Trade Liberalization, Export quality and Wage inequality: Evidence from China

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Abstract

This paper explores the impacts of trade liberalization on wage inequality between skilled and unskilled labor in the presence of endogenous quality choice of firms. We consider two types of trade liberalization: tariff reduction in intermediates and tariff reduction in final goods. We capture the causal effect of input trade liberalization on wage inequality by adopting the firms that are exempted from the input tariff as a natural control group. Using the Chinese firm-level production data, we find that input trade liberalization widens the wage inequality of skills and improves the export quality of Chinese firms. We also provide evidence that tariff reduction in the final goods narrows the wage inequality of domestic firms between skilled and unskilled labor, which is associated with lower export quality.

Keywords: Trade liberalization, export quality, wage inequality, firm heterogeneity

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1 Introduction

Traditional trade theory indicates that trade liberalization would have narrowed the wage inequality between skilled and unskilled workers as developing countries are abundant in unskilled labor. However, the fact is developing countries tend to have a rising trend of wage inequality of skills accompanied by substantial breakthroughs in trade liberalization in recent decades. Many studies have proposed various channels to explain this puzzle, such as skill-biased technological change, offshoring and labor market frictions. But few of them highlighted the following facts. First, the impacts of trade liberalization on wage inequality of skills are heterogeneous across firms[3]. Second, quality is endogenous determined in the production of firms, which can be affected by trade liberalization[4]. The third is the pervasive evidence that producing high-quality products needs higher-quality inputs, such as higher-skilled labor or imported intermediates[Hallak (2010), Fajgelbaum et al. (2011), Fieler et al. (2016)].

In this paper, we explain the rising wage inequality of skills from trade liberalization via firms' endogenous quality choice. To achieve this, we develop a theoretical model with firm heterogeneity, endogenous quality choices, and various inputs, including different types of skill inputs. The model argues that quality, as an essential feature of products, is determined endogenously by the demand side and supply side of firms. In the model, we assume consumers prefer products with high quality-price ratios rather than low price only. In a sense, trade liberalization will change the firm's production decision as well as quality choices. The model further constructs the input linkage of endogenous quality by introducing various skills and intermediates in the production function. Producing high-quality uses high-quality labor and quality upgrading of firms will improve the relative price of skilled labor. This paper explores the impact of trade liberalization on wage inequality of the skills through endogenous quality choices of heterogeneous firms.

[3] An increasing amount of literature study the impact of trade liberalization on wage inequality in terms of firm heterogeneity such as Yeaple (2005),Helpman et al. (2010),Amiti and Davis (2012) and Kamal et al. (2014)

[4] Many studies that present trade liberalization will upgrade quality of exporters such as Goldberg et al. (2009),Haruyama et al. (2008),Fan et al. (2015),Martin and Mejean (2014),Bas and Strauss-Kahn (2015),Antoniades (2015).

The model predicts that tariff reduction could change the wage inequality of skills within firms through the channel of endogenous quality choice. Trade liberalization will rule inefficient firms out of the domestic market and reduce domestic profits with fierce competition. For domestic firms and small exporters whose overseas profits cannot make up the domestic profit loss, their quality is lowered to reduce cost and maintain eligible profits, which further decreases the relative wages of skilled workers. For large exporters whose trading cost is largely reduced by tariff reduction, they tend to upgrade the quality to keep competitive. The model also considers the effect of input tariff reduction and finds that firms using imported inputs raise quality and promise to pay more to skilled labor for quality upgrading. But for firms using domestic intermediates, import tariff reduction would degrade their quality and narrow the wage gaps between skilled workers and unskilled workers. The model also predicts that the effect of trade liberalization on wage inequality through quality upgrading is more significant for firms in dual trade than those only import or export.

The paper constructs a Chinese micro-database in combination with the annual surveys conducted by the National Bureau of Statistics (NBS), the product-level transaction statistics of Chinese Customs, and the product-level tariff data of WTO Tariff Database during 2000-2006[5]. Using the firm production data, we estimate the endogenous quality of firms from the model. Our estimates indicate that the average quality of Chinese firms was slightly declining in 2000- 2006 as a result of the quality degradation of low-quality firms. The exporters using imported intermediates have a higher average quality than exporters using domestic inputs only. For exporters with higher productivity or exporting scales, their exporting quality is higher than inefficient exporters.

The data also enables us to estimate the wage inequality of skills within firms, which is rarely studied in China due to data limitation[6]. In the paper, we introduce the fair-wage

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[5] China entered the WTO in 2001 and thus experienced a dramatic trend of trade liberalization and trade explosion during 2000-2006. We also provide a robustness check using more recent data from 2000 to 2011.

[6] The previous wage inequality studies of China were limited to the regional level [Wood et al. (1997);Han et al. (2012)], sectoral level [Khan and Riskin (1998)] or firm-level with small samples [Xu and Li (2008)]. The reason for

constraint[7] in the model and estimate the fair wage gaps among skilled, semi-skilled and unskilled workers. The estimates enable us to conduct the counterfactual exercise as fair wage rates depend on firm-level renting shares instead of the compositional changes of the firm-specific labor [Frıas et al. (2009); Egger et al. (2013)]. As nominal wages promised by the firms, the fair wage will motivate skilled labors to upgrade quality without changing skilled input share. Our estimation results indicate that the absolute annual wage gap between skilled labor and unskilled labor is 18,325 RMB (about $2300) and the absolute annual wage gap between semi-skilled labor and unskilled labor is 7,528 RMB (about $940). The results also show high heterogeneity of skill fair wage gaps across sectors. Labor-intensive sectors such as textile and apparel have larger wage gaps between skilled and unskilled labor than capital-intensive sectors. But the wage gaps between semi-skilled and unskilled labor are smaller across the sectors. In some energy-intensive sectors, the semi-skilled wage is even higher than the skilled wage.

With the estimates, we study the relationship between trade liberalization, export quality, and wage premium of skills empirically. We consider two types of trade liberalization: tariff reduction in intermediates and tariff reduction in final goods. We capture the causal effect of input trade liberalization on wage inequality by adopting the firms that are exempted from the input tariff as a natural control group. The approach enables us to disentangle the effect of output and input tariffs reduction on wage inequality that emphasizes endogenous quality, within-firm skill composition, and imported intermediates. We find that trade liberalization raises export quality in firms with larger scales and higher productivity, but lowers the quality of small and inefficient firms. Firms with higher quality tend to pay higher wages to skilled workers relative to unskilled workers. We find that input trade liberalization widens the wage inequality of skills and improves the export quality of Chinese firms. We also provide evidence that tariff reduction in the final goods narrows the wage

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limited research on wage inequality at the firm-level is the unavailability of real skill wages in the firms.

[7] Fair wage refers to the nominal wage that firms promise to pay. The imperfect labor market is the key assumption of fair-wage constraint that workers determine their efforts in accordance with the fair wage. The models of fair wage are developed by Egger and Kreickemeier (2009),Egger et al. (2013) and Amiti and Davis (2012). Frıas et al. (2009) identify fair wage as an important contributor to wage inequality across the firms and Chen et al. (2013) estimates the fair wage gaps between skilled and unskilled workers as a proxy of wage inequality within firms.

inequality of domestic firms between skilled and unskilled labor, which is associated with lower export quality. These effects are heterogeneous across firm types and trade regimes.

This paper is related to the literature on quality measurement. In previous literature, most studies treat quality as exogenous and estimates quality by using unit value or market share conditional on prices [Schott (2004); Hummels and Klenow (2005); Hallak and Schott (2011); Khandelwal (2010); Baldwin and Harrigan (2011); Amiti and Khandelwal (2013)]. Feenstra and Romalis (2014) add the supply side of quality and estimate the optimal import and export quality using trade data. The method reduces the inevitable estimation bias of proxy estimation from the demand side. Our estimation follows Feenstra and Romalis (2014) by considering different skills and intermediate inputs of the production cost and estimate the endogenous quality within firms implied by the model.

This paper adds new evidence to the current studies on trade liberalization and wage inequality. Many studies investigate trade liberalization on wage inequality through other channels such as skilled bias technological improvement [Acemoglu(1998); Acemoglu(2002)], offshoring [Feenstra and Hanson (1996)] and intermediate trade liberalization[Amiti and Khandelwal (2013); Chen et al. (2017)]. However, few studies focus on quality. Verhoogen (2008) proposes the new mechanism linking trade liberalization and wage inequality via quality upgrading in the developing countries and proves that quality upgrading induced by depreciation increases wage inequality within industries. But they show little evidence of the impact of trade liberalization on wage inequality within firms. Fieler et al. (2016) highlights the magnification effect of inputs in quality upgrading with trade liberalization and concludes that exporting firms with large scales are more likely to upgrade quality through input linkages. Our approach is based on Fieler et al. (2016), whereas specifically concentrated on the role of different skills. In contrast to Fieler et al. (2016), we cut off the adverse effect of inputs on quality by introducing the fair-wage constraint and assumption of unit-value intermediates with homogeneous quality in the model. The approaches enable us to study the link between trade liberalization and wage inequality through endogenous quality adjustment within firms without reverse causality. Moreover, as high-skilled labors are rare in developing countries, we include semi-skilled workers in the model to better describe countries with the absolute majority of unskilled and semi-skilled labors such as China.

The remaining paper is organized as follows. Section 2 constructs a theoretical model to explain the above mechanism. Section 3 gives a detail description of the data and provides new measurements of quality, skill wage gaps within firms, input, and output tariffs on firm-level. Section 4 presents the empirical results and imposes robustness checks. Section 5 concludes.

2 Theory

In this section, we construct a model of endogenous quality choice in the framework of heterogeneous firms of trade. The model has four key features. First, firms are heterogeneous in productivity and quality, producing similar but distinctive products. Firms determine cut-off productivity and optimal quality at the same time [Feenstra and Romalis (2014)]. Second, firms choose whether to use imported intermediates, which are homogeneous with unit value across countries, in the production. Importing firms have to pay fixed trade costs and the iceberg cost for importing, and the latter largely depends on the input tariff reduction [Kugler and Verhoogen (2009); Bas and Strauss-Kahn (2015)]. Third, high-quality is intensive in skilled labor [Fieler et al. (2016)] and quality upgrading will increase skill premium with the skilled-unskilled complementarity assumption[Parro (2013); Mazzolari and Ragusa (2013)]. Fourth, the labor market is imperfect where firms and workers share rents Helpman et al. (2010). Only skilled and semi-skilled labor is motivated by the fair wage that is related to the performance of firms because unskilled workers are assumed to have no bargaining power in the production [Chen et al. (2017)]. The settings construct a theoretical framework where skill wage inequality within firms could be influenced by endogenous quality adjustment with trade liberalization.

2.1 Demand

A representative consumer consumes a continuum of final good varieties ω with the CES preference to minimize total expenditure E. Demand arises from the following expenditure function.

$$\text{Min E} = \int p(\omega)x(\omega)d\omega \quad \text{s.t.} \ [\int x(\omega)^{\frac{\sigma-1}{\sigma}} d\omega]^{\frac{\sigma}{\sigma-1}} = U \tag{1}$$

where $p(\omega)$is the price of ω, and $x(\omega)$is the demand for final goods ω. σ is the elasticity of substitution between final goods($\sigma > 1$). As a result of CES preference, the demand for final product ω is $x(\omega) = [\frac{p(\omega)}{P}]^{-\sigma}Q$while $Q \equiv U$. And the revenue from final product ω is $r(\omega) = p(\omega)x(\omega) = [\frac{p(\omega)}{P}]^{1-\sigma}Q$ where R is the total revenue of the country and P is the aggregate price index given by $P = [\int p(\omega)^{1-\sigma} d\omega]^{\frac{1}{\sigma-1}}$ with $PQ = R$.

2.2 Production

2.2.1 Production with skill-intensive quality

To highlight the role of quality, we assume the final product ω has two parts, the quality $q(\omega)$ and the quality-free part $z(\omega)$, following a Cobb-Douglas production function of $x(\omega) = \varphi[z(\omega)]^{(1-\alpha)}[q(\omega)]^{\alpha}$. φ is the firm-specific productivity, which is unaffected by the quality and complies with a certain distribution following Melitz (2003). α is the input share of each part with the range of $\alpha \in (0, 1)$. The quality $q(\omega)$ and the quality-free part $z(\omega)$ are further produced with various skills and intermediates.

The quality-free part z(ω) is produced with intermediates either from the domestic market or foreign countries. For simplicity, the intermediates are assumed to be homogeneous in quality with unit value. The production of z(ω) exhibits constant return to scales in which one unit intermediate produces one unit of z(ω). In a closed economy, the price of z(ω) equals to 1. In an open economy, the firm chooses to import intermediates with an iceberg cost of $\tau_{m\omega}$. The price of $z(\omega)$ equals to the aggregated prices of all the intermediates, which is written as $p^z(\omega) = [1 + n\tau_{m\omega}{}^{1-\gamma}]^{\frac{1}{1-\gamma}} \le 1$. n is the number of importing countries, and γ is the elasticity of substitution for intermediates across countries. $\gamma > 1$ indicates firms prefer to use more varieties of intermediates. $\tau_{m\omega}$ is the iceberg cost that importers have to pay for importing except the fixed suck cost f_m, and it equals to the price of imported intermediates with $\tau_{m\omega} > 1$. It could be inferred that firms using imported intermediates enjoy a lower cost of $z(\omega)$ than those with domestic intermediates only.

Quality is produced by various labor inputs of skills, including skilled, semi-skilled and unskilled labor. The output of quality $q(\omega)$ follows a nested CES function as below:

$$q(\omega) = \{\Phi_M(q)^{\frac{\delta_L-1}{(\rho-1)\delta_L}} M(\omega)^{\frac{\delta_L-1}{\delta_L}} + \left[\Phi_U(q)^{\frac{1}{\rho}} U(\omega)^{\frac{\rho-1}{\rho}} + \Phi_s(q)^{\frac{1}{\rho}} S(\omega)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}\frac{\delta_L-1}{\delta_L}}\}^{\frac{\delta_L}{\delta_L-1}} \tag{2}$$

$U(\omega)$, $M(\omega)$, *and* $S(\omega)$ represent the inputs of unskilled, semi-skilled and skilled labor in production respectively. $\Phi_i(q)$ (i=u,m or s) is the productivity shifter of different skills in quality. It is an increasing function of quality indicating that high-quality products need higher productivity of skilled labor. Quality is assumed to be skilled-intensive, as a result, $\frac{\Phi_s(q)}{\Phi_m(q)}$ and $\frac{\Phi_m(q)}{\Phi_u(q)}$ are increasing in quality q. ρ is the elasticity of substitution between skilled labor and unskilled labor. δ_L is the elasticity of substitution between semi-skilled labor and unskilled labor. We introduce the skilled-unskilled complementarity[8] in the production function by assuming $0 < \rho < 1$ and $\delta_L > 1$.

Denote w_u, w_m and w_s are the wages of unskilled, semi-skilled and skilled labor, the relative wages of skills are shown below by minimizing quality production cost with the constraint of quality production.

$$\frac{w_s}{w_u} = [\frac{\Phi_s(q)}{\Phi_u(q)}]^{\frac{1}{\rho}}[\frac{S}{U}]^{-\frac{1}{\rho}} \tag{3}$$

$$\frac{w_s}{w_m} = [\frac{\Phi_s(q)}{\Phi_m(q)}]^{\frac{\sigma_L-1}{(\rho-1)\sigma_L}}[\frac{M}{S}]^{-\frac{1}{\sigma_L}}\{\left[\frac{\Phi_u(q)}{\Phi_s(q)}\right]^{\frac{1}{\rho}}\left[\frac{S}{U}\right]^{-\frac{1-\rho}{\rho}}+1\}^{\frac{\sigma_L-\rho}{(\rho-1)\sigma_L}} \tag{4}$$

$$\frac{w_u}{w_m} = [\frac{\Phi_u(q)}{\Phi_m(q)}]^{\frac{\sigma_L-1}{(\rho-1)\sigma_L}}[\frac{M}{U}]^{-\frac{1}{\sigma_L}}\{\left[\frac{\Phi_s(q)}{\Phi_u(q)}\right]^{\frac{1}{\rho}}\left[\frac{U}{S}\right]^{-\frac{1-\rho}{\rho}}+1\}^{\frac{\sigma_L-\rho}{(\rho-1)\sigma_L}} \tag{5}$$

The relative price of skilled and unskilled labor increases with quality upgrading and decreases with skilled labor intensity from Equation (3). If $0 < \rho < 1$ and $\delta_L > 1$, the wage premium between skilled and semi-skilled labor will be increased by quality upgrading and decreased by skilled and unskilled labor intensity according to Equation (4). Similarly, equation (5) shows that the relative wage of unskilled and semi-skilled labor is not only determined by the relative input of unskilled and semi-skilled labor but also the skilled labor intensity. Under the condition of constant input share, quality upgrading will decline the relative wage of unskilled and semi-skilled wage, which widens the wage gaps between semi-skilled and unskilled workers.

[8] Plenty of studies categorize skill into skilled labor and unskilled labor and refer them as gross substitutes with $\rho > 1$ [Heckman and Rubinstein (2001); Acemoglu and Autor (2011)].Most of the studies focus on developed countries. Our model categorizes skills into unskilled, semi-skilled and skilled labor to better capture the skill composition of China. According to Mazzolari and Ragusa (2013) and David and Dorn (2013), the least skilled workers performing low-skill service jobs complement to high-skilled workers in cognitive tasks. Semi-skilled workers performing routine tasks are easily replaced by computerization or service offshoring. As a result, we assume that unskilled labor could complement skilled workers while substituting unskilled labor. Our estimation in Section 3 confirms the result.

Proposition 1 *Under the assumptions of skill-intensive quality and skilled-unskilled complementary, the relative wages of skills are determined by the quality and their relative inputs. Quality upgrading enlarges the wage premium of higher-skilled labor and unskilled labor with constant skill input share.*

2.2.2 Fair-wage constraint and labor market

The partial equilibrium in *Proposition 1* indicates that the within-firm wage inequality among skills is determined by the quality and the relative inputs of skills. Quality is intensive in higher-skilled labor. However, the growth of wage premiums from quality upgrading would be offset by the increasing share of skilled labor within the firm. To identify the linkage between quality and wage premiums of skills, we further introduce the fair-wage constraint in the model.

The fair-wage constraint is proposed by Akerlof (1982) that workers have the motivation to adjust their efforts according to their fairness preference. Workers' fairness preference depends on the real wage they receive relative to the reference wage that they expect to be as fair as their efforts [Egger et al. (2013)]. The reference wage of workers depends on firms' economic performance. The better the firm is doing, the higher fair wage workers expect to be paid [Akerlof and Yellen (1990); Danthine and Kurmann (2004)]. If workers fail to get their fair wages, they tend to reduce their efforts in the production to ensure fairness. The equilibrium ends up with firms pay the fair wage to maximizes their workers' efforts. Egger et al. (2013) used firms' operating profits to measure firms' economic performance. Amiti and Davis (2012) also found that fair wage is an increasing function of firm profits, but they assume all the labor is homogeneous in the same level of skill. Chen et al. (2013) categorized labor into skilled and unskilled workers and found that skill wage premium is also determined by firm profits as skilled workers tend to have larger bargaining power than unskilled workers.

Following Amiti and Davis (2012) and Chen et al. (2013), we assume that the skilled and semi-skilled workers receive wage $ws(\pi)$ and $wm(\pi)$ that are related to the performance of the firm where they work. But the unskilled workers rarely have bargaining power in their wages so that their wages are fixed at wu. As a result, the cost of quality is a bundle of skills in Equation (6).

$$C_q(q,\pi) = \{w_m(\pi)^{1-\sigma_L}\Phi_m(q)^{\frac{1-\sigma_L}{1-\rho}} + [\Phi_u(q){w_u}^{1-\rho} + \Phi_s(q)w_s(\pi)^{1-\rho}]^{\frac{1-\sigma_L}{1-\rho}}\}^{\frac{1}{1-\sigma_L}}$$

or (6)

$$C_q(q,\pi) = \Phi_u(q)w_u\{(\frac{w_m(\pi)}{w_u})^{1-\sigma_L}(\frac{\Phi_m(q)}{\Phi_u(q)})^{\frac{1-\sigma_L}{1-\rho}} + \left[1 + \frac{\Phi_s(q)}{\Phi_u(q)}(\frac{w_s(\pi)}{w_u})^{1-\rho}\right]^{\frac{1-\sigma_L}{1-\rho}}\}^{\frac{1}{1-\sigma_L}}$$

The fair wage constraint determines the nominal wage premium without changing the skill input shares. Under the constraint, the relative premium of skills is determined by firm performance and quality. High-profit firms would like to pay a higher fair wage to be skilled and semi-skilled workers to elicit efforts without changing the input share. Skilled workers with higher fair wages produce higher quality whereas increasing the production cost. The increasing cost reduces firm profits until the equilibrium that the firm determines the optimal fair wage for workers and optimal quality to produce. The mechanism will be depicted in the following sections combined with the globalization mode decision of firms.

2.2.3 Firm's problem

The firm's marginal cost of production is shown as follows with constraints of the production function and input bundles:

$$c_\omega = \frac{\kappa c_q^{\alpha} c_z^{1-\alpha}}{\varphi} \tag{7}$$

where $\kappa = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$ is constant. The marginal cost consists of two parts, the cost of quality c_q and the cost of intermediate c_z . The cost of quality c_q depends on quality and wage premium of skills as shown in Equation (6). The marginal cost of intermediates equals to 1 if the firm only use domestic products and equals to p^z if the firm imports intermediates.

Firms choose the optimal price when their marginal revenue equals marginal cost as $\mathrm{MR} = \mathrm{p}\left(1-\frac{1}{\sigma}\right) = c_\omega$. As a result, the optimal price of ω equals $\mathrm{p} = \frac{c_\omega}{\mu}$ where $\mu = 1-\frac{1}{\sigma}$ represents the price markup [9]. For firms selling in the domestic market only, their revenue

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[9] For any two firms, their relative price equals to their cost ratio with $\frac{p_1}{p_2} = \frac{c_1}{c_2}$. Equation (7) indicates that marginal cost is increasing in quality cost, which is further raised by quality upgrading under the constraint of constant skill input share. As a result, high-quality products is associated with higher costs and price. It means that products with higher quality are of higher prices regardless of firms' importing status and labor input shares. And it corresponds to some previous method using unit value as a proxy of quality.

is r(ω) $= \mathrm{RP}^{\sigma-1}[\frac{\kappa c_q^{\alpha} c_z^{1-\alpha}}{\varphi}]^{1-\sigma}$. R is the total revenue of the country and P is the aggregate price. But for firms that export to other countries, the revenue is different. Similar to imports, exporting firms have to pay sunk cost fx and the iceberg cost τxω for exports. The revenue of exporters is $([1 + n{\tau_{x\omega}}^{1-\sigma}]r(\omega)$ where $n{\tau_{x\omega}}^{1-\sigma}$represents the total iceberg costs of exporting to n foreign markets and satisfies $n{\tau_{x\omega}}^{1-\sigma} < 1$.

A representative firm chooses its globalization mode and quality at the same time to maximize its profits. The profits could be written as $\pi(\omega) = \frac{\mathrm{r}(\omega)}{\sigma} - F$. F is the total fixed cost depending on the globalization modes of firms, by which domestic firms have the sunk cost of f_e, importer and exporters pay the fixed cost of f_m and of f_x respectively. The revenue r(ω) depends on the globalization mode (whether to export or import intermediates), the premium of skills and quality cost. For domestic firms, their revenues are given as $\mathrm{RP}^{\sigma-1}[\frac{\kappa c_q^{\alpha}}{\varphi}]^{1-\sigma}$, where $c_z = 1$ as they use domestic intermediates only. For firms that use imported intermediates, their intermediate cost is $[1 + n{\tau_{m\omega}}^{1-\gamma}]^{\frac{1}{1-\gamma}}$ and the revenue of the firm is $\mathrm{RP}^{\sigma-1}[\frac{\kappa c_q^{\alpha}}{\varphi}]^{1-\sigma}[1 + n{\tau_{m\omega}}^{1-\gamma}]^{\frac{(1-\alpha)(1-\sigma)}{1-\gamma}}$. Following Amiti and Davis (2012), we assume $\Gamma_{m\omega} = [1 + n{\tau_{m\omega}}^{1-\gamma}]^{\frac{(1-\alpha)(1-\sigma)}{1-\gamma}}$ as the "import globalization" factor that reflects the reduced cost of using imported intermediates. Similarly, for firms that export their final goods, their foreign revenue is reduced by the iceberg of exporting $\tau_{x\omega}$ so that so that the total revenue of exporters becomes $[1 + n{\tau_{x\omega}}^{1-\sigma}]$ $\mathrm{RP}^{\sigma-1}[\frac{\kappa c_q^{\alpha}}{\varphi}]^{1-\sigma}$ with the export globalization factor $\Gamma_{x\omega} = 1 + n{\tau_{x\omega}}^{1-\sigma} > 1$. Exporting firms' revenue is larger than domestic firms because they have access to n additional markets despite bearing the iceberg costs. As a result, the total profits of different kinds of firms are as follows:

$$\pi(\omega) = \begin{cases} 0 & \text{exited firms} \quad (8) \\ \frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_q^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e & \text{domestic firms only} \quad (9) \\ \Gamma_{m\omega}\frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_q^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e - nf_m & \text{importing intermediates only} \quad (10) \\ \Gamma_{x\omega}\frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_q^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e - nf_x & \text{exporting final goods only} \quad (11) \\ \Gamma_{m\omega}\Gamma_{x\omega}\frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_q^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e - n(f_m + f_x) & \text{both} \quad (12) \end{cases}$$

Following Amiti and Davis (2012), we assume that $f_x > \frac{f_e}{n}\Gamma_{x\omega}$ and $f_m > \frac{f_e}{n}\Gamma_{m\omega}$. The first assumption ensures the zero-profit firms would not choose to export because they can't overcome the fixed exporting costs. The second assumption makes sure that zero-profit firms won't import because their importing costs are higher than their benefits of importing. The assumptions ensure zero-profit firms would neither export or import. With the assumptions, the profit of firms could be expressed as $\pi(c_q, \varphi, \tau_{m\omega}, \tau_{x\omega})$, which is determined by the quality cost, cut-off productivity, and its globalization modes. Firms with higher productivity tend to choose higher quality, which is further bounded by the inputs of skills. The firm's profits increase with its productivity while decrease with its quality cost. Firms with large profits could bear the high quality cost and have the motivation to spire skilled workers with a higher fair wage, which in turn raises their quality. Compared to domestic firms, importers have higher profits because they have lower intermediate costs by importing. Exporters also yield higher profits as a result of access to additional markets.

2.3 Equilibrium

In an autarky economy, there is a unique equilibrium existing where firms with high cut-off productivity tend to choose a higher quality (See appendix A). According to Equation (9), the profits of firms eventually decrease in quality costs. With the fair-wage constraint, profitable firms tend to promise higher fair wage to skilled / semi-skilled workers to upgrade quality, which raise the quality costs[10.] As a result, there is an equilibrium between profits and quality costs as shown in Figure (1).

[10] We assume $0 \leq c_q^{'}(\pi) \leq \infty$ that there is an upper bond of quality cost with the constraint of fair wage.

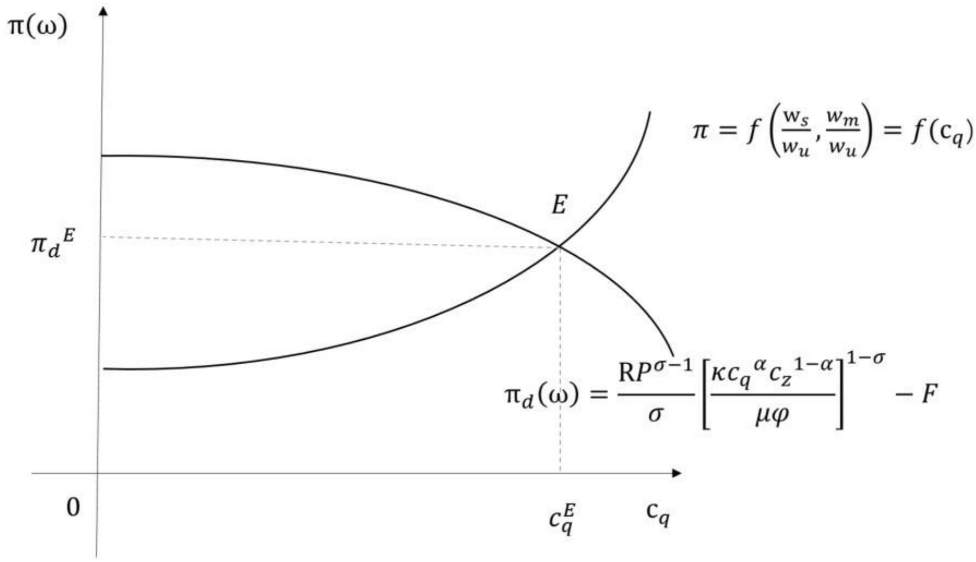

Figure 1: The quality decision with exogenous macro variables and productivity

The firm determines its optimal quality and profit according to its profit maximum decision and fair-wage constraint. There is a unique equilibrium in which optimal quality cost is determined with the maximum profits under the condition that the macro-variables such as *R* and *P* are unchanged, and the productivity is given by certain distribution. With the optimal quality and profits, the relative prices of different skills could be determined by Equation (6).

The move to open economy from the autarky will raise the marginal profits of firms engaged in profits and rule the high-cost firms out of the domestic market. Only firms with a lower marginal cost could import or export or do both (See Appendix B). In the autarky, the profits of domestic firms equal to Equation (9) and can be rewritten as $\pi_d(\omega) = f_e[(\frac{c_\omega}{c_\omega^*})^{1-\sigma}$-1] where c_ω^* is is the cut-off marginal cost in the closed economy. However, after opening up, the marginal profits of the domestic firm will become $\pi_d^T = f_e[(\frac{c_\omega}{c_\omega^{T*}})^{1-\sigma}$-1]. As $c_\omega^{T*} < c_\omega^*$, for domestic firms, trade liberalization will decrease their profits with $\pi_d^T < \pi_d(\omega)$. The changes are shown in Figure (2).

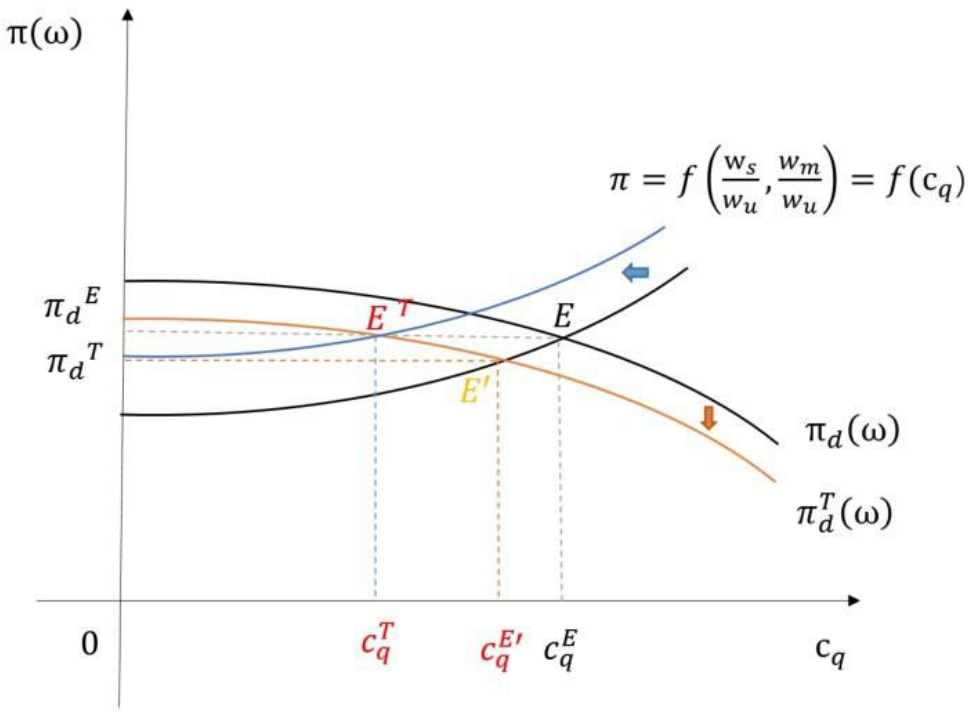

Figure 2: The quality and profits adjustment of domestic firms in the open economy

For domestic firms, trade liberalization in final goods will lower its profits compared to the profits in autarky as a result of the lower cut-off marginal cost of production. The inefficient firms in producing quality are forced to exit and foreign firms with marginal costs lower than the cut-off point enter the domestic market. The fierce competition reduce the profits in the domestic market from $\pi_d(\omega)$ to π_d^T instantly (Figure 2). There is a new equilibrium point of E' instead of E that the profits and quality costs of domestic firms are compressed as a result of trade liberalization.

The loss of profits after trade liberalization makes firms to adjust their fair wage according to their current profits. The firms reduce the fair wage of skilled and semi-skilled workers to reduce quality costs further and maintain eligible profits. As fair wage are nominal and can't change the relative inputs of skills, the adjustment will compress the quality cost further and degrade the output quality with fixed skill inputs. The adjustment will stop at a new equilibrium point E^T that the domestic firms reduce output quality and skilled/semi-skilled fair wages to maintain profitably. In this case, the wage inequality of high-skills and low-skills is reduced as a result of reduced profits and quality degradation.

For marginal exporters or importers, their expected profits of entering any foreign markets are zero. It means that they don't have extra profits from the markets other than the domestic market. As a result, similar to domestic firms, the marginal exporters and importers will reduce their quality and wage inequality within firms after opening up.

Proposition 2 *Moving from autarky to an open economy will reduce the quality of domestic firms as well as marginal exporters or importers. The wage gaps between higher-skilled and lower-skilled workers are narrowed, which is not only via adjustment of firms' profits but also amplified by quality degradation after trade liberalization.*

For non-marginal importing firms, there is at least one importing market that makes importing intermediates is profitable for the firms, which satisfies $\frac{r_d(c_\omega^{m*})\tau_{m\omega}{}^{1-\gamma}}{\delta} - f_m - f_e > 0$. If the profits from importing are larger than the loss in the domestic market, the importing is profitable. The condition for a profitable non-marginal firm could be written as follows.

$$c_\omega^{T*} < c_\omega^{*} < c_\omega^{T*}\Gamma_{m\omega}{}^{\frac{1}{\sigma-1}} \tag{13}$$

Where c_ω^{T*} is the cut-off marginal cost of open economy while c_ω^{*} is the cut-off marginal cost of the autarky. $\Gamma_{m\omega}$ is the import globalization factor which is determined by input tariff $\tau_{m\omega}$ and the number of importing countries (import scale) n. If the import globalization factor is large enough, the importing firms could gain extra profits by importing intermediates satisfying$\pi_d^T(\omega) > \pi_d(\omega)$. A great import globalization factor exists when the input tariff is low or the import scale is large.

For the profitable importing firms, trade liberalization will increase their profits, which moves their profit curve left, as shown in Figure (3). Trade liberalization brings a new equilibrium point where the firm's profit is raised as a result of using foreign intermediates in quality production. In the long term, the firm promises to pay higher wages for skilled and unskilled workers which further improves their productivity in producing quality. At last, the firm will produce higher quality with a larger inequality between skilled and unskilled workers within the firm.

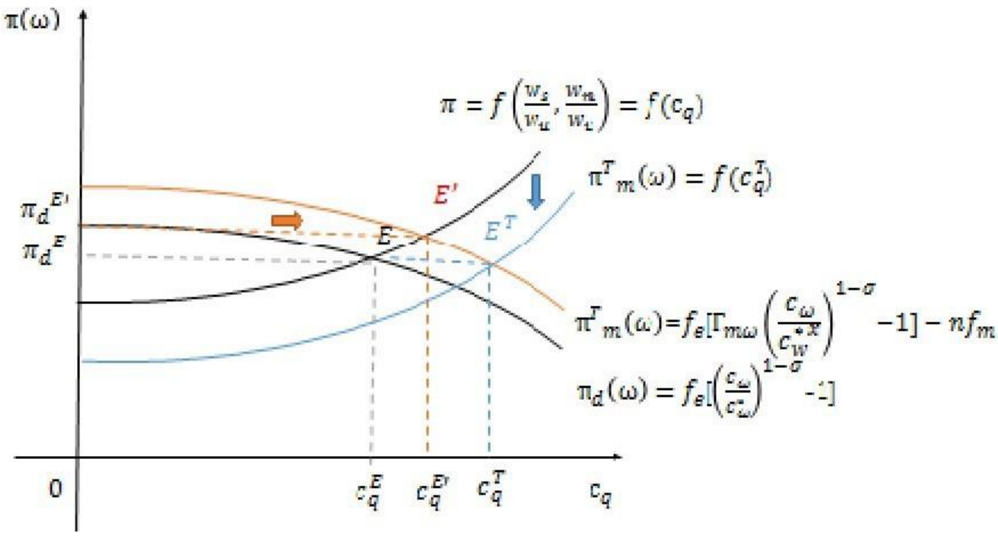

Figure 3: The quality and profits adjustment of profitable importers in an open economy

A similar effect exists in profitable non-marginal exporters whose profits will be increased by the access to additional foreign market under the condition of $c_\omega^{T*} < c_\omega^* < c_\omega^{T*}\Gamma_{x\omega}{}^{\frac{1}{\sigma-1}}$. The exporting firms could gain higher profits after opening up with an increase in exporting quality as well as skill wage inequality within firms. For firms in dual trade, they are more easily to gain extra profits from trade with the condition of $c_\omega^{T*} < c_\omega^* < c_\omega^{T*}(\Gamma_{x\omega}\Gamma_{m\omega})^{\frac{1}{\sigma-1}}$. Their profits are not only affected by output tariff reduction but also the imported tariff reduction. Compared to importers or exporters, the firms in two-wage trade are more easily to upgrade the quality and enlarge wage inequality of skills after trade liberalization.

Proposition 3 *A move from autarky to trade will raise the quality of profitable importers and exporters, which further enlarges the wage inequality among skills within the firms. A move from autarky to trade will raise the quality of profitable importers and exporters, which further enlarges the wage inequality among skills within the firms. Mixed traders have higher quality and skill wage gaps than single importers and exporters after opening up the economy. Firms with larger scales of trade are more likely to gain extra profits from trade and upgrade their quality. The reduction of tariffs in inputs and final goods will improve the profit level of these firms, thus lead to further quality upgrading and wage inequality among skills.*

3 Data and Measures

In this section, we use the Chinese firm-level production data and transaction-level trade data to measure the quality from the supply side of production. We also measure the trade liberalization by input tariff reduction and output tariff reduction. With the modified approach following Chen et al. (2013), we measure the wage inequality among skilled, semi-skilled and unskilled labor.

3.1 Data

In this paper, we use three highly disaggregated firm-level databases: the manufacturing enterprise survey data from China's National Bureau of Statistics(NBS), the product-level trading data from China's General Administration of Customs (GAC) and the HS 6-digit tariff data from the World Integrated Trade Solutions (WITS).

The manufacturing enterprise data from China's National Bureau of Statistics(NBS) includes survey data on two types of firms: the state-owned (SOE) enterprises and the non-SOEs with an average of sales over RMB 5 million. The NBS database covers almost 95% of the total outputs of Chinese manufacturing sectors. There are more than 130 indicators in the database, giving rich information about firms' financial characteristics. Despite the wide coverage and long period, the NBS data contains some statistical mistakes including the non-unique identification code, missing variables, abnormal values and reporting bias. We first filter the data following Brandt et al. (2014) to identify the firms across the period and get the unique identification code of firms. Then we follow Cai and Liu (2009) to eliminate misreporting information. Firstly, we delete the duplicates and abnormal values. Secondly, we remove the observations with critical variables missing, e.g., the missing variables of profits, value added, inputs, employment, fixed assets and so on. Thirdly, we delete the small-scale firms with less than eight employees. Fourth, we remove observations that break the generally accepted accounting principles (GAAP), for example, the total assets exceed cash or capital; the net value of fixed assets is smaller than total assets; the capital is less than 0 or the exports are higher than total sales. There were 1,560,004 observations in the NBS database, and 79,810 ones are deleted after processing with Cai and Liu (2009), accounting for 5.1% of the total sample.

Even though the NBS database has the export value, it doesn't distinguish the destinations and has no information about the importing. We rely on the GAC database to get the product-level trading information within firms. The GAC database provides monthly product-level import and export data from 2000-2006, covering more than 290,000 firms. The database mainly contains three kinds of information: the firm information including the name, address, postcode and telephone number; the shipment information including the trade volume, quantity, imports or exports, and unit values; the trade type including ordinary trade, processing trade, and others. There are 18 trade regimes in the 2000-2006 data, which is essential for our analysis. It should be noticed that importing intermediates under the processing trade regimes are exempted from tariff in China. The imported intermediates are tariff-free, but all the imported intermediates should be used in the production of exports. But in ordinary trade, importing intermediates are subject to the tariff.

Although there are identification codes of firms in the GAC database, it is totally different from the one in the NBS database. Therefore, we follow Yu and Tian (2012) to use the firm's name (in Chinese), telephone number(the last seven digits) and zip code to match the two databases. The matched results are shown in Table (1).

Table 1: The matched data description

Year	Observations	Firms	Matched firms in NBS(%)	Matched firms in GAC (%)
2000	1,168,745	21,584	15.02%	26.90%
2001	1,302,202	31,248	19.75%	35.75%
2002	1,473,416	34,041	19.91%	35.03%
2003	1,682,256	37,436	19.87%	33.09%
2004	2,257,771	56,650	21.47%	42.00%
2005	2,204,878	53,804	20.45%	38.44%
2006	2,370,679	82,479	28.24%	41.76%

The matched firms account for about 20% of the NBS database and 35% of the GAC database. All the matched firms are trading firms including exporting firms, importing firms and firms in dual trade[11]. We further categorize firms according to their trade types into ordinary trade, processing trade, mixed trade and others[12]. The mixed trade refers to the

[11] It has to be noted that the rest of unmatched firms in NBS database could be seen as domestic firms. But as we don't have the domestic price of the firms, we can't measure the quality of domestic firms, as well as importing only firms. Thus we delete the importing firms from the matched database and only study the exporting firms.

[12] One of the dramatic characteristics of China's trade structure is the majority of processing trade[Yu and Tian (2012)]. The processing exporters import raw materials or intermediates from abroad, and re-exported them after

firms involved in ordinary trade and processing trade at the same time. The categorization result is shown as follows:

Table 2: The matched firms categorization by trade regimes

	Total Firms	Ordinary trade	Processing Trade	Mixed Trade	Others
2000	17,293	6,724	2,933	7,559	77
2001	21,257	8,997	2,916	8,616	728
2002	23,933	10,900	2,741	9,593	699
2003	27,879	13,942	2,818	10,577	542
2004	43,338	23,264	4,461	14,898	715
2005	43,643	23,990	4,336	14,813	504
2006	50,458	29,298	47,60	15,614	786

3.2 Measures

3.2.1 The measure of export quality

We estimate the exporting quality from the theoretical framework with firm-level data in the section. In the model, consumers prefer consuming more and pay higher prices for high-quality products. Firms choose the optimal quality and price at the same time, and the optimal price could be written as $p(\omega) = \frac{\kappa c_q^\alpha}{\mu\varphi}[1 + n{\tau_{m\omega}}^{1-\gamma}]^{\frac{1-\alpha}{1-\gamma}}$. As a result, we can get the optimal quality cost as Equation (14).

$$\ln c_q = \frac{1}{\alpha}[\ln\frac{\mu}{\kappa} + lnp(\omega) + ln\varphi - \frac{1-\alpha}{1-\gamma}\ln(1 + n{\tau_{m\omega}}^{1-\gamma})] \quad (14)$$

Equation (14) has multiple meanings. First, products with higher price $p(\omega)$ need higher quality inputs. Second, firms with higher productivity bear higher quality costs if the other variables are fixed. Thirdly, input trade liberalization will reduce the cost of using imported intermediates and increase the inputs in quality production. If quality is produced with unit labor, the estimates of quality cost c_q could be used as a proxy of quality. But under the hypothesis of heterogeneous labor inputs, the quality cost is a function of skill premiums and

processing and assembling. The processing exporters enjoy the duty exemption in pure assembly processing trade but are required to sell all their outputs aboard [Kee and Tang (2016)].

real quality as Equation (6) shows. Considering equation (3) and (5), the quality cost is determined as follows.

$$\ln c_q \approx \frac{1}{1-\rho} ln\Phi_u(q) + lnw_u + \frac{\sigma_L(1-\sigma_L)+(1-\rho)(\sigma_L-\rho)}{(1-\rho)(1-\sigma_L)\rho\sigma_L} \ln\frac{\Phi_s(q)}{\Phi_u(q)} + \frac{1}{(1-\rho)\sigma_L} \ln\frac{\Phi_m(q)}{\Phi_u(q)} \frac{\sigma_L(1-\sigma_L)+(1-\rho)(\sigma_L-\rho)}{(1-\sigma_L)\rho\sigma_L} \ln\frac{\mathrm{U}}{\mathrm{S}} + \frac{1}{(1-\rho)\sigma_L} ln\frac{\mathrm{U}}{\mathrm{M}} \tag{15}$$

Equation (15) indicates that quality cost could be seen as a function of relative inputs of different skills and the quality productivity $\Phi_i(q)$. In general, we assume $\frac{\Phi_s(q)}{\Phi_u(q)} = e^{2(q+1)}$ and $\frac{\Phi_m(q)}{\Phi_u(q)} = e^{(q+1)}$ where $\Phi_u(q) = \overline{\Phi_u}$. As a result, we could get the quality from the quality cost equation.

$$\mathrm{q} = \beta_0 + \beta_1 lnc_q + \beta_2 \ln\frac{\mathrm{U}}{\mathrm{S}} + \beta_3 \ln\frac{\mathrm{U}}{\mathrm{M}} \tag{16}$$

Where $\beta_1 = \frac{(1-\rho)(1-\sigma_L)\rho\sigma_L}{(1-\sigma_L)(1+\rho+\sigma_L)+2(1-\rho)(\sigma_L-\rho)} > 0$; $\beta_2 = -\beta_1\frac{(1-\sigma_L)\sigma_L+(1-\rho)(\sigma_L-\rho)}{(1-\sigma_L)\rho\sigma_L} < 0$; $\beta_3 = -\beta_1\frac{(1-\rho)}{(1-\sigma_L)\sigma_L} < 0$ and $\beta_0 = -\beta_1 lnw_u$. Quality is determined by the relative inputs of skills and quality cost, which is further determined as Equation (6) shows. With quality cost fixed, the more inputs of skilled and semi-skilled labor induce higher quality, while the more inputs of unskilled labor induce lower quality. With fixed labor inputs, the quality cost could be a proxy of quality, which could be estimated by controlling the unit value, productivity, and relative skill shares.

Our database is a panel of exporters, either importing intermediates or use domestic intermediates. The unit value of firm i exporting product g to country j in time t could be given as $uv_{igt} = \frac{total\ exports_{ijgt}}{exports\ quantity_{ijgt}}$[13]. The productivity of firms is estimated using the NBS database with Olley and Pakes (1992)'s approach and Petrin and Levinsohn (2012)'s

[13] The Customs data is monthly data denominated in US dollars. In the process of calculating exporting price, we translated the exporting value into RMB using the monthly exchange rate and aggregated the monthly data into annual data. Then we get the total exports and quantity of the disaggregated HS 8-digit products within firms.

method[14]. The average productivity of all the firms estimated by Olley Pakes method and LP method [15]is shown in Figure (4).

The paper considers the role of different skills in exporting quality and indicates that products using the high ratio of skilled labor are of higher quality. But there is a limitation in our data that the NBS database only contains detail skill data for 2004 when China conducts the population census. The 2004 data includes the employment of firms' employees by education and occupations. We follow the International Standard Classification of Education (ISCED 2011) to categorize the firm's employees into skilled labor with tertiary education or above, semi-skilled labor with secondary education level and unskilled labor with primary education or below. Following Chen et al. (2013), we estimate the proxy of the skilled and semi-skilled labor share of the other years by using the provincial-level skill shares as weights. The approach based on the hypothesis that the growth rates of firms' skillshares are the same across the province. The approach could capture the firm-specific variables with skill shares of 2004. Meanwhile, we get the firm-level skill shares of the other years with the provincial-level skill growth rate based on 2004.

The paper adopts the results of Feenstra and Romalis (2014) on the substitution elasticity of final goods σ of China. The data is on the SITC 4-digit level, so we match the elasticity to the HS 6-digit level of the database. Imbs et al. (2010) estimated the import substitution elasticity of China at 1.57 with a standard error of around 0.2. We use their estimation as a proxy of the elasticity of imports for intermediates γ. The share of quality cost in total cost could be inferred by the share of intermediates in production, which is estimated in calculating productivity at 0.439. As a result, the estimated share of quality cost $\hat{\alpha}$ equals to 0.561.

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[14] Olley and Pakes (1992) eliminated the selection bias and simultaneous bias by using intermediates input as a proxy of capital in estimating firm-level productivity. Melitz and Polanec (2015) improves Olley and Pakes (1992)'s approach by considering the exit of less productive firms. Our paper follows their approaches and also estimates the firm-level productivity with Petrin and Levinsohn (2012)'s method as a robustness check

[15] The elasticities estimation results are shown in Table (16)of Appendix (C).

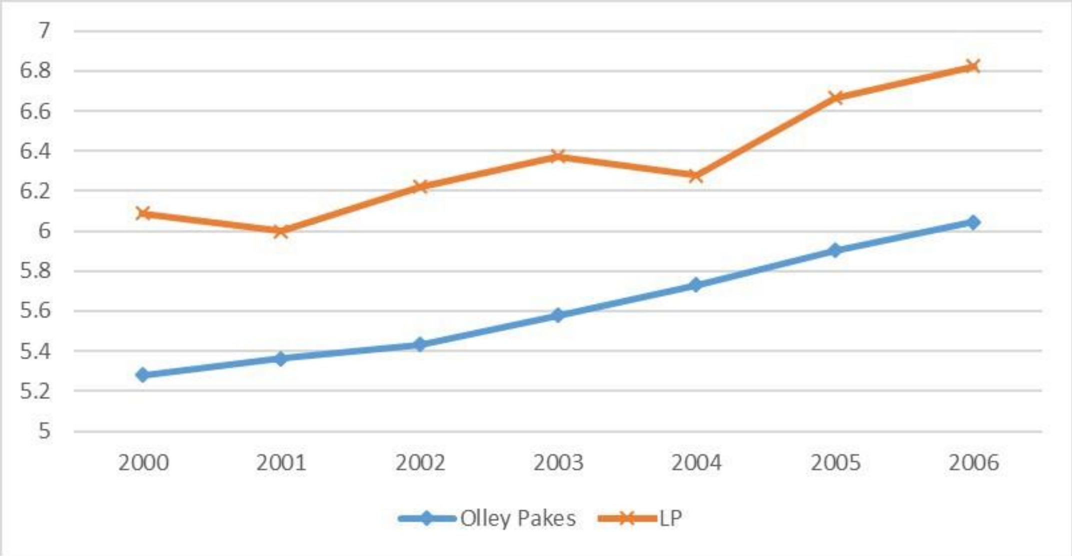

Figure 4: The average logarithm productivity by Olley-Pakes and LP method

The constant substitution of elasticity for the skilled and unskilled labor ρ and constant substitution of elasticity for the semi-skilled and unskilled labor σ are estimated by the translog cost function and associated skill shares (See Appendix C). The elasticity of substitution for skilled/unskilled labor is -0.51 while the elasticity for semi-skilled and unskilled labor is -1.03. It means that the unskilled labor complements to skilled labor while substitutes to semi-skilled labor. The estimation is consistent with the Behar (2008) study of labor substitution elasticities in Africa.

With the export price, productivity, import cost, and parameters, we can estimate the quality cost. By controlling the relative inputs share of skills and unskilled wages [16], we can estimate the quality following Equation (15). The exporting quality is on the HS 8-digit product level of firms. We remove the observations of the quality index over the 99% percentile and below 1% percentile to eliminate outlines. To compare the quality index across sectors and countries, we follow Khandelwal (2010) to construct the standard quality index r_q. r_q ranges from 0 to 1.The closer it comes to 1, the closer it comes to the quality frontier of Chinese exporting firms.

[16] We use the provincial-level minimum wage as the wages for skilled labor

$$r_q = \frac{q_{ijgt} - \min(q_{gt})}{\max(q_{gt}) - \min(q_{gt})} \quad (17)$$

The average quality of Chinese exporters in the manufacturing sectors is shown in Table (3). China became a member of WTO since 2001 and benefit the exporters by tariff reduction. Table (3) shows that the average exporting quality of Chinese firms declined slightly after accession into WTO. According to the percentile analysis, the median quality of Chinese exporting firms decreased by 12.6% during the period. The 25% percentile quality kept decreasing and declined by 10% than in 2000. The 75% percentile quality maintained stable and the 90% percentile quality keep increasing since accession to the WTO. The results show that the decrease in average Chinese quality is mainly due to the quality degradation in low-quality firms. About 75% of exporters in China are of low quality with an average quality index of less than 0.5. High-quality firms improve their quality after trade liberalization.

Table 3: The average exporting quality of China, 2000-2006

Year	Observations	Mean	Median	25% percentile	75% percentile	90% percentile	Standard Error
2000	87693	0.395	0.406	0.245	0.534	0.644	0.189
2001	120116	0.385	0.386	0.210	0.528	0.649	0.199
2002	173236	0.389	0.384	0.218	0.534	0.658	0.202
2003	228995	0.385	0.369	0.216	0.527	0.665	0.201
2004	381706	0.385	0.364	0.212	0.530	0.671	0.202
2005	407169	0.385	0.365	0.211	0.535	0.670	0.202
2006	418216	0.385	0.354	0.220	0.530	0.670	0.198

Table (4) reports the average quality of different types of firms in China. The first three columns describe the exporting quality of firms that use imported intermediates in the production of exports. The last three columns are the average quality of pure exporters using domestic inputs. The two types of firms are further categorized into firms in ordinary trade, processing trade, and mixed trade according to their trade regimes. It is shown that the quality of exporters using importing intermediates is much higher than the quality of exporters with domestic intermediates. The processing exporters have the highest quality than the other two types of firms. Trade liberalization will improve the quality of exporters with relatively large scales and multiple trading regimes, which is consistent with our theoretical proposition.

Table 4: The average exporting quality of China by trade regimes, 2000-2006

	Using imported Intermediates			Using domestic intermediates	
Year	Ordinary	Processing	Mixed	Ordinary	Mixed
2000	0.325	0.481	0.479	0.161	0.183
2001	0.340	0.492	0.489	0.158	0.177
2002	0.340	0.559	0.498	0.169	0.191
2003	0.361	0.528	0.506	0.182	0.196
2004	0.376	0.544	0.523	0.196	0.205
2005	0.386	0.574	0.531	0.206	0.215
2006	0.396	0.566	0.533	0.224	0.234

3.2.2 The Measure of firm-level wage inequality

The wage gaps among skills within firms are important indicators to measure firm-level wage inequality. Following Chen et al. (2013), decompose the skilled and semi-skilled wage paid by firm i of sector j in time t into two parts: the industrial average wage w_{jt}^{g} and the firm-specific error term ε_{ijt}^{g} (g=s or m). As indicated in the model, the unskilled labor has no bargaining power in their wages; thus, their wages are given by the minimum wage of each province. The absolute wage gap between higher-skilled labor and unskilled labor can be written as follows.

$$wgap_{ijt}^{g} = w_{iht}^{g} - w_{iht}^{u} + (\varepsilon_{ijt}^{g} - \varepsilon_{ijt}^{u}) \tag{18}$$

Where g refers to skilled or semi-skilled workers. And their wage gaps with unskilled labor could be decomposed into the sector-level wage gap α_{jt}^{g} and the residual gap. As indicated in the fair-wage hypothesis, the residual gap is a function of firm performance that the profitable firms tend to provide pay higher wages to skilled workers to motivate them to produce higher quality. As a result, the residual gap could be written as a function of firms' profits like $\varepsilon_{ijt}^{g} - \varepsilon_{ijt}^{u} = \beta_{jt}^{g}\pi_{ijt}$[17]. As a result, the wage gaps between higher-skilled labor and unskilled workers are expressed as:

[17] Considering the firms are in different sectors with various sizes, we use the ratio of profits to sales to get the profit rate as a proxy of firm's performance.

$$wgap_{ijt}^{g} = \alpha_{jt}^{g} + \beta_{jt}^{g}\pi_{ijt} \tag{19}$$

The average wage of the firm equals to the sum of wages of different skills weighted by their share in total labor inputs. Assuming θ_{ijt}^{g} is the share of skill g in total labor inputs, the firm's average wage could be expressed as follows:

$$\overline{w_{ijt}} = \theta_{ijt}^{s}w_{ijt}^{s} + \theta_{ijt}^{m}w_{ijt}^{m} + (1 - \theta_{ijt}^{s} - \theta_{ijt}^{m})w_{ijt}^{u} \tag{20}$$

The share of different skills within firms could be estimated using 2004 as the base year weighted by the provincial growth rate of skills, as indicated above. According to the fair wage assumption, the wage of skilled and semi-skilled labor is determined by its average industrial wage and its firms' performance. As a result, the average wage of the firm could be written as:

$$\overline{w_{ijt}} = \theta_{ijt}^{s}\alpha_{jt}^{s} + \theta_{ijt}^{m}\alpha_{jt}^{s} + \theta_{ijt}^{s}\beta_{jt}^{s}\pi_{ijt} + \theta_{ijt}^{m}\beta_{jt}^{m}\pi_{ijt} + w_{ijt}^{u} + \varepsilon_{ijt}^{u} \tag{21}$$

The average wage of firms is calculated by the wage expenditure over employment and deflated by the price index. With data on the average wage, firms' profit rate and the share of different skills within the firm, we can estimate the coefficients of $\widehat{\alpha_{jt}^{s}}$, $\widehat{\alpha_{jt}^{m}}$, $\widehat{\beta_{jt}^{m}}$ and $\widehat{\beta_{jt}^{s}}$. The unskilled wage varies by region and time t, and it could be considered as a constant with fixed effects of time, industry and regions. The absolute wage gaps between skilled and unskilled labor as well as between semi-skilled and unskilled labor could be estimated with the coefficients of $\widehat{\alpha_{jt}^{s}}$, $\widehat{\alpha_{jt}^{m}}$, $\widehat{\beta_{jt}^{m}}$ and $\widehat{\beta_{jt}^{s}}$.

$$w\widehat{gap_{ijt}}^{g} = \widehat{\alpha_{jt}^{g}} + \widehat{\beta_{jt}^{g}}\pi_{ijt} \tag{22}$$

Table (5) shows the average of estimated firm-level wage inequality $w\widehat{gap_{ijt}}$ by Chinese aggregated industries. The average firm wage gap between skilled and unskilled labor is RMB 38,868 (approximatlye US $4,807), while the average firm wage gap between semi-skilled and unskilled labor is RMB 2,756 RMB (approximately US $342). The average wage inequality of firms also varies across sectors. The labor-intensive industries such as textile and wood processing have a much larger wage gap between skilled and unskilled labor while a smaller wage gap between semi-skilled and unskilled labor compared to the capital-intensive industries such as machinery and chemical industries. For high-tech industries that are relatively intensive in skilled and semi-skilled labor, the wage gaps still exist but much smaller, especially between higher-skilled workers. For example, semi-skilled labor even has a higher average wage than the skilled labor in the computer and equipment sectors.

Table 5: The Average of Measured firm-level Wage Gaps

Sector	$\widehat{wgap_{ijt}}^s$	$\widehat{wgap_{ijt}}^m$
Processing of Food	17.821	7.676
Textile and Leather	23.744	5.817
Processing of Wood	24.441	5.598
Paper and Printing	22.556	6.190
Petroleum and Fuel	9.029	10.437
Chemical Fibers and Medicines	15.206	8.497
Rubber, Plastics, and other non-metallic goods	23.686	5.835
Metal processing and products	16.167	8.196
Machinery	19.304	7.211
Transport Equipment	17.157	7.885
Computer and Equipment	9.702	10.226
Others	18.436	7.483

Note:$\widehat{wgap_{ijt}}^s$ is the fair wage gap between skilled and unskilled labor. $\widehat{wgap_{ijt}}^m$ is the fair wage gap between semi-skilled and unskilled labor. The unit of the estimation is 1000RMB (approximately US $123).

3.2.3 Tariff

There are two kinds of the tariff in the paper: the input tariff levied on imported intermediates and the tariff in final goods. All the tariff data comes from the WTO database at the HS 6 digit level. The tariff data is mapped with the Customs data on the HS 8-digit level. The Chinese customs data has 18 trade regimes, in which imports under processing trade are exempt from paying tariffs. For processing trade, we can identify the imported intermediates imports under the trade regimes of "processing and assembly trade" and "processing with imported materials trade". We identified firms conducting these processing trade only as pure processing firms, which are not subject to input tariff.

For ordinary firms, we identify the intermediates imports from the Broad Economic Categories (BEC) classification. We construct the firm-level input tariff following Goldberg et al. (2009). If imp_{ijgt} represents the intermediate imports of product g in firm i from country j during time t, andτ_{igt} represents its import tariff. The firm-level intermediate import tariff could be calculated as follows:

$$\tau_{it} = \sum_g \frac{imp_{igt}}{\sum_g imp_{igt}} \frac{imp_{igjt}}{\sum_j imp_{igjt}} \tau_{igt} \tag{23}$$

Where the weights represent the cost share of product g in the total input cost of the firm and the cost share of product g from country j in the total cost of product g respectively. The weights could be constructed with the combined data of tariff, GAC, and NBS. It measures the extent of China's trade liberalization to other countries. The reduction in the input tariff will reduce the cost of importing intermediates and improve the importing firms' profits. Profitable firms would like to employ more skilled workers to upgrade quality. The input tariff is reported on the HS 2 digit section-level in Table (6). China had a high input tariff before accession to WTO in 2000. But the input tariff was reduced steadily as the commitments across the sectors. The average industry input tariff was cut from 7.08% in 2000 to 3.9% in 2006[18]. The output tariffs generally exceed input tariffs until 2006. The correlation between output tariffs and input tariffs is only 0.072 over the period.

Then we construct an aggregated firm-level tariff in final goods using the share of each final goods as weight. The firm-level output tariff is constructed as follows:

$$\tau_{it}{}^{f} = \sum_g \frac{imp_{igt}}{\sum_g imp_{igt}} \frac{imp_{igjt}}{\sum_j imp_{igjt}} \tau_{it}{}^{f} \tag{24}$$

$\tau_{it}{}^{f}$s the tariff of firm i in time t, and it equals the weighted average tariff of all the final products in the firm. The weight is calculated as the share of each final product g in total imports and the share of product g from destination j in the total imports of product g. $\tau_{igt}{}^{x}$is the tariff that country j imposed on the exporting firms on product g at time t, which comes from the WTO tariff database on the HS 6-digit level. The average output tariff on the sector level is reported in Table (7). There is a declining trend in most sectors except some labor-intensive sectors such as leather and textile during 2000-2006.

[18] The input tariff is different from the import tariff of consumption products. The tariff of consumption products declined from 19.38% to 11.8%.

Table 6: China's input tariff by sectors,2000-2006

Sector	2000	2001	2002	2003	2004	2005	2006
Food Processing	11.23%	14.24%	6.18%	7.10%	6.71%	6.68%	6.62%
Mineral Products	3.89%	4.22%	2.70%	2.64%	2.70%	2.56%	2.46%
Chemical Products	5.28%	5.82%	4.00%	3.85%	3.54%	3.50%	3.65%
Plastics and Rubber	4.57%	5.27%	3.34%	3.20%	2.97%	2.82%	2.72%
Leather Products	2.99%	3.35%	2.49%	2.34%	2.12%	2.08%	2.11%
Wood Processing	3.70%	4.00%	2.87%	2.76%	2.67%	2.60%	2.52%
Paper Products	3.95%	3.94%	2.68%	2.32%	2.12%	1.94%	1.73%
Textile	1.61%	1.86%	1.30%	1.36%	1.36%	1.41%	1.29%
Footwear	1.20%	1.31%	0.60%	0.98%	1.17%	1.07%	1.45%
Non-metallic Products	5.79%	6.32%	4.14%	4.01%	3.79%	3.53%	3.60%
Jewelry	3.02%	3.47%	2.21%	1.82%	1.58%	1.53%	1.11%
Metal Products	4.12%	4.59%	2.84%	2.76%	2.67%	2.50%	2.41%
Machinery	5.91%	6.36%	3.54%	3.19%	2.92%	2.74%	2.58%
Transport Equipment	6.03%	6.19%	4.59%	4.39%	3.85%	3.69%	3.62%
Computer and Instruments	4.57%	4.90%	3.42%	3.39%	3.02%	3.04%	3.02%
Others	3.13%	3.27%	2.00%	2.07%	1.89%	1.71%	1.53%

Note: The reported tariff is the mean of tariff imposed on Chinese imported intermediates across industries categorized by the HS 2002 Sections.

Table 7: China's output tariff by sectors,2000-2006

Sector	2000	2001	2002	2003	2004	2005	2006
Food Processing	8.50%	10.60%	7.01%	7.24%	6.36%	6.70%	7.03%
Mineral Products	2.86%	2.62%	2.48%	1.76%	2.31%	2.49%	1.85%
Chemical Products	3.22%	3.65%	3.30%	3.14%	2.81%	2.93%	2.96%
Plastics and Rubber	4.46%	4.71%	4.37%	4.45%	3.73%	4.08%	3.90%
Leather Products	3.31%	4.55%	4.34%	4.43%	4.04%	4.03%	3.98%
Wood Processing	2.10%	2.95%	2.89%	3.07%	2.38%	2.65%	2.39%
Paper Products	2.79%	2.42%	2.00%	2.36%	2.39%	2.46%	2.45%
Textile	4.03%	5.47%	5.68%	5.92%	5.15%	5.78%	5.98%
Footwear	5.31%	5.81%	5.55%	5.44%	4.97%	5.23%	4.97%
Non-metallic Products	3.87%	4.25%	4.37%	4.09%	3.48%	3.98%	3.84%
Jewelry	2.49%	2.95%	2.98%	2.65%	2.59%	2.89%	2.99%
Metal Products	3.03%	3.58%	2.96%	2.80%	2.56%	2.58%	2.46%
Machinery	2.82%	2.96%	2.91%	2.64%	2.43%	2.67%	2.64%
Transport Equipment	2.01%	1.92%	2.15%	2.05%	1.86%	1.97%	1.89%
Computer and Instruments	2.86%	3.17%	2.98%	2.72%	2.74%	2.65%	2.62%
Others	2.55%	2.94%	2.81%	2.70%	2.29%	2.39%	2.48%

Note: The reported tariff is the mean of output tariff in Chinese final goods imports. The tariff is reported by industries categorized in the HS 2002 Sections

4 Empirical Strategy and Estimation

4.1 Trade liberalization, quality, and wage inequality

We introduce endogenous quality in the model and propose that trade liberalization will affect firm-level wage inequality through their quality choices. To test the predictions empirically, we estimated the following empirical model. The dependent variables are the estimated wage gaps between skilled and unskilled workers as well as between semi-skilled and unskilled workers. The key variable is quality index rq_{it}, which measures the quality index of firm i in sector j at time t. The tariff reduction is measured by $\Delta\tau_{it}$, it refers to either input tariff reduction or output tariff reduction. β_3 is the interaction between the quality index and tariff reduction, which captures the effect of the quality index on the marginal effect of trade liberalization on wage inequality between skills. X_{it} are control variables.

$$\Delta\widehat{wagp}_{ijt}^{fu} = \alpha + \beta_1\Delta rq_{it} + \beta_2\Delta\tau_{it} + \beta_3\Delta\tau_{it} * rq_{it} + \beta_4 X_{it} + \varepsilon_t + \varepsilon_i + \epsilon_{ijt} \quad (25)$$

Table 8 reports the estimation results of Equation (25). Columns 1-4 report the impacts of trade liberalization on wage inequality between skilled and unskilled workers. Columns 5-8 show the estimation of wage inequality between semi-skilled and unskilled labor. All the results indicate that both types of tariff reductions increase the wage inequality between higher-skilled and unskilled workers within the firms. As predicted in the model, quality upgrading also increases the wage gaps between higher-skilled labor and unskilled labor. If we interact quality index with tariff reduction, we find that the interactions of both tariff reduction are significantly negative. It means firms with higher quality tend to have larger wage inequality of skills from trade liberalization. Quality upgrading exaggerates the impacts of input and output trade liberalization on wage inequality between higher-skilled and unskilled labor. Moreover, we also observe that the impacts are larger on wage inequality between skilled and unskilled labor compared to the wage gap between semi-skilled and unskilled labor. The coefficients of control variables indicate that firms with higher profits, productivity, and average wages tend to have larger wage inequality among skills.

Table 8. Baseline Results, control for fixed effects

	$\Delta \widehat{wagp}_{ijt}^{su}$				$\Delta \widehat{wagp}_{ijt}^{mu}$			
	(1) input tariff	(2) output tariff	(3) input tariff	(4) output tariff	(5) input tariff	(6) output tariff	(7) input tariff	(8) output tariff
Δrq_{it}	0.309***	0.342***	0.256***	0.353***	0.150***	0.165***	0.124***	0.171***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\Delta \tau_{it}$	-0.346**	-1.855***	1.560***	6.101***	-0.168**	-0.898***	0.755***	2.952***
	(0.017)	(0.000)	(0.007)	(0.000)	(0.017)	(0.000)	(0.007)	(0.000)
$\Delta \tau_{it} * rq_{it}$			-5.299***	-18.812***			-2.564***	-9.103***
			(0.004)	(0.000)			(0.004)	(0.000)
size	-0.357	-0.416	-0.408	-0.401	-0.173	-0.201	-0.197	-0.194
	(0.217)	(0.184)	(0.197)	(0.179)	(0.217)	(0.184)	(0.197)	(0.179)
profitrate	5.924***	5.936***	5.919***	5.999***	2.866***	2.872***	2.864***	2.903***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
rndshare	-2.634***	-2.570***	-2.640***	-2.627***	-1.275***	-1.244***	-1.277***	-1.271***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
tfpop	0.018	0.013	0.018	0.008	0.009	0.006	0.009	0.004
	(0.653)	(0.755)	(0.647)	(0.843)	(0.653)	(0.755)	(0.647)	(0.843)
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
N	138263	138263	138263	138263	138263	138263	138263	138263
r2	0.075	0.075	0.075	0.078	0.075	0.075	0.075	0.078

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

4.2 The role of Processing trade

As indicated, the processing firms of pure assembling are exempt from tariffs in China. The existence of processing trade tends to have two impacts. First, it will underestimate the role of input trade liberalization on wage inequality. More importantly, it could be acted as a clean natural experiment to identify the casual causality of input trade liberalization on wage inequality.

The endogenous problem of trade liberalization is a major concern in our estimation. For example, the labor unions in many developed countries have strong bargaining power in affecting the trade policies if they think their benefits are harmed by trade liberalization [Bown and Crowley (2013)]. Although the labor unions in China are relatively symbolic, there are still possible endogenous problems from the political lobby. We can control the time-invariant political factors using the time fixed effect, but it would be hard to control the time-variant ones. As a result, we use pure processing firms as a natural control group to identify the impact of input trade liberalization on wage inequality. We choose ordinary firms with similar export characteristics of processing firms as the treatment group. Following Bas and Strauss-Kahn (2015), we require that for each ordinary firm, there is at least one processing firm that exporting the same variety to the same destination in the same year. We also exclude the foreign-owned companies and control for the initial firm size and sector-year fixed effects following Bas and Strauss-Kahn (2015) to ensure the quality of the control group. The empirical strategy is a time-varying difference-in-difference model where ordinary trade firms are treated while pure processing firms are controlled. We use the dummy for ordinary to identify the two groups. The empirical model specification is as follows:

$$\Delta \widehat{wagp}_{ijt}^{fu} = \alpha + \beta_1 \Delta rq_{it} + \beta_2 O_i + \beta_3 \Delta\tau_{ikt} + \beta_4 O_i * \Delta\tau_{ikt} + + \beta_5 \Delta\tau_{it} * rq_{it} + \beta_6 O_i * \Delta\tau_{it} * rq_{it} + \beta_5 X_{it} + \varepsilon_{jt} + \varepsilon_{ik} + \epsilon_{ijt} \qquad (26)$$

Where $\Delta \widehat{wagp}_{ijt}^{fu}$ is still the wage gap between skilled (semi-skilled) labor and unskilled labor in firm i of industry j at time t. O_i is the dummy for whether the firm is an ordinary firm, but it will not vary across time. $\Delta\tau_{it}$ is the input tariff reduction of firm i in imported intermediates k between time t-1 and t. We control the firm-product, sector-year fixed effects. We also control for firm size, productivity, and profit rate. The estimation results are shown in Table (9).

Table 9. Input tariff, quality, and Wage inequality

	(1)	(2)	(3)	(4)
	$\Delta\widehat{wagp}_{ijt}^{su}$	$\Delta\widehat{wagp}_{ijt}^{su}$	$\Delta\widehat{wagp}_{ijt}^{mu}$	$\Delta\widehat{wagp}_{ijt}^{mu}$
$\Delta\tau_{it}$	2.297***	-0.914	1.111***	-0.442
	(0.000)	(0.715)	(0.000)	(0.715)
Δrq_{it}	0.369***	0.437***	0.179***	0.212***
	(0.005)	(0.002)	(0.005)	(0.002)
o_{it}	-0.002	-0.021	-0.001	-0.010
	(0.862)	(0.383)	(0.862)	(0.383)
$\Delta\tau_{it} * rq_{it}$		9.101		4.403
		(0.257)		(0.257)
$\Delta\tau_{it} * o_{it}$	-2.752***	-0.059	-1.331***	-0.028
	(0.000)	(0.982)	(0.000)	(0.982)
$\Delta\tau_{it} * rq_{it} * o_{it}$		-7.212*		-3.490*
		(0.014)		(0.014)
size	0.648*	0.751	0.313*	0.364
	(0.085)	(0.104)	(0.085)	(0.104)
profitrate	4.446***	4.456***	2.151***	2.156***
	(0.000)	(0.000)	(0.000)	(0.000)
rndshare	-0.224	-0.193	-0.108	-0.093
	(0.485)	(0.524)	(0.485)	(0.524)
tfpop	0.252**	0.246***	0.122**	0.119***
	(0.013)	(0.009)	(0.013)	(0.009)
Time FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
N	37938	37938	37938	37938
r2	0.032	0.033	0.032	0.033

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

As shown in Column 1, the coefficient on skill-unskilled wage inequality of input tariffs for ordinary firms is negative and significant, which indicates a decline in input tariffs is widens the wage inequality between skilled and unskilled labor. In column 2, we interact quality, ordinary firms, and input tariff reduction and still find a negative coefficient of triple interactions. The results indicate that quality upgrading will strengthen the marginal effects of input trade liberalization on wage inequality. We find similar results in the third and fourth columns which indicate that input trade liberalization also widens the wage gaps between semi-skilled and unskilled firms via quality upgrading. But the effects are smaller on semi-skilled wage gaps than skilled-unskilled wage gaps.

For the output tariff in final goods, both processing firms and ordinary firms are subject to tariffs. As a result, we follow Chen et al. (2013) and adopt an IV approach to deal with the endogeneity problem. As indicated, we use the one-year lagged changes of tariffs as the instruments of current tariff changes. It is clear that the industries with strong protection previously would be less likely to reduce tariffs now. We reestimate the empirical model (Equation 26) with two-stage least square method(2SLS). And the results are shown in Table (10).

Table 10 2SLS results on output tariff, quality, and wage inequality

	(1)	(2)	(3)	(4)	(1)
	$\Delta\widehat{wagp}^{su}_{ijt}$	$\Delta\widehat{wagp}^{su}_{ijt}$	$\Delta\widehat{wagp}^{su}_{ijt}$	$\Delta\widehat{wagp}^{mu}_{ijt}$	$\Delta\widehat{wagp}^{mu}_{ijt}$
$\Delta\tau_{it}$	-0.0826	-5.5982**	22.6705***	-2.7088**	10.9696***
	(1.2393)	(2.5766)	(3.9497)	(1.2467)	-1.9111
Δrq_{it}	0.5113***	0.9149***	0.9193***	0.4427***	0.4448***
	(0.0844)	(0.1400)	(0.1386)	(0.0677)	-0.0671
$\Delta\tau_{it} * rq_{it}$			-42.418***		-20.525***
			(10.0433)		-4.8597
size		-7.3895**	-6.6860***	-3.5756**	-3.2351***
		(3.1789)	(1.8531)	(1.5382)	-0.8966
Profit rate		1.8208***	1.8219***	0.8810***	0.8816***
		(0.1469)	(0.0549)	(0.0711)	-0.0266
R&D		-0.9082**	-0.8999***	-0.4395**	-0.4354***
		(0.3879)	(0.3160)	(0.1877)	-0.1529
TFP		0.1715***	0.1697***	0.0830***	0.0821***
		(0.0172)	(0.0067)	(0.0083)	-0.0033
wage		7.2232**	6.6186***	3.4951**	3.2026***
		(2.9748)	(1.7234)	(1.4394)	-0.8339
Constant	0.0556***	-1.1462***	-1.1513***	-0.5546***	-0.5571***
	(0.0046)	(0.1174)	(0.0521)	(0.0568)	(0.0252)
Underidentification test	0.000	0.000	0.000	0.000	0.000
Weak Identification test	47.15	982.67	330.11	982.67	330.11
time fixed effect	YES	YES	YES	YES	YES
Sector fixed effect	YES	YES	YES	YES	YES
Observations	80840	44690	44690	44690	44690
Adjusted R2	0.013	0.072	0.060	0.072	0.06

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

Column 1 of Table (10) shows a significantly positive coefficient of quality upgrading on wage inequality but no significant impact from trade liberalization. Column 2 incorporates the control variables which shows that both output tariffs reduction will enlarge the wage inequality between skilled and unskilled labor for all the firms. Column 3 adds the cross-terms of quality and tariff reduction and reveals the distinct effect of trade liberalization on firms via quality. The coefficients of tariff reduction are significantly positive while the coefficients of cross-terms are significantly negative in output tariffs. It indicates that the output tariff reduction will reduce wage inequality between the skilled and unskilled labor of low-quality firms and increase the wage inequality of high-quality firms. The results are similar on the wage gaps between semi-skilled and unskilled labor.

The bottom of Table (10) provides several tests to verify the effectiveness of the instruments. We use the Kleibergen-Paap LM statistics to conduct the Underidentification test and all the null hypothesis are rejected at one percent significance level. And we adopt the Cragg-Donald Wald F statistics to identify weak instruments and we reject the null hypothesis that the maximum relative bias due to weak instruments is 5%. The tests suggest that the instruments are strong and valid.

4.3 Robustness Tests

Our estimations support the model's prediction that trade liberalization affects firm-level wage inequality through quality choices. This highlights the importance of firm heterogeneity of firms in choosing quality and globalization modes. The estimations confirm that trade liberalization will enlarge wage inequality in firms with more quality upgrading. In this section, we provide more robustness tests on these results.

4.3.1 Mechanisms

This paper predicts that firms with more profits or higher productivity are more likely to upgrade in quality after trade liberalization. In this section, we identify the effect of tariff reduction on the quality upgrading of Chinese manufacturing exporters following the reduced form of the model in Equation (27):

$$\Delta rq_{ijgt} = \alpha + \beta_1 \Delta\tau_{it} + \beta_2 \Delta\tau_{it} * TFP_{it} + \beta_3 X_{it} + \varepsilon_t + \varepsilon_i + \epsilon_{ijt} \quad (27)$$

The dependent variable is the difference of exporting quality of product g from firm i to destination country j during time t-1 and t. The key independent variables are the lagged difference of tariffs at time t-1. One of the identification problems is whether tariff reduction is endogenous. For example, countries with low-quality are more likely to lower tariffs to import high-quality products. Thus we use the lagged tariff changes as a proxy of tariff reduction. On the one hand, the lagged tariff is highly related to the current tariff difference. On the contrary, the lagged tariff changes rarely affect the current quality upgrading. We tested our model proposition by introducing the cross-terms of productivity and exporting size. Other control variables include the profit rate, average wage, R&D, and age. We use the time and sector fixed effects to control the shocks over time that affects quality across sectors. The description of variables is shown in Table (11)

Table 11: Robustness Tests on Quality Upgrading from Trade Liberalization

	(1) input tariff	(2) input tariff	(3) input tariff	(4) output tariff	(5) output tariff	(6) output tariff
$\Delta\tau_{it}$	0.601	-0.910***	-0.980***	-2.107***	-0.214***	-0.251***
	(0.148)	(0.000)	(0.000)	(0.008)	(0.003)	(0.000)
$\Delta\tau_{it} * TFP_{it}$	-0.242***			0.280**		
	(0.000)			(0.020)		
$\Delta\tau_{it} * Profit_{it}$		-0.695**			-0.547	
		(0.015)			(0.440)	
$\Delta\tau_{it} * size_{it}$			3.832**			1.875
			(0.013)			(0.305)
size	-0.180	-0.109	-0.073	0.098	0.078	0.060
	(0.734)	(0.831)	(0.886)	(0.842)	(0.872)	(0.903)
profitrate	-0.046	-0.044	-0.042	-0.025	-0.028	-0.027
	(0.105)	(0.123)	(0.142)	(0.401)	(0.341)	(0.362)
rndshare	0.002	-0.017	-0.005	0.072	0.073	0.073
	(0.960)	(0.695)	(0.902)	(0.213)	(0.209)	(0.209)
tfpop	0.032***	0.034***	0.033***	0.021***	0.020***	0.020***
	(0.000)	(0.000)	(0.000)	(0.002)	(0.003)	(0.003)
N	37938	37938	37938	37938	37938	37938
r2	0.162	0.159	0.159	0.046	0.044	0.044

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

The model is estimated with OLS with time and sector fixed effects in Table (11). The first three columns are the estimations of input trade liberalization, while the last three columns are estimates of output trade liberalization. Column 1 shows that the reduction in the input tariff will upgrade the quality of firms with higher productivity. Column 2 shows that the effect is similar for firms with more profits. Input trade liberalization boosts quality upgrading at a higher level in more profitable firms. However, the coefficient of the cross-term of input tariff with size is significantly positive, which means input trade liberalization firm's exporting quality in smaller firms. In column 4, we find that output trade liberalization also upgrades quality in more productive firms. But the coefficient of output tariff interacted with profits are small and insignificant, These results show that there are no significant difference in profits when trade liberalization upgrade quality. In column 6, The coefficient of cross-terms with size becomes insignificant after controlling firm's size, whose coefficient is significantly positive. It means that large firms are more likely to upgrade quality, but the effect doesn't convey through trade liberalization.

4.3.2 Regression by Quality Quantile

The model predicts that tariff reduction induces increasing wage inequality in high-quality firms, while narrows wage inequality in low-quality firms. The estimation with cross-terms with tariff and quality has proved the prediction, but it doesn't reveal the threshold of quality where trade liberalization will enlarge the wage inequality. More precisely, we estimate the following model on each quartile of the firm's exporting quality and include the results in Table (12) and (13).

$$\Delta \widehat{wagp}_{ijt}^{fu} = \alpha + \beta_1 imp\tau_{it} + \beta_2 output\tau_{it} + \beta_3 X_{it} + \varepsilon_t + \varepsilon_i + \epsilon_{ijt} \qquad (28)$$

Table (12) describes the regression of trade liberalization on wage inequality between skilled and unskilled labor by the quanntile of quality. The coefficients of output tariff reduction change from significantly positive to negative in Row 1. The result indicates that output tariff reduction will reduce the wage inequality between skilled and unskilled labors with quality under 50% quantile while widening the wage inequality for firms with quality over 90% quantile. The second row reveals a similar trend except that input trade liberalization has no significant impact on firms in the first two quality quantile. Input tariff reductions increase the wage inequality of firms whose quality are over 75% quantile.

Table (13) shows the quantile regression results of wage inequality between semi-skilled and unskilled labor. It is shown that output tariff reduction will enlarge the wage inequality between semi-skilled and unskilled labor in firms with quality over 90% or under 10% quantiles while narrowing the wage inequality of firms with quality across 10% to 50% quantile. The input trade liberalization has no significant effect on the low-quality firms but widens the wage inequality for the firms with quality over 75% percentile. The results confirm the predictions that trade liberalization will enlarge the wage inequality among skills in high-quality firms while narrowing the wage inequality in low-quality firms.

Table 12: Estimation on skilled-unskilled wage inequality by the quantile of quality

	<Q10	Q10-25	Q25-50	Q50-75	Q75-90	>Q90
output tariff	1.7232***	0.7729***	0.8079***	-0.1165	-0.2423	-3.7389***
	(0.3555)	(0.2667)	(0.2039)	(0.2742)	(0.4257)	-0.9632
input tariff	0.0602	0.0891	0.6758***	0.2347	-0.9468***	-0.9709*
	(0.1561)	(0.1429)	(0.0925)	(0.1468)	(0.3120)	-0.6793

TFP by op	0.0627***	0.0763***	0.1004***	0.0307***	0.0584***	0.4377***
	(0.0124)	(0.0104)	(0.0054)	(0.0079)	(0.0108)	-0.0211
Size	-7.8666	0.1738	0.7781	-36.4296***	-2.8006	-10.5510**
	(11.2234)	(3.1607)	(1.4910)	(2.0421)	(4.4782)	-5.2996
Age	-0.0006	0.0007	0.0001	-0.0081***	0.0051***	0.0151***
	(0.0008)	(0.0006)	(0.0004)	(0.0006)	(0.0010)	-0.0021
R&D	-0.1318	1.2643***	-0.1139	-3.1236***	-3.7797***	-1.7536
	(0.2880)	(0.4722)	(0.1991)	(0.3554)	(0.5997)	-1.1897
profitrate	0.4435***	0.7494***	0.9468***	1.9824***	2.3039***	4.0193***
	(0.0446)	(0.0506)	(0.0403)	(0.0600)	(0.0766)	-0.1936
wage	38.5849***	1.3096	-0.4701	38.4088***	-6.8549**	19.0789***
	(4.0954)	(3.0540)	(1.4779)	(1.8907)	(2.7375)	-4.0934
Constant	-1.0074***	-0.4630***	-0.6824***	-0.2286***	-0.6928***	-3.3654***
	(0.2753)	(0.1401)	(0.0740)	(0.0756)	(0.0940)	(0.1963)
Time FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Obs	2263	5843	30606	46120	30894	20246

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

Table 13: Estimation on semi-unskilled wage inequality by the quantile of quality

	<Q10	Q10-25	Q25-50	Q50-75	Q75-90	>Q90
output tariff	-0.8338***	0.3740***	0.3909***	-0.0564	-0.1173	-1.8092***
	(0.1720)	(0.1291)	(0.0986)	(0.1327)	(0.2060)	-0.466
input tariff	0.0291	0.0431	0.3270***	0.1135	-0.4581***	-0.4698
	(0.0755)	(0.0691)	(0.0447)	(0.0710)	(0.1510)	-0.3287
TFP	0.0303***	0.0369***	0.0486***	0.0149***	0.0283***	0.2118***
	(0.0060)	(0.0050)	(0.0026)	(0.0038)	(0.0052)	-0.0102
size	-3.8065	0.0841	0.3765	-17.6272***	-1.3551	-5.1053**
	(5.4306)	(1.5293)	(0.7214)	(0.9881)	(2.1668)	-2.5643
age	-0.0003	0.0004	0.0000	-0.0039***	0.0024***	0.0073***
	(0.0004)	(0.0003)	(0.0002)	(0.0003)	(0.0005)	-0.001
R&D	-0.0638	0.6118***	-0.0551	-1.5114***	-1.8289***	-0.8485
	(0.1394)	(0.2285)	(0.0964)	(0.1720)	(0.2902)	-0.5757
Profit rate	0.2146***	0.3626***	0.4581***	0.9592***	1.1148***	1.9448***
	(0.0216)	(0.0245)	(0.0195)	(0.0290)	(0.0370)	-0.0937
wage	18.6701***	0.6337	-0.2275	18.5848***	-3.3169**	9.2317***
	(1.9816)	(1.4778)	(0.7151)	(0.9148)	(1.3246)	-1.9807
Constant	-0.4874***	-0.2240***	-0.3302***	-0.1106***	-0.3352***	-1.6284***
	(0.1332)	(0.0678)	(0.0358)	(0.0366)	(0.0455)	(0.0950)
Time FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Obs	2263	5843	30606	46120	30894	20246

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

4.3.3 Estimation with Cross-sectional Data

Another concern about the regression is that the wage gaps among skills are estimated under the fair-wage hypothesis using the provincial-level labor data. It may arises the problem of heterogeneity at provincial level instead of firm-level [Chen et al. (2017)]. Due to the data limitation, only labor data by skills in 2004 is available. In order to eliminate the possible bias of constructed data, we run the regression with cross-section data of 2004.

The first two columns of Table (14) reports the regression results with OLS while the last four columns regress the model using the 2SLS with lagged tariff as instrument. Exporting quality has a significantly positive relationship with wage inequality of skills in each method, which is robust to the previous estimation. Input trade liberalization will narrow the wage inequality of all firms but has different impact on wage inequality when considering the quality heterogeneity of firms. The results on input trade liberalization is consistent with our prediction. The effect of output tariff reduction is inconsistent with our prediction in OLS at first but improved by the 2SLS. All the results show that our predictions not only hold in regression of panel data but in cross-sectional regression.

Table 14 Estimation with Cross-section Data in 2004

	OLS $wagp_{ijt}^{su}$	OLS $wagp_{ijt}^{mu}$	2SLS $wagp_{ijt}^{su}$	2SLS $wagp_{ijt}^{mu}$	2SLS $wagp_{ijt}^{su}$	2SLS $wagp_{ijt}^{mu}$
Rq	0.39***	0.19***	1.57***	0.76***	0.90***	0.43***
	(0.01)	(0.05)	(0.17)	(0.08)	(0.24)	(0.12)
Imput tariff	-1.86***	-0.89***	-3.37***	-1.63***	14.33***	6.93***
	(0.32)	(0.16)	(0.80)	(0.39)	(1.72)	(0.83)
Outputariff	-0.87**	-0.42**	-1.88***	-0.91***	10.310***	4.986***
	(0.37)	(0.18)	(0.70)	(0.34)	(1.87)	(0.90)
size	-79.99***	-38.70***	-73.92***	-35.77***	-72.50***	-35.08***
	(4.92)	(2.38)	(7.84)	(3.79)	(7.85)	(3.81)
Profit rate	14.64***	7.08***	6.23***	3.01***	6.01***	2.91***
	(0.12)	(0.06)	(0.20)	(0.10)	(0.20)	(0.10)
TFP	0.17***	0.08***	1.05***	0.51***	1.06***	0.52***
	(0.02)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
wage	84.19***	40.73***	61.19***	29.61***	60.407***	29.23***
	(3.77)	(1.83)	(4.92)	(2.38)	(4.93)	(2.39)
rq*impt					-46.00***	-22.26***
					(4.00)	(1.94)
rq*oupt					-27.01***	-13.06***
					(3.72)	(1.80)
constant	34.09	0.4736	30.90***	-1.10***	32.01***	-0.57***
	(0.21)	(0.10)	(0.21)	(0.10)	(0.22)	(0.11)

Observations	251557	251557	44608	44608	44608	44608
Adjusted R2	0.08	0.08	0.09	0.09	0.09	0.09

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

4.3.4 Estimation with updated data

This paper uses the 2000-2006 data for two reasons. First, in this period, China entered the WTO in 2001 and experienced a dramatic decline in both input and output tariffs. Second, as the skill data at the firm-level is only available in 2004, we use the provincial-level skillshare to estimate the wage inequality between skilled and unskilled labor. As the wage data is highly persistent, it is reasonable to predict the skill wage before or after 3 years of 2004. However, this approach will be less precise if the period is longer.

Despite the reasonability of using 2000-2006 data, this data may be less representative in recent years. As a result, we update the tariff and firm-level data to 2011 and re-estimate the export quality. However, we are unable to get new firm-level skill data. To deal with this, we follow Chen et al. (2017) approach to using the Mincer-type model to estimate the wage inequality of skills. The specification is as follows.

$$\ln\overline{w_{ijgt}} = \gamma_0 + \gamma_u \ln w_{it}^{u} + \gamma_1 \theta_{ijgt} rq_{ijgt} + \gamma_2 \theta_{ijgt} \Delta\tau_{ijgt} + \gamma_3 \theta_{ijlt} * rq_{ijgt} * \Delta\tau_{ijgt} + \boldsymbol{\gamma} \theta_{ijgt} \boldsymbol{x_{ijgt}^{g}} + \sigma_i + \sigma_{jl} + \sigma_t + \epsilon_{ijgt}$$

where $\ln\overline{w_{ijgt}}$ is the log of the average wage of firm i in sector j of product g at time t. $\ln w_{ijgt}^{u}$ is the unskilled wage at the provincial level. θ_{ijgt} is the share of skilled labor in total labor inputs, which is estimated by the 2004 data and the provincial-level skill labor. The interactions between quality index and skill share investigate whether quality upgrading affects their skill wage inequality via changing skill shares. $\Delta\tau_{ijgt}$ measures the input or output tariff reduction. The theory predicts that trade liberalization enlarges firms' wage inequality between skilled and unskilled labor via quality upgrading. So we expect γ_3 to be neagtive and statistically significant. $\boldsymbol{x_{ijlt}^{g}}$ is a vector of control variables interacted with skill share (θ_{ijlt}) including firm size, TFP or profit rate. Firm size is measured by firm's sales over the industrial sales to control for the within-industry heterogeneity. The model also controls the time-specific, firm-specific and sector-province specific fixed effects. The results are shown in Table 14.

Columns 1 and 2 report the impact of input trade liberalization on wage inequality. As predicted, input trade liberalization widens the wage inequality between skilled and unskilled labor. Moreover, quality upgrading also increases the wage inequality of skills. The interaction fo quality and input tariffs are significantly negative, which indicates that quality upgrading increases the marginal effect of input trade liberalization on wage inequality. Moreover, in columns 3 and 4, we observe output trade liberalization also enlarges the wage inequality of skills via quality upgrading. Column 5 reports the input trade liberalization on wage inequality using precessing trade as a natural control group. The results keep robust with our baseline model that input trade liberalization enlarges wage inequality via changing endogenous quality.

Table 15 Estimation using Micer-type specification, 2000-2011

	Input tariff		Output tariff		Input tariff
	(1)	(2)	(3)	(4)	(5)
		×Skillshare		×Skillshare	Skillshare×ordinary
lnunskilledwage	0.410***	0.620***	0.943**	0.964**	0.981**
	(0.030)	(0.030)	(0.386)	(0.380)	(0.380)
Skillshare	-0.299***	-1.016***	-0.456***	-1.214***	-1.536***
	(0.048)	(0.316)	(0.059)	(0.385)	(0.384)
Rq	0.291***	0.152***	0.215***	0.099***	0.126***
	(0.021)	(0.028)	(0.022)	(0.029)	(0.030)
Tariff	-0.155***	0.126***	-0.048***	0.099***	-0.079***
	(0.012)	(0.016)	(0.017)	(0.021)	(0.021)
Rq*Tariff		-0.615***		-0.409***	-0.142
		(0.111)		(0.093)	(0.111)
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
N	363426	363426	363426	363426	96305
R2	0.114	0.126	0.199	0.212	0.092

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

4.3.5 Firm Heterogeniety Analysis

Table 16 reports the results by domestic firms and dual exporters using foreign intermeidates. Colums(1)-(4) reports the impacts on skilled-unskilled wage gaps while the last four columns report the impacts on semi-skilled and unskilled wage gaps. As shown in the first column, input trae liberalization enlarges the wage inequality of dual exporters but have no impact on domestic firms. As predicted in the model, output trade liberalization

Table 16 Domestic Firms versus Exporting firms using imported intermediates, 2000-2006

	Skilled-unskilled Wage gaps				Semi-skilled-unskilled Wage gaps			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Input	Input	Output	Output	Input	Input	Output	Output
	Dual	Domestic	Dual	Domestic	Dual	Domestic	Dual	Domestic
D.rq	0.197***	0.343**	0.293***	0.490***	0.095***	0.166**	0.142***	0.237***
	(0.008)	(0.023)	(0.000)	(0.000)	(0.008)	(0.023)	(0.000)	(0.000)
D. τ	1.732***	1.138	4.764***	9.790***	0.838***	0.551	2.305***	4.737***
	(0.000)	(0.525)	(0.000)	(0.000)	(0.000)	(0.525)	(0.000)	(0.000)
Rq*D.τ	-5.687***	-4.992	-14.697***	30.534***	-2.752***	-2.416	-7.112***	14.775***
	(0.000)	(0.371)	(0.000)	(0.000)	(0.000)	(0.371)	(0.000)	(0.000)
size	-0.427	-0.606	-0.320	-0.801	-0.207	-0.293	-0.155	-0.388
	(0.279)	(0.291)	(0.387)	(0.176)	(0.279)	(0.291)	(0.387)	(0.176)
profitrate	5.140***	8.692***	5.193***	8.903***	2.487***	4.206***	2.513***	4.308***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
rndshare	-1.753**	-4.085***	-1.738**	-4.070***	-0.848**	-1.977***	-0.841**	-1.969***
	(0.015)	(0.001)	(0.015)	(0.001)	(0.015)	(0.001)	(0.015)	(0.001)
tfpop	-0.002	0.070	-0.012	0.053	-0.001	0.034	-0.006	0.026
	(0.965)	(0.430)	(0.780)	(0.543)	(0.965)	(0.430)	(0.780)	(0.543)
N	89426	48837	89426	48837	89426	48837	89426	48837
r2	0.086	0.074	0.087	0.078	0.086	0.074	0.087	0.078

p-values in parentheses
* p<.1, ** p<0.05, *** p<0.01

narrows the wage inequality of domestic firms via quality degradation. But output trade liberalization enlarges the wage inequality of dual expoters via quality upgrading. The results are similar in examining the impacts on semi-skilled and unskilled wages, but at smaller magnitude.

5 Conclusion

In the paper, we propose a new channel that trade liberalization affects wage inequality via firm endogenous quality choices. We develop a heterogeneous-firm model of trade with endogenous quality under the framework of the heterogeneous firm model of trade. The model predicts that trade liberalization will upgrade the quality of dual exporters while degrading in the quality of domestic firms. With the fair-wage hypothesis, the paper estimates the fair wage gaps among skills as a proxy of firm-level wage inequality and explores the impact of trade liberalization on firm-level wage inequality via heterogeneous quality choices within firms.

The results strongly support the predictions of the theory and keep robust across various of robustness checks. The productive firms are more likely to export and upgrade quality after trade liberalization and quality upgrading will enlarge the wage inequality among skills. The research highlights the role of quality heterogeneity in studying the relationships between trade liberalization and wage inequality. Input trade liberalization widens the wage inequality of skills and improves the export quality of Chinese firms. We also provide evidence that tariff reduction in the final goods narrows the wage inequality of domestic firms between skilled and unskilled labor, which is associated with lower export quality.

Our study sheds a new light on the researches on trade liberalization and wage inequality. However, there is still some room for improvement for the paper. For example, we use the estimated parameters from other papers to estimate the quality. Even though the method is common in empirical studies, it would be better to estimate the counterfactual coefficients. We will further extend our research in the direction.

Reference

[1] Acemoglu D. Why do new technologies complement skills? Directed technical change and wage inequality . The Quarterly Journal of Economics. 1998 Nov 1;113(4):1055-89.

[2] Acemoglu D. Technical change, inequality, and the labor market. Journal of economic literature. 2002 Mar 1;40(1):7-2.

[3] Acemoglu D, Autor D. Skills, tasks and technologies: Implications for employment and earnings[M]. Handbook of labor economics. 2011 Dec 31;4:1043-171.

[4] Acemoglu D. What does human capital do? A review of Goldin and Katz's The race between education and technology. Journal of Economic Literature. 2012 Jun 1;50(2):426-63.

[5] Aiginger K. The use of unit values to discriminate between price and quality competition. Cambridge Journal of Economics. 1997 Sep 1;21(5):571-92.

[6] Aiginger K. The use of unit values to discriminate between price and quality competition. Cambridge Journal of Economics. 1997 Sep 1;21(5):571-92.

[7] Alcalá F. Specialization across goods and export quality. Journal of International Economics. 2016 Jan 31;98:216-32.

[8] Alchian AA, Allen WR, Newcomb R, Ramsey D. University economics[M]. Wadsworth Publishing Company; 1967.

[9] Alvarez R, Lopez RA. Exporting and performance: evidence from Chilean plants. Canadian Journal of Economics/Revue canadienne d'économique. 2005 Nov 1;38(4):1384-400.

[10] Amiti M, Davis DR. Trade, firms, and wages: Theory and evidence. The Review of economic studies. 2012 Jan 1;79(1):1-36.

[11] Amiti M, Khandelwal AK. Import competition and quality upgrading. Review of Economics and Statistics. 2013 May 1;95(2):476-90.

[12] Baldwin R, Harrigan J. Zeros, quality, and space: Trade theory and trade evidence. American Economic Journal: Microeconomics. 2011 May 1;3(2):60-88.

[13] Bas M, Strauss-Kahn V. Input-trade liberalization, export prices and quality upgrading. Journal of International Economics. 2015 Mar 31;95(2):250-62.

[14] Bastos P, Silva J. The quality of a firm's exports: where you export to matters. Journal of International Economics. 2010 Nov 30;82(2):99-111.

[15] Berman E, Bound J, Griliches Z. Changes in the demand for skilled labor within US manufacturing: evidence from the annual survey of manufactures.The Quarterly Journal of

Economics. 1994 May 1;109(2):367-97.
[16] Berman E, Machin S. Skill-biased technology transfer around the world. Oxford review of economic policy. 2000 Sep 1;16(3):12-22.
[17] Bernard AB, Wagner J. Export entry and exit by German firms . Weltwirtschaftliches Archiv. 2001 Mar 1;137(1):105-23.
[18] Bils M. Measuring the growth from better and better goods . National Bureau of Economic Research; 2004 Jul 5.
[20] Bo C, Yu M, Yu Z. Wage Inequality and Input Trade Liberalization: Firm-Level Evidence from China . Working Paper.2013
[21] Boorstein R, Feenstra RC. Quality upgrading and its welfare cost in US steel imports, 1969-74 . Working Paper.1987
[22] Bratti M, Matteucci N. Is there skill-biased technological change in Italian manufacturing? Evidence from firm-level data . Brussels Economic Review. 2005;48(1-2).
[23] Burstein A, Vogel J. Globalization, technology, and the skill premium: A quantitative analysis. National Bureau of Economic Research; 2010 Oct 14.
[24] Bustos P. Trade liberalization, exports, and technology upgrading: Evidence on the impact of MERCOSUR on Argentinian firms. The American economic review. 2011 Feb 1;101(1):304-40.
[25] Davis DR, Mishra P. Stolper-Samuelson is dead: And other crimes of both theory and data In Globalization and poverty[M]. 2007 Mar 9 (pp. 87-108). University of Chicago Press.
[26] De Loecker J. Do exports generate higher productivity? Evidence from Slovenia.Journal of international economics. 2007 Sep 30;73(1):69-98.
[27] Eaton J, Kortum S, Kramarz F. Dissecting trade: Firms, industries, and export destinations. National Bureau of Economic Research; 2004 Mar 8.
[28] Edwards L. Globalisation and the skills bias of occupational employment in South Africa.South African Journal of Economics. 2001 Mar 1;69(1):40-71.
[29] Ederington J, McCalman P. Endogenous firm heterogeneity and the dynamics of trade liberalization. Journal of International Economics. 2008 Mar 31;74(2):422-40.
[30] Esquivel G, Rodrıguez-López JA. Technology, trade, and wage inequality in Mexico before and after NAFTA. Journal of Development Economics. 2003 Dec 31;72(2):543-65.
[31] Fajgelbaum P, Grossman GM, Helpman E. Income distribution, product quality, and international trade. Journal of political Economy. 2011 Aug 1;119(4):721-65.

[32] Fan H, Li YA, Yeaple SR. Trade liberalization, quality, and export prices. Review of Economics and Statistics. 2015 Dec 1;97(5):1033-51.
[33] Feenstra RC, Hanson GH. The impact of outsourcing and high-technology capital on wages: estimates for the United States, 1979–1990. The Quarterly Journal of Economics. 1999 Aug 1;114(3):907-40.
[34] Feenstra R, Hanson G. Global production sharing and rising inequality: A survey of trade and wages. National Bureau of Economic Research; 2001 Jul 1.
[35] Feenstra RC, Romalis J. International prices and endogenous quality.The Quarterly Journal of Economics. 2014 May 1;129(2):477-527.
[36] Fieler AC, Eslava M, Xu DY. Trade, Quality Upgrading, and Input Linkