufacturing industry, one of the high-skill intensive industries, accounts for 29.6% of processing exports in 2000 and 52.8% in 2006, an increase of 78.4%. It means that processing exports have first-order stochastic dominance over ordinary exports for skill intensity. Moreover, the dominance was more significant in 2006 than in 2000.

Table 2.2 reports the descriptive statistics of skill premium and demand shocks (ΔPE^H and ΔPE^L), by period. As Panel B and C show, the mean high- and low-skill demand shocks from 2000 to 2004 are \$246 and \$73, respectively. The mean high-skill shock increases slightly to \$258 in the period 2004-2006, whereas the mean low-skill shock decreases to \$52. The variation in processing export shocks is considerable across cities due to the significant regional difference in industry specialization. Besides, the difference in ΔPE^H between cities at the 25th and 75th percentile is \$57 between 2000 and 2004 and increases to \$84 between 2004 and 2006. In contrast, for ΔPE^L, the differences remain \$14 in both the first and second periods.

2.6.2 Determinants of processing exports

Since China's processing exports have significant skill-upgrading expansions between 2000 and 2006, their composition and distribution have crucial effects on skill demand and wage premium. So I would explore various deter-

accumulative distribution function can be obtained by using $F(s) = \sum_{m=1}^{30} I(s \geqslant s_m)P(s_m)$, where $I(s \geqslant s_m)$ is the indicator function and $P(s_m)$ is the share of the m-th manufacturing industries in processing exports.

Table 2.3: Determinations of processing export

	(1) $log(Value)$	(2) $log(Value)$	(3) $log(Value)$	(4) $log(Value)$	(5) $log(Value)$
ln(1+Tariff)	-1.739***	-1.812***	-1.827***	-1.829***	-1.840***
	(0.215)	(0.224)	(0.227)	(0.252)	(0.250)
$EPZ^N_{i,t-1}$		0.098**	0.096**	0.081**	
		(0.031)	(0.031)	(0.032)	
$EPZ^P_{i,t-1}$		0.043***	0.044***	0.041**	
		(0.013)	(0.013)	(0.014)	
Density of Highways		0.354***	0.518***	0.515***	
		(0.054)	(0.058)	(0.062)	
Encouragement Policy			0.193**	0.174**	0.163*
			(0.084)	(0.084)	(0.084)
Restriction Policy			-0.165*	-0.156 *	-0.152*
			(0.084)	(0.084)	(0.083)
City-industrial fraction of FDI			0.375***	0.383***	0.255***
			(0.051)	(0.053)	(7.24)
Cap. Intensity×Cap. Endowment				0.004*	0.004*
				(0.003)	(0.002)
Skill Intensity×Skill Endowment				0.817***	0.846***
				(0.099)	(0.099)
Industry FE	+	+	+	+	+
City FE	+	+	+	+	
Year FE	+	+	+	+	
City-Year FE					+
N	21678	21044	21040	20595	20754

Notes: The dependent variable is the log value of processing exports. The city-year cluster robust standard errors are enclosed in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

minants of China's processing exports across regions and industries based on equation (2.22), which serves as the first-stage estimation. Table 2.3 shows the corresponding estimation results.

I start with a simple specification in Column (1) that independent variables only include the city-industry-specific weighted import tariffs imposed by China's trading partners and the fixed effects for city, industry, and year, respectively. The coefficient of city-industry-specific import tariffs, the estimated trade elasticity, is -1.739 and statistically significant at the one percent level.[35] The estimation result is consistent with the effects of bilateral tariffs on trade volume under the structural gravity equation summarized by Head and Mayer (2014).

Column (2) adds the accumulative number of economic policy zones (national and provincial, respectively) and the density of highways to measure

[35] I regard the rest of the world as a trading partner for each city in China and aggregate trade flows and tariffs to the city-industry level. Besides, the tariffs used here are weighted tariffs obtained from TRAINS. I also use the simple average tariffs from TRAINS to substantiate the robustness of the results, and there are no significant differences between the estimated results.

changes in offshoring costs in China.[36] The estimated coefficients are statistically significant and positive, empirically confirming the positive effects of reducing offshoring costs on China's processing exports.[37] Under this specification, adding one more national (provincial) economic policy zone leads to a 9.8% (4.3%) increase in processing exports. Besides, a 1% increase in highway density raises processing exports by 0.354%. The coefficient of import tariffs remains stable.

To consider the effects of foreign investment on processing exports, Column (3) further incorporates the proxy variables for encouragement and restriction policies for foreign investors, respectively, and the city-industry-specific fraction of foreign-invested enterprise in processing exports. The coefficient of encouragement (restriction) policy is positive (negative) and statistically significant, proving the entrance of foreign-invested firms contributes to China's processing exports.[38] Furthermore, the positive and statistically significant coefficient of the fraction of foreign-invested enterprise in processing exports confirms the relationship at the city-industry level. It could be attributed to the fact that foreign-invested firms have relative advantages in production technology and management experiences over state-owned and private enterprises.[39] According to the selection effect of trade costs by Melitz (2003), the relatively high productivity enables foreign-invested firms to be more likely to participate in processing exports.

Column (4) includes the intersection term between the city-level factor (capital and skill, respectively) endowment and the corresponding city-industry-specific factor intensity. The result confirms the comparative advantage that cities with more capital (skill) endowment tend to produce and export higher capital-intensive (skill-intensive) products. Compared with Column (3), the national policy zones have a reduced magnitude and statistical significance. The reduction can be attributed to the fact that the national policy zones possibly correlate with city-level endowment variables. However, the effects of import tariffs, provincial economic policy zones, and infrastructure on processing exports remain stable.

Column (5) incorporates the city-year fixed effects and eliminates the sep-

[36] The national-level economic policy zones should be authorized by China central government. In contrast, the provincial-level economic policy zones are authorized by the provincial government to which the city belongs. The former provides firms participating in processing exports with more preferential policies than the latter.

[37] Here I don't take into account the changes in railway mileages because the data on China railway mileages at the city level is not available. So I only apply the log density of highways to approximate China's infrastructure investment for measuring offshoring costs at the city level. At the province level, Sheng and Yang (2019) combine the mileages of highways and railways in China and identify their positive effect on exports.

[38] The magnitude of encouragement policy is more significant than that of restriction policy, which could be attributed to the revisions of CGFII in 2002 and 2004. In these revisions, China further relaxes the ownership controls by increasing the encouragement coverage and decreasing the restriction coverage for foreign ownership.

[39] According to Heieh and Klenow (2009), foreign-owned enterprises have 23% higher total factor productivity on average compared with state-owned plants and collectively-owned plants (part private, part local government).

Table 2.4: Processing exports: low-skill and high-skill industries

	low-skill industries		high-skill industries	
	(1)	(2)	(3)	(4)
	$log(Value)$	$log(Value)$	$log(Value)$	$log(Value)$
ln(1+Tariff)	-1.961***	-2.029***	-1.916***	-1.867***
	(0.299)	(0.300)	(0.552)	(0.606)
$EPZ^N_{i,t-1}$	0.051		0.099**	
	(0.042)		(0.045)	
$EPZ^P_{i,t-1}$	0.058***		0.034*	
	(0.020)		(0.018)	
Density of highways	0.427***		0.638***	
	(0.080)		(0.093)	
Encouragement policy	0.124	0.157	0.199*	0.203*
	(0.122)	(0.126)	(0.113)	(0.113)
Restriction policy	-0.099	-0.119	-0.158	-0.171
	(0.127)	(0.122)	(0.108)	(0.11)
City-industrial fraction of FDI	0.445***	0.324***	0.341***	0.203*
	(0.068)	(0.065)	(0.081)	(0.078)
Cap. intensity × Cap. endowment	0.004	0.004*	0.008	0.007***
	(0.003)	(0.002)	(0.009)	(0.003)
Skill intensity × Skill endowment	0.469**	0.439**	0.74***	0.767***
	(0.209)	(0.210)	(0.124)	(0.126)
Industry FE	+	+	+	+
City FE	+		+	
Year FE	+		+	
City-year FE		+		+
N	11249	11343	9346	9411
R^2	0.481	0.476	0.48	0.473

Notes: The dependent variable is the log value of processing exports. The city-year cluster robust standard errors are enclosed in parentheses. * $p < 0.05$, ** $p < 0.01$, ***.

arate fixed effects for city and year to account for other unobserved city-year changing factors. Besides, the city-year changing variables are withdrawn from the regression to avoid multi-collinearity. The coefficients of other independent variables remain stable under the preferred specification with more robust controls. The estimated trade elasticity regarding import tariffs is -1.840 and is still consistent with the trade elasticity summarized by Head and Mayer (2014). Furthermore, considering the effects of foreign investment on China's processing exports, implementing an encouragement policy in a specific industry increases its processing exports by 16.6%. In contrast, restriction policy in a particular sector reduces relevant processing exports by 15.2%. Given the specific industry and city, as the fraction of foreign-invested enterprises in processing exports increase 1%, the corresponding processing export values increase by 0.255%.

Finally, to explore how the effects of import tariffs, offshoring costs, and foreign investment on China's processing exports differ across industries, I also regress processing exports on these factors for low- and high-skill intensive sectors separately.[40] The results in Table 2.4 show that the trade elasticity regarding weighted tariffs in low-skill intensive industries is larger than that in high-skill intensive sectors. Columns (1) and (3) show that high-skill intensive industries benefit more from economic policy zones and highway constructions than low-skill intensive industries.[41] Both encouragement and restriction policies are not statistically significant for low-skill intensive industries. However, the positive effect of the encouragement policy on high-skill intensive industries is identified. Overall, the impact of foreign-invested enterprises on high-skill intensive industries is more substantial than that on low-skill intensive industries.

2.6.3 Processing exports and skill premium

The empirical results above have confirmed the importance of import tariffs by trading partners, offshoring costs, and foreign investment for China's processing exports. According to Proposition 2, the skill-upgrading expansion of processing exports will raise the local skill premium in developing countries. In this section, I will test this implication by predicting the labor market outcomes of the exposure to processing exports based on equation (2.25). The estimation results are displayed in Table 2.5.

Column (1) firstly presents the basic regression of changes in regional skill premium on processing export demand shocks. The inclusion of initial skill premium accounts for the city-specific trends related to the initial condition of skill premium. The coefficient of ΔPE_{it}^{H} (ΔPE_{it}^{L}) is statistically significant and positive (negative), which is consistent with the theoretical prediction. Besides, the results also imply that ΔPE_{it}^{L} has a more substantial effect than ΔPE_{it}^{H} on skill premium, implying that the local skill endowment constrains the rising skill premium induced by processing exports.

Column (2) adds the start-of-the-period capital per capita and log GDP per capita to account for the regional-specific trends that correlate with initial states of capital stock and economic development. The positive effect of initial log GDP per capita is consistent with the regional differences in skill premium between developed and underdeveloped areas in China. The estimated results about demand shocks remain stable.

Column (3) incorporates changes in other determinants of skill premium, including ordinary exports and capital stocks, which are normalized by the

[40]The classification of low-skill and high-skill industries is slightly different from that in Table C.2. To make comparison across industries simple, I treat industries with skill intensity belonging to the bottom 50% and top 50% as low- and high-skill industries in Table 2.4, respectively.

[41]The national economic policy zone is significant for high-skill intensive industries but not for low-skill intensive sectors. The possible reason is that national economic policy zones prefer high-skill intensive industry to low-skill intensive industry. According to DZRAC (2006), national economic policy zones concentrate on high-skill intensive fields, including electronic information, biological medicine, mechanical manufacture, and automation.

Table 2.5: Changes in skill premium and processing export demand shocks

	(1) ΔPremium	(2) ΔPremium	(3) ΔPremium	(4) ΔPremium	(5) ΔPremium
ΔPE^H	0.093***	0.097***	0.108***	0.152***	0.141***
	(0.027)	(0.028)	(0.039)	(0.029)	(0.027)
ΔPE^L	-0.214**	-0.240**	-0.307**	-0.484**	-0.473**
	(0.096)	(0.091)	(0.157)	(0.164)	(0.160)
$\Delta \frac{\text{Ordinary Export}}{\text{Industry Output}}$			0.404***	0.281***	0.269***
			(0.088)	(0.076)	(0.065)
$\Delta \frac{\text{Capital Stock}}{\text{Industry Output}}$			0.221*	0.355*	0.369*
			(0.106)	(0.193)	(0.190)
ΔTFP			0.027**	0.014**	0.015**
			(0.013)	(0.007)	(0.007)
Kleibergen-Paap rk LM statistic					3.228*
Kleibergen and Paap Wald F statistic					186.9
R^2	0.23	0.40	0.465	0.858	0.734
N	440	439	349	349	349
Province×Year	Y	Y	Y	Y	Y
Initial conditions		Y	Y	Y	Y
City Dummy				Y	Y

Notes: All regressions are weighted by the start-of-the-period city's population. Initial conditions include the start of period school captial per capita and log GDP per capita. Standard errors are clustered at the province level and shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

local industrial output, and TFP.[42] The regression result shows that ordinary exports, as processing exports, also positively affect the regional skill premium. It is consistent with the findings of Han et al. (2012) that export expansion enlarges China's wage inequality after the trade liberalization shocks in 1992 and 2001, respectively. Besides, the estimated coefficient of the capital-output ratio is positive and statistically significant, proving the complement effect between capital and skill in China. It is in accordance with Raveh and Reshef (2016) and Li etc. (2020). Finally, the positive and significant coefficient of TFP implies that the effects of technology development on high-skill and low-skill workers are unequal in China. The impact of processing exports on skill premium remains stable.

Column (4) augments the regression models with the city dummies to effectively control the city-specific linear time trend of skill premium. So the role of processing exports in the determination of skill premium is identified through the time variation of processing exports within a city. The regression results remain similar to that in Column (3). So it releases the concern that the impact

[42] According to Acemoglu (1998), skilled-biased technology changes also have positive effects on skill premium. So I use the ratio of the government scientific expenses to industrial output to measure the research and development (R&D) activity at the city level. However, its positive coefficient is not statistically significant. It may be because enterprises play a more critical role than the government in R&D in China. On average, R&D by enterprises accounts for the fraction 66.3% of total R&D expenses in China between 2000 and 2006. However, the data on R&D by enterprises at the city level is unavailable. Thus the ratio of R&D expenses by the government to industrial output cannot fully approximate the regional R&D activities.

of skill demand shocks on skill premium is confounded by the city-specific trends related to the initial industry specialization.

To solve the potential endogenous problem, I use the estimated values of processing exports from Column (4) in Table 2.3 to construct the instrumental variables for demand shocks as equation (2.27). Column (5) shows the results of the 2SLS analysis using these instrumental variables. In the under-identification tests, the Kleibergen-Paap rk LM statistics reject the null hypothesis that the model is under-identified. In the tests for the weak instrument, the Kleibergen and Paap (2006) Wald F statistic under the assumption of heteroscedasticity is above the Stock-Yogo critical values at 10%, so the weak instrument assumptions are rejected, and the results in Column (5) are preferred specifications.

Quantitatively, as Column (5) shows, a $1000 increase in processing exports per high-skill worker increases skill premium by 14.1 percentage points. In contrast, a $1000 increase in processing exports per low-skill worker reduces skill premium by 37.6 percentage points. Besides, skill premium in the cities at the 25th percentile of ΔPE^H increased by 1.66 percentage points less than those in the cities at the 75th percentile. This difference corresponds to 6.74% of the interquartile change in skill premium between 2000 and 2006. Similarly, skill premium in the cities at the 25th percentile of ΔPE^L increased by 1.47 percentage points more than those in the cities at the 75th percentile. This difference explains 5.88% of the interquartile range of the changes in the skill premium.[43] In summary, the results confirm that the skill-upgrading offshoring through the Feenstra-Hanson's channel plays an essential role in increasing skill premium in China after China joined the WTO in 2001.

For the complementary effect between capital and skill, Column (5) shows that a one percent increase of the capital-output ratio will raise the regional skill premium by 0.369 percentage points. For a specific city at the 25th percentile of the capital-output ratio distribution, its skill premium will increase by 6.27 percentage points if the ratio rises to the level of a city at the 75th percentile. The difference can account for 25.1% of the interquartile change of skill premium, larger than that of high- and low-skill demand shocks. However, the capital stock partly captures the effect of processing trade on China's skill premium because imported capital plays an essential role in accumulating capital stocks in China.[44] Li et al. (2019) report that China's average imported capital goods intensity achieved 0.33 between 1998 and 2009.[45]

[43]Following Feenstra and Hanson (1996), I also use the ratio of processing exports to industrial output to approximate the role of processing exports in determining skill premium. So I take the regression of changes in regional skill premium on changes in the processing exports to industrial output ratio. The estimation results are shown in Table C.5 in Appendix C. Although the estimated coefficient is positive and significant, the interquartile variation of the processing exports to output ratio could only account for 0.81 percent of that of skill premium. The reason is that the fraction of processing exports to industrial output rarely changed, making their quantitative contributions to the rising college premium insignificant.

[44]According to the policy of China's customs, the imported capital used for processing trade in China was free from the value-added tax and import tariff between 1998 and 2009. Although China canceled the value-added tax exemption policy in 2009, the import tariff on relevant imported capital remains zero.

[45]The imported capital goods intensity defined by Li at al. (2019) is the ratio of the amount

Column (5) also presents that a one percentage point rise in the ratio of ordinary exports to local industrial output increases the skill premium by 0.269 percentage points. However, an interquartile increase of the ratio of ordinary exports to industrial output can only explain 2.2% of the interquartile change in skill premium. It results from insignificant changes in the ratio between 2000 and 2006. Finally, regarding the role of TFP in determining skill premium, the marginal positive effect of TFP on skill premium is larger than other factors.[46] But its total contribution to China's skill premium is less significant than that of processing exports and capital. An interquartile increase of TFP raises the skill premium by 1.5 percentage points, and it accounts for 4.47% of the interquartile increase in skill premium. It also partly captures the impact of skill-biased technological changes on skill premium at the city level. The reason is that technology development plays an essential role in the growth of TFP, and it results from the RD activities by the firms pursuing monopoly profits, according to Romer (1990).[47]

2.7 Robustness

2.7.1 Different geographic sample

To examine whether a particular geographic region drives the baseline findings, I estimate the specification of Column (4) in Table 2.5, and drop one province or two provinces at a time. Columns (1) and (2) of Table 2.6 show the results for dropping one province at a time. After dropping one province at a time, the estimated coefficient of ΔPE^H ranges from 0.121 to 0.162, and that of ΔPE^L goes from -0.455 to -0.396. All these estimates are significant at the conventional level. Columns (3) and (4) of Table 6 display the results for dropping two provinces at a time. The estimates are not sensitive to the exclusion of any combination of two provinces.

To illustrate the difference in the effects of processing exports on skill premium across high-exposure and low-exposure regions, I exclude the regions from the sample in Column (5) and Column (6), respectively. The results show that the effects of demand shocks on skill premium are not significant after dropping the high-exposure regions, whereas the results remain significant after dropping the low-exposure regions. Besides, the magnitude of coefficients after dropping

of imported capital goods to regional capital stocks. In the calculation of Li et al. (2019), capital goods include products that belong to the ISIC Rev. 3 codes 29-33, excluding those that do not belong to Broad Economic Classification (BEC) industry 41 (capital goods) and BEC industry 42 (Parts and accessories of capital goods) and adding those that belong to BEC industry 521 (transportation equipment used for the industry).

[46]The unit of TFP is percentage points, so the estimated results in Column (5) of Table 2.5 implies that a one percent increase of TFP raises the skill premium by 1.5 percentage points.

[47]Sheng and Yang (2019) use the ratio of RD expenditure to aggregate output to measure the skill-biased technological changes and identify its effect on China's skill premium at the province level. They find that the RD expenditure contributes 5.19% of the rising skill premium in China between 1992 and 2006. It is in line with the effects of TFP on skill premium at the city level here.

Table 2.6: Robustness: different geographic sample

	Dropping one province		Dropping two province		Dropping high -exposure regions	Dropping low -exposure regions
	min	max	min	max		
ΔPE^H	0.121***	0.162***	0.120***	0.206***	0.066	0.172***
	(0.028)	(0.022)	(0.029)	(0.060)	(0.123)	(0.028)
ΔPE^L	-0.455**	-0.396**	-0.664**	-0.353**	-0.486	-0.172**
	(0.028)	(0.022)	(0.029)	(0.164)	(0.739)	(0.192)

Notes: All regressions are weighted by the start-of-the-period city's population. All reg -ressions include the controls in the specification (4) of Table 2.5. Standard errors are clu -stered at the province level and shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

low-exposure regions is larger than the baseline results. The comparison identifies the effects of processing exports on skill premium indirectly.

2.7.2 Alternative measures of processing exports and skill premium

In the baseline regression, I exclude the trading companies from the sample because the place of origin of their exporting goods can't be identified from the data. Besides, I also exclude the processing exports to developing countries from the baseline analysis. Therefore, I would test the robustness of baseline results by adding these samples in this part. Meanwhile, I also use the alternative skill premium, the estimated college effect in the Mincer regression model without including personal characteristics. Table 2.7 shows the robustness test results.

In column (1), I add trading companies into the sample with the assumption that they collect processing exports goods from producers who locate in the same city.[48] The estimated results remain stable. The fraction of trading companies in total processing exports decreases from 7.38% to 2.96% between 2000 and 2006. It implies that China's domestic producers are more likely to obtain the offshoring tasks from foreign partners directly instead of through trading companies after China joined WTO in 2001. Besides, the fractions of low, medium, and high skill-intensive industries in processing exports by trading companies are 46%, 17% and 37%, respectively, on average during this period. It means that trading companies are more concentrated on low-skill industries in processing exports relative to non-trading companies. So the addition of trading companies strengthens the effect of low-skill demand shocks on skill premium more than that of high-skill demand shocks.

In column (2), I consider processing exports to all China's trade partners instead of exports to only developed countries. The alternative measure of

[48] The exclusion of trading companies from the sample in the baseline regression is based on the assumption that all the trading companies and their own suppliers don't locate in the same city. The exclusion and inclusion of trading companies correspond to two opposite extreme situations: (1) trading companies collect exporting goods from local producers; (2) trading companies and their exporting goods suppliers locate in different cities. The real world is between these two extreme situations.

Table 2.7: Alternative measures of processing exports and skill premium

	Premium with individual characteristics			Premium without individual characteristics		
	(1)	(2)	(3)	(4)	(5)	(6)
	ΔPremium	ΔPremium	ΔPremium	ΔPremium	ΔPremium	ΔPremium
ΔPE^H	0.143***	0.140***	0.143***	0.228***	0.225***	0.228***
	(0.033)	(0.024)	(0.025)	(0.056)	(0.040)	(0.041)
ΔPE^L	-0.490**	-0.491**	-0.503**	-0.757**	-0.760**	-0.777**
	(0.185)	(0.135)	(0.143)	(0.323)	(0.237)	(0.251)
$\Delta \frac{\text{Ordinary Export}}{\text{Industry Output}}$	0.278***	0.282***	0.280***	0.398***	0.404***	0.401***
	(0.076)	(0.077)	(0.079)	(0.116)	(0.117)	(0.115)
$\Delta \frac{\text{Capital Stock}}{\text{Industry Output}}$	0.358*	0.348	0.350*	0.535*	0.519*	0.522*
	(0.192)	(0.195)	(0.193)	(0.260)	(0.265)	(0.263)
$\Delta(TFP)$	0.014**	0.014**	0.011	0.025*	0.024*	0.024*
	(0.006)	(0.007)	(0.006)	(0.011)	(0.011)	(0.013)
R^2	0.86	0.861	0.862	0.843	0.843	0.843
N	339	339	339	339	339	339
Trading Companines	Y		Y	Y		Y
Developing Countries		Y	Y		Y	Y

Notes: All regressions are weighted by the start-of-the-period city's population. All regre -ssions include the controls in the specification (4) of Table 2.5. Standard errors are clust -ered at the province level and shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

offshoring takes into account the products outsourced from developing countries to China. Besides, it also considers the possibility that outsourced goods from developed countries would be sold to other countries instead of shipping back to outsourcing countries. The results reported in Column 2 are consistent with the benchmark results. The reason is that although the fraction of processing exports to developing countries in China's total processing exports increases continuously from 7.43% to 11.36%, processing exports to developed countries still account for the vast majority during the sample period.

In column (3), I add processing exports by trading companies and processing exports to non-developed countries into the sample together. It could be regarded as the combination of processing export measures used in columns (1) and (2). In this composite measure, low, medium, and high skill-intensive industries account for 23%, 18%, and 59% of China's total processing exports, respectively, on average between 2000 and 2006. It is close to the skill distribution of China's processing exports in the benchmark case. Therefore, the results under the new measure of processing exports remain stable.

From columns (4) to (6), I switch to using the estimated skill premium from the Mincer regression without including individual characteristics and do the same robustness test as columns (1) to (3), respectively.[49] The alternative measure of skill premium doesn't take into account the effects of individual characteristics on skill premium. Under the alternative estimation of skill premium, the positive (negative) impact of the high-skill (low-skill) demand shock on skill premium is still statistically significant. However, the magnitudes of

[49] According to Equation (24), the alternative measure of skill premium becomes $\alpha_{it} = E(ln(w_{jit})|E_j = 1, \delta_{it}) - E(ln(w_{jit})|E_j = 0, \delta_{it})$, without including individual characteristics.

Table 2.8: Changes in skill premium and total export demand shocks

	(1) ΔPremium	(2) ΔPremium	(3) ΔPremium	(4) ΔPremium
ΔTE^H	0.089***	0.095***	0.097***	0.123***
	(0.025)	(0.025)	(0.032)	(0.019)
ΔTE^L	-0.196**	-0.248**	-0.258**	-0.414**
	(0.094)	(0.090)	(0.119)	(0.119)
$\Delta\frac{\text{Capital Stock}}{\text{Industry Output}}$			0.194*	0.277*
			(0.089)	(0.144)
ΔTFP			0.023*	0.012
			(0.013)	(0.008)
R^2	0.396	0.409	0.418	0.852
N	440	439	424	424
Province×Year	Y	Y	Y	Y
Initial conditions		Y	Y	Y
City Dummy				Y

Notes: All regressions are weighted by the start-of-the-period city's population. Initial conditions include the start of period school captial per capita and log GDP per capita. Standard errors are clustered at the province level and shown in parentheses. * $p < 0.10$,** $p < 0.05$, *** $p < 0.01$.

these corresponding effects are larger than that in the baseline results.

2.7.3 Skill demand embodied in total exports

In the regression model, I use the ratio of ordinary exports to industrial output to control ordinary exports' effect on skill premium. However, the fraction doesn't imply ordinary exports' skill composition and distribution. To capture the effect of total exports on skill premium comprehensively, being analogous to equation (2.26), I construct the high- and low-skill demand shocks for total exports as

$$\Delta PE_{it}^{H} = \sum_{k} \frac{H_{ik0}}{E_{ik0}} \frac{\Delta TE_{ikt}}{H_{i0}} \quad \text{and} \quad \Delta PE_{it}^{L,I} = \sum_{k} \frac{L_{ik0}}{E_{ik0}} \frac{\Delta TE_{ikt}}{L_{i0}} \tag{2.30}$$

where ΔTE_{ikt} represents changes in total exports for industry k in city i and period t. The city-industry-specific factor intensities, $\frac{H_{ik0}}{E_{ik0}}$ and $\frac{L_{ik0}}{E_{ik0}}$, and the city-level factor endowments, H_{i0} and L_{i0}, are the same as that in (2.26).

I take the regressions of the change in skill premium on the total export demand shocks. The estimation results are shown in Table 2.8. The results show that the high-skill (low-skill) total export demand shock has a statistically significant and positive (negative) effect on skill premium. Quantitatively, the results in Column (4) imply that skill premium in the cities at the 25th percentile of ΔTE^H increased by 0.010 log point less than those in the cities at the 75th percentile. Similarly, skill premium in the cities at the 25th percentile of ΔTE^L increased by 0.013 log point more than those in the cities at the 75th percentile. These interquartile difference account for 4.28% and 5.3% of the interquartile change in skill premium between 2000 and 2006, respectively.

2.8 Conclusion

In this chapter, I construct the two-country, two-factor Heckscher-Ohlin model in which the offshoring production activities from the developed country increase skill premium in the developing country. Using the Chinese Urban Household Survey data, I explore the effects of processing export on skill premium in China between 2000 and 2006. Constructing corresponding high- and low-skill demand shocks, I analyze whether cities more exposed to processing exports experienced larger changes in skill premium relative to cities less exposed to processing exports.

I obtain two main findings in this chapter. Firstly, the reduction in import tariffs by trading partners, offshoring costs, and increased foreign investment contribute significantly to China's processing exports. Especially, the high-skill intensive industries benefit more from the economic policy zones, infrastructure investment, and ownership liberality policy than low-skill intensive industries. It confirms China's skill-upgrading policy for processing exports. Secondly, processing export expansion has differential effects on skill premium, depending on the initial industry composition of a city's processing exports. Cities initially specializing in high-skill intensive industries had stronger positive wages premium shocks than those initially specializing in low-skill intensive industries.

The findings in this chapter have direct policy implications for developing countries increasingly integrated into the global value chain. If developing countries intend to benefit more from the production globalization, they should join in relevant trade agreements to reduce trade friction, increase infrastructure investment to reduce offshoring costs, and relax ownership restrictions for foreign investors. In this way, foreign companies have an incentive to transfer relatively more high-skill intensive production activities to developing countries. Moreover, the skill-upgrading expansion in offshoring increases the return to high-skill workers in the developing countries, consequentially enhancing human capital accumulation and economic growth in the long run.

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Appendices

A Proof for Proposition 1

Here I define $\widehat{x} = d(ln(x)) = \frac{dx}{x}$ as the logarithmic change of variable x. Then

Step 1 Equation (7) implies that the final good producer in North is indifferent between sourcing from domestic and foreign market at the cutoff stage z^*. Take the log differential in both sides of Equation (7) as follows:

$$d(ln(c_{NN}(w_N^L, w_N^H, z^*))) = d(ln(c_{SN}(w_S^L, w_S^H, z^*, \tau)))$$

$$\frac{\partial ln(c_{NN})}{\partial z^*}dz^* + \frac{\partial ln(c_{NN})}{\partial w_N^L}dw_N^L + \frac{\partial ln(c_{NN})}{\partial w_N^H}dw_N^H =$$

$$\frac{\partial ln(c_{SN})}{\partial z^*}dz^* + \frac{\partial ln(c_{SN})}{\partial w_S^L}dw_S^L + \frac{\partial ln(c_{SN})}{\partial w_S^H}dw_S^H + \frac{\partial ln(c_{SN})}{\partial \tau}d\tau$$

$$\frac{\partial ln(c_{NN})}{\partial z^*}dz^* + (1-z^*)\widehat{w_N^L} + z^*\widehat{w_N^H} = \frac{\partial ln(c_{SN})}{\partial z^*}dz^* + (1-z^*)\widehat{w_S^L} + z^*\widehat{w_S^H} + \widehat{\tau}$$

$$(\frac{\partial ln(c_{SN})}{\partial z^*} - \frac{\partial ln(c_{NN})}{\partial z^*})dz^* = \left[(1-z^*)\widehat{w_N^L} + z^*\widehat{w_N^H}\right] - \left[(1-z^*)\widehat{w_S^L} + z^*\widehat{w_S^H}\right] - \widehat{\tau} \quad (A.1)$$

According to the production technology of intermediate inputs, z^* not only denotes the skill intensity of intermediate input, but also represents the share of high-skill workers in total labor costs of producing intermediate input z^*. That is $z^* = \frac{w_j^H H_j(z^*)}{w_j^H H_j(z^*) + w_j^L L_j(z^*)}$, $j = N, S$.

Step 2 Define λ_j as the fraction of high-skill workers in total labor income in country j. That is $\lambda_j = \frac{w_j^H H_j}{w_j^H H_j + w_j^L L_j}$, $j = N, S$. Thus,

$$\begin{aligned}
(1-z^*)\widehat{w_S^L} + z^*\widehat{w_S^H} &= \widehat{w_S^L} + z^*(\widehat{w_S^H} - \widehat{w_S^L}) \\
&= (\lambda_S + (1-\lambda_S))\widehat{w_S^L} + z^*(\widehat{w_S^H} - \widehat{w_S^L}) \\
&= (1-\lambda_S)\widehat{w_S^L} + \lambda_S\widehat{w_S^H} - \lambda_S\widehat{w_S^H} + \lambda_S\widehat{w_S^L} + z^*(\widehat{w_S^H} - \widehat{w_S^L}) \\
&= (1-\lambda_S)\widehat{w_S^L} + \lambda_S\widehat{w_S^H} + (z^* - \lambda_S)(\widehat{w_S^H} - \widehat{w_S^L}) \\
&= (1-\lambda_S)\widehat{w_S^L} + \lambda_S\widehat{w_S^H} + (z^* - \lambda_S)\frac{\partial ln(\frac{w_N^H}{w_N^L})}{\partial z^*}dz^* \qquad (A.2)
\end{aligned}$$

Using the labor market clearing conditions for the South, Equation (13) and (14), I can obtain:

$$w_S^L L_S + w_S^H H_S = w_S^L \left[\int_0^{z^*} \frac{\eta(z) Y_N P_N}{c_{jN}(z)} \left(\frac{w_S^H}{w_S^L}\right)^z (1-z)dz + (1-\alpha) Y_S \left(\frac{w_S^H}{w_S^L}\right)^\alpha \right]$$

$$+ w_S^H \left[\int_0^{z^*} \frac{\eta(z) Y_N P_N}{c_{jN}(z)} \left(\frac{w_S^H}{w_j^L}\right)^{z-1} zdz + \alpha Y_S \left(\frac{w_S^H}{w_S^L}\right)^{\alpha-1} \right]$$

$$= \int_0^{z^*} \frac{\eta(z) Y_N P_N}{c_{jN}(z)} {w_S^H}^z {w_S^L}^{1-z} dz + Y_S P_S$$

$$= \int_0^{z^*} \frac{\eta(z) Y_N P_N}{\tau} dz + Y_S P_S$$

$$= \int_0^{z^*} \frac{\eta(z) \alpha E}{\tau} dz + (1-\alpha) E \quad \text{because} \quad P_N Y_N = \alpha E, \quad P_S Y_S = (1-\alpha) E$$

$$= \left(\int_0^{z^*} \frac{\eta(z)\alpha}{\tau} dz + (1-\alpha) \right) E$$

$$= \left(\int_0^{z^*} \frac{\eta(z)\alpha}{\tau} dz + (1-\alpha) \right) \quad \text{because} \quad E = 1 \quad \text{by normalization} \quad (A.3)$$

Since $w_S^L L_S + w_S^H H_S = E_S$, take the log differentiation in both sides of Equation (A.3) as follows:

$$(1-\lambda_S)\widehat{w_S^L} + \lambda_S \widehat{w_S^H} = \frac{1}{E_S} \left(\frac{\eta(z^*)\alpha}{\tau} dz^* - \frac{\int_0^{z^*} \eta(z)\alpha dz}{\tau} \widehat{\tau} \right) \qquad (A.4)$$

By substituting Equation (A.4) into Equation (A.2), I can obtain:

$$(1-z^*)\widehat{w_S^L} + z^* \widehat{w_S^H} = \left(\frac{\eta(z^*)\alpha}{tE_S} + (z^* - \lambda_S) \frac{\partial ln(\frac{w_S^H}{w_S^L})}{\partial z^*} \right) dz^* - \frac{\int_0^{z^*} \eta(z)\alpha dz}{\tau E_S} \widehat{\tau} \qquad (A.5)$$

Similarly, using the labor market clearing condition for the North, I can obtain:

$$(1-z^*)\widehat{w_N^L} + z^* \widehat{w_N^H} = \left(-\frac{\eta(z^*)\alpha}{E_N} + (z^* - \lambda_N) \frac{\partial ln(\frac{w_N^H}{w_N^L})}{\partial z^*} \right) dz^* \qquad (A.6)$$

Step 3

By substituting Equation (A.5) and (A.6) into Equation (A.1), I can obtain

$$(\frac{\partial ln(c_{SN})}{\partial z^*} - \frac{\partial ln(c_{NN})}{\partial z^*}) dz^* = \left(-\left(\frac{\eta(z^*)\alpha}{E_N} + \frac{\eta(z^*)\alpha}{tE_S} \right) + (z^* - \lambda_N) \frac{\partial ln(\frac{w_N^H}{w_N^L})}{\partial z^*} - (z^* - \lambda_S) \frac{\partial ln(\frac{w_S^H}{w_S^L})}{\partial z^*} \right) dz^*$$

$$+ \left(\frac{\int_0^{z^*} \eta(z)\alpha dz}{\tau E_S} - 1 \right) \widehat{\tau}$$

The equation can be simplified as:

$$\frac{dz^*}{d\tau} = (\tau * B)^{-1}\left(\frac{\int_0^{z^*}\eta(z)\alpha dz}{tE_S} - 1\right) \qquad (A.7)$$

with

$$B = \underbrace{(\frac{\partial ln(c_{SN})}{\partial z^*} - \frac{\partial ln(c_{NN})}{\partial z^*})}_{(i)} + \underbrace{(\frac{\eta(z^*)\alpha}{E_N} + \frac{\eta(z^*)\alpha}{\tau E_S})}_{(ii)} + \underbrace{(z^* - \lambda_S)\frac{\partial ln(\frac{w_S^H}{w_S^L})}{\partial z^*} - (z^* - \lambda_N)\frac{\partial ln(\frac{w_N^H}{w_N^L})}{\partial z^*}}_{(iii)}$$

where $(i) > 0$ because it is the difference between the slopes of the uni-cost curves of intermediate input for the North and the South, which is positive; (ii) is obviously positive; according to the definitions of λ_j, $j = N, S$, since the cost share of high-skill worker used in z^* in North (South) is less (more) than the average for the North (South), $z^* > \lambda_S$ ($z^* < \lambda_N$) and (iii) is also positive. In summary, $B > 0$. Besides, since $\tau > 1$ and $\int_0^{z^*}\eta(z)\alpha dz < E_S$, $\frac{\int_0^{z^*}\eta(z)\alpha dz}{\tau E_S} - 1 < 0$. In general, the cutoff stage z^* decreases with the offshoring cost τ. □

B Proof for Proposition 2

(a) Take the log-differential in both sides of D_S as defined in Equation (17):

$$ln(D_S) = ln\left(\int_0^{z^*}\frac{\eta(z)}{c_{SN}(z)}h_{SN}(z)dz\right) - ln\left(\int_0^{z^*}\frac{\eta(z)}{c_{SN}(z)}l_{SN}(z)dz\right) \qquad (B.1)$$

$$\begin{aligned}\frac{\partial ln(D_S)}{\partial z^*} &= \frac{\frac{\eta(z^*)}{c_{SN}(z^*)}h_{SN}(z^*)}{\int_0^{z^*}\frac{\eta(z)}{c_{SN}(z^*)}h_{SN}(z)dz} - \frac{\frac{\eta(z^*)}{c_{SN}(z^*)}l_{SN}(z^*)}{\int_0^{z^*}\frac{\eta(z^*)}{c_{SN}(z^*)}l_{SN}(z)dz} \\ &= \frac{\frac{\eta(z^*)}{c_{SN}(z^*)}l_{SN}(z^*)}{\int_0^{z^*}\frac{\eta(z)}{c_{SN}(z^*)}h_{SN}(z)dz}\left(\frac{h_{SN}(z^*)}{l_{SN}(z^*)} - \frac{\int_0^{z^*}\frac{\eta(z)}{c_{SN}(z^*)}h_{SN}(z)dz}{\int_0^{z^*}\frac{\eta(z)}{c_{SN}(z^*)}l_{SN}(z)dz}\right) \\ &= \frac{\frac{\eta(z^*)}{c_{SN}(z^*)}l_{SN}(z^*)}{\int_0^{z^*}\frac{\eta(z)}{c_{SN}(z^*)}h_{SN}(z)dz}\left(\frac{h_{SN}(z^*)}{l_{SN}(z^*)} - \frac{H_{SN}}{L_{SN}}\right) \qquad (B.2)\end{aligned}$$

Since the skill intensity of the cutoff task z^* is larger than the average skill intensity of tasks in South, $\frac{h_{SN}(z^*)}{l_{SN}(z^*)} > \frac{H_{SN}}{L_{SN}}$. That is $\frac{\partial ln(D_S)}{\partial z^*} > 0$.

Similarly, for the North, take the log-differentiation in both sides of D_N defined in Equation (17), I can obtain:

$$\frac{\partial ln(D_N)}{\partial z^*} = \frac{\frac{\eta(z^*)}{c_{NN}(z^*)}l_{NN}(z^*)}{\int_0^{z^*}\frac{\eta(z)}{c_{NN}(z^*)}h_{NN}(z)dz}\left(\frac{H_{NN}}{L_{NN}} - \frac{h_{NN}(z^*)}{l_{NN}(z^*)}\right) \qquad (B.3)$$

Since the skill intensity of the cutoff task z^* is smaller than the average skill intensity of tasks in the North, $\frac{h_{NN}(z^*)}{l_{NN}(z^*)} < \frac{H_{NN}}{L_{NN}}$. That is $\frac{\partial ln(D_N)}{\partial z^*} > 0$. In summary, the rising offshoring cutoff stage z^* raises the relative skill demand for producing intermediate inputs in these two countries.

(b) According to the labor market clearing conditions for the South, Equation (11) and (12), I can obtain

$$\frac{w_S^H H_S}{w_S^L L_S} = \frac{\int_0^{z^*} \frac{\eta(z) Y_N P_N}{c_{SN}(z)} {w_S^H}^z {w_S^L}^{1-z} z dz + \beta Y_S {w_S^H}^\beta {w_S^L}^{1-\beta}}{\int_0^{z^*} \frac{\eta(z) Y_N P_N}{c_{SN}(z)} {w_S^H}^z {w_S^L}^{1-z} (1-z) dz + (1-\beta) Y_S {w_S^H}^\beta {w_S^L}^{1-\beta}} \quad (B.3)$$

Since $Y_N P_N = \alpha E$ and $Y_S P_S = (1-\alpha)E$, Equation (B.3) can be simplified as:

$$\frac{w_S^H H_S}{w_S^L L_S} = \frac{\int_0^{z^*} \frac{\eta(z) \alpha E}{c_{SN}(z)} {w_S^H}^z {w_S^L}^{1-z} z dz + \beta \frac{(1-\alpha)E}{P_S} {w_S^H}^\beta {w_S^L}^{1-\beta}}{\int_0^{z^*} \frac{\eta(z) \alpha E}{c_{SN}(z)} {w_S^H}^z {w_S^L}^{1-z} (1-z) dz + (1-\beta) \frac{(1-\alpha)E}{P_S} {w_S^H}^\beta {w_S^L}^{1-\beta}} \quad (B.4)$$

Using the formula of $c_{jN}(z)$ defined in Equation (6), Equation (B.4) can be simplified as:

$$\frac{w_S^H H_S}{w_S^L L_S} = \frac{\alpha \int_0^{z^*} \frac{\eta(z) z}{\tau} dz + \beta(1-\alpha)}{\alpha \int_0^{z^*} \frac{\eta(z)(1-z)}{\tau} dz + (1-\beta)(1-\alpha)} \quad (B.5)$$

Multiplying $\frac{L_S}{H_S}$ in both sides of Equation (B.5), I can obtain the wage premium in the South as a function of z^*, L_S, H_S, β, and α:

$$\frac{w_S^H}{w_S^L} = \frac{L_S}{H_S} \frac{\alpha \int_0^{z^*} \eta(z) z dz + \beta(1-\alpha)\tau}{\alpha \int_0^{z^*} \eta(z)(1-z) dz + (1-\beta)(1-\alpha)\tau} \quad (B.6)$$

Taking the partial derivative of $\frac{w_S^H}{w_S^L}$ respect to z^*, it would be

$$\begin{aligned}
\frac{\partial \frac{w_S^H}{w_S^L}}{\partial z^*} &= \frac{L_S}{H_S} \frac{\alpha \eta(z^*) z^* \left(\alpha \int_0^{z^*} \eta(z)(1-z) dz + (1-\beta)(1-\alpha)\tau\right) - \alpha \eta(z^*)(1-z^*) \left(\alpha \int_0^{z^*} \eta(z) z dz + \beta(1-\alpha)\tau\right)}{\left(\alpha \int_0^{z^*} \eta(z)(1-z) dz + (1-\beta)(1-\alpha)\tau\right)^2} \\
&= \frac{L_S}{H_S} \frac{\alpha \eta(z^*) z^* \left(\alpha \int_0^{z^*} \eta(z) dz + (1-\alpha)\tau\right) - \alpha \eta(z^*) \left(\alpha \int_0^{z^*} \eta(z) z dz + \beta(1-\alpha)\tau\right)}{\left(\alpha \int_0^{z^*} \eta(z)(1-z) dz + (1-\beta)(1-\alpha)\tau\right)^2} \\
&= \frac{L_S}{H_S} \frac{\alpha \eta(z^*) \left(\alpha \int_0^{z^*} \eta(z)(z^*-z) dz + (1-\alpha)(z^*-\beta)\tau\right)}{\left(\alpha \int_0^{z^*} \eta(z)(1-z) dz + (1-\beta)(1-\alpha)\tau\right)^2} \quad (B.7)
\end{aligned}$$

According to Assumption 2, $\alpha \int_0^{z^*} \eta(z)(z^*-z) dz + (1-\alpha)(z^*-\beta)\tau > 0$, so $\frac{\partial \frac{w_S^H}{w_S^L}}{\partial z^*} > 0$.

Similarly, using the labor market clearing condition for North, Equation (13) and (14), I can obtain

$$\frac{w_N^H}{w_N^L} = \frac{L_N}{H_N} \frac{\int_{z^*}^1 \eta(z) z dz}{\int_{z^*}^1 \eta(z)(1-z) dz} \quad (B.8)$$

Taking the partial derivative of $\frac{w_N^H}{w_N^L}$ respect to z^*, I can obtain

$$\begin{aligned}
\frac{\partial \frac{w_N^H}{w_N^L}}{\partial z^*} &= \frac{L_N}{H_N}\frac{-\eta(z^*)z^*\int_{z^*}^1 \eta(z)(1-z)dz + \eta(z^*)(1-z^*)\int_{z^*}^1 \eta(z)zdz}{\left(\int_{z^*}^1 \eta(z)(1-z)dz\right)^2} \\
&= \frac{L_N}{H_N}\frac{-\eta(z^*)z^*\int_{z^*}^1 \eta(z)dz + \eta(z^*)\int_{z^*}^1 \eta(z)zdz}{\left(\int_{z^*}^1 \eta(z)(1-z)dz\right)^2} \\
&= \frac{L_N}{H_N}\frac{\eta(z^*)\int_{z^*}^1 \eta(z)(z-z^*)dz}{\left(\int_{z^*}^1 \eta(z)(1-z)dz\right)^2} \\
&> 0 \quad \text{because} \quad \eta(z)(z-z^*) > 0 \quad \text{for all} \quad z \in (z^*, 1) \qquad (B.9)
\end{aligned}$$

In summary, both wage premium in the two countries increase as more relative skill-intensive tasks are shifted from the North to the South (the offshoring cutoff stage z^* increases).□

C Additional data summary and empirical analysis

Table C.1: Effect of policy zones and infrastructure on changes in wage premium

	Changes in wage premium			
Panel A: Economic policy zones except Processing Export Zone				
	1992-2000		1996-2000	
$Wage\ premium_0$	-0.634***	-0.607***	-0.534***	-0.522
	(0.160)	(0.155)	(0.106)	(0.110)
$National\ policy\ zones_0$	0.017	0.016	-0.020	-0.018
	(0.012)	(0.012)	(0.025)	(0.025)
$Provincial\ policy\ zones_0$	-0.021	-0.016	0.010	0.010
	(0.028)	(0.026)	(0.010)	(0.010)
$Density\ of\ highways_0$	0.027	0.029	0.005	0.003
	(0.054)	(0.051)	(0.027)	
Control variables		Y		Y
N	82	82	90	90
R^2	0.207	0.291	0.292	0.311
Panel B: Processing Export Zone				
	2000-2006		2004-2006	
$Wage\ premium_0$	-0.519***	-0.514***	-0.395***	-0.391***
	(0.088)	(0.081)	(0.070)	(0.071)
$National\ policy\ zones_0$	0.012	0.010	0.016	0.012
	(0.018)	(0.008)	(0.012)	(0.016)
$Provincial\ policy\ zones_0$	0.03	0.01	0.006	0.004
	(0.04)	(0.03)	(0.03)	(0.003)
$Density\ of\ highways_0$	0.048	0.052	-0.015	-0.018
	(0.056)	(0.056)	(0.025)	(0.026)
Control variables		Y		Y
N	86	86	180	180
R^2	0.36	0.34	0.15	0.15

Notes: Panel A tests the effect of economic policy zones built-in 1992-1996 on wage premium, including the High-tech Development Areas, Bonded Areas, and Economic and Technological Development Zones; Panel B does the same examination but for Processing Export Zones built-in 2000-2004. The independent variables shown in the table are the initial values of skill premium, the number of economic policy zones, and the density of highways in corresponding periods. The control variables include the initial values of export-output ratio, capital-output ratio, and TFP. * $p < 0.10$,** $p < 0.05$, *** $p < 0.01$.

Table C.2: Skill intensities of manufacturing industries at 2-digit Level

Skill Intensity	2000	2004
Low	19. Leathers,Furs and related products (1.35%)	19. Leathers,Furs and related products (4.17%)
	21. Furniture Manufacturing (1.48%)	18. Garments, Footwear and Related Products (5.39%)
	18. Garments, Footwear and Related Products (1.55%)	42. Manufacturing, n.e.c. (5.67%)
	43. Recycling and Disposal of Waste (1.56%)	24. Cultural,Edu. and Sport Goods (5.87%)
	42. Manufacturing, n.e.c. (1.57%)	17. Textiles (6%)
	20. Timber Processing and Related Products (1.72%)	21. Furniture Manufacturing (7.67%)
	24. Cultural,Edu. and Sport Goods (2.61%)	20. Timber Processing and Related Products (7.76%)
	17. Textiles (2.74%)	29. Rubber Products (9.88%)
	13. Food Processing (3.77%)	31. Nonmetal Mineral Products (10.01%)
	34. Metal Products (3.86%)	30. Plastic Products (10.02%)
Medium	30. Plastic Products (3.92%)	43. Recycling and Disposal of Waster (10.63%)
	31. Nonmetal Mineral Products (3.99%)	22. Pulp, Paper, Paper Products (10.76%)
	22. Pulp, Paper, Paper Products (4.87%)	34. Metal Products (11.02%)
	14. Food Production (5.93%)	13. Food Processing (12.69%)
	23. Printing and Publishing (6.68%)	23. Printing and Publishing (14.76%)
	29. Rubber Products (7.79%)	28. Cultural,Edu. and Sport Goods (15.16%)
	39. Electric Equipment and Machinery (9.59%)	14. Food Production (16.79%)
	15. Beverage (9.61%)	35. General Machinery Production (16.98)
	35. General Machinery Production (9.98%)	39. Electric Equipment and Machinery (17.11%)
	28. Chemical Fiber (10.82%)	33. Smelting and Pressing of Nonferrous Metals (18.3%)
High	37. Transport Equipment (11.35%)	15. Beverage (20.62%)
	41. Cultural and Office Machinery, meters (12.73%)	32. Smelting and Pressing of Ferrous Metals (21.59%)
	33. Smelting and Pressing of Nonferrous Metals (12.77%)	26. Chemical Raw Materials and Products (21.62%)
	32. Smelting and Pressing of Ferrous Metals (13.2%)	40. Electronic and Telecomm. Equipment (22.2%)
	26. Chemical Raw Materials and Products (13.48%)	36. Special Machinery Production (23.05%)
	40. Electronic and Telecomm. Equipment (13.87%)	25. Petroleum Processing and Coking (23.84%)
	16. Tobacco (14.02%)	37. Transport Equipment (23.97%)
	36. Special Machinery Production (14.69%)	41. Cultural and Office Machinery, meters (25.61%)
	25. Petroleum Processing and Coking (21.26%)	16. Tobacco (30.19%)
	27. Medical and Pharmaceutical Products (22.06%)	27. Medical and Pharmaceutical Products (36.25%)
Mean	7.27%	13.16%
Std. dev	4.97%	5.85%

Notes: 2-digit CIC codes are ahead of manufacturing sectors' name and sector-specific skill intensities are in the parentheses. Sectors belonging to the bottom 33% , middle 33%, and top 33% are treated as low-, medium- and high-skill groups, respectively.

Table C.3: Summary statistics of control variables in the main stage of estimation

	10th	25th	50th	75th	90th	Mean	Std
Panel A: $\Delta \frac{\text{Ordinary Export}}{\text{Industry Output}}$							
00-04	-0.006	0.001	0.008	0.018	0.043	0.008	0.043
04-06	-0.015	-0.003	0.002	0.011	0.048	0.011	0.052
00-06	-0.018	-0.001	0.007	0.020	0.071	0.016	0.056
Panel B: $\Delta \frac{\text{Capital}}{\text{Industry Output}}$							
00-04	0.220	0.254	0.309	0.373	0.449	0.323	1.096
04-06	0.110	0.140	0.179	0.219	0.260	0.181	0.060
00-06	0.317	0.416	0.492	0.586	0.710	0.509	0.147
Panel C: ΔTFP (%)							
00-04	0.434	0.759	1.028	1.337	1.578	1.040	0.424
04-06	-0.032	0.191	0.492	0.798	0.1.160	0.516	0.420
00-06	1.113	1.217	1.466	1.699	2.000	1.501	0.348

Notes: The number of city in the sample is 192.

Table C.4: Summary statistics of total export demand shocks

	10th	25th	50th	75th	90th	Mean	Std
Panel A: ΔTE^H							
00-04	-0.003	0.002	0.017	0.069	0.349	0.182	0.669
04-06	-0.030	-0.012	-0.001	0.034	0.159	0.066	0.430
00-06	-0.008	-0.001	0.010	0.085	0.432	0.248	1.012
Panel B: ΔTE^L							
00-04	0	0.001	0.005	0.023	0.123	0.064	0.222
04-06	-0.006	-0.002	0	0.006	0.055	0.018	0.104
00-06	-0.002	0	0.003	0.032	0.180	0.088	0.336

Notes: The number of city in the sample is 192. Unit of high- and low-skill demand shocks is 1000 USD.

Table C.5: Skill premium and the ratio of processing export to industrial output

	(1) ΔPremium	(2) ΔPremium	(3) ΔPremium	(4) ΔPremium	(5) ΔPremium
$\Delta \frac{\text{Processing exports}}{\text{Industrial Output}}$	0.357***	0.396***	0.365***	0.401***	0.376***
	(0.129)	(0.127)	(0.118)	(0.076)	(0.057)
$\Delta \frac{\text{Ordinary export}}{\text{Industrial Output}}$			0.383***	0.261***	0.261***
			(0.082)	(0.076)	(0.077)
$\Delta \frac{\text{Capital stock}}{\text{Industrial output}}$			0.350*	0.376*	0.373*
			(0.181)	(0.209)	(0.207)
ΔTFP			0.033**	0.012*	0.011**
			(0.013)	(0.007)	(0.006)
Kleibergen-Paap rk LM statistic					4.264*
Kleibergen and Paap Wald F statistic					472.769
R^2	0.414	0.420	0.455	0.859	0.734
N	440	439	349	349	349
Province×Year	Y	Y	Y	Y	Y
Initial conditions		Y	Y	Y	Y
City Dummy				Y	Y

Notes: All regressions are weighted by the start-of-the-period city's population. Initial conditions include the start of period school captial per capita and log GDP per capita. Standard errors are clustered at the province level and shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Curriculum Vitae

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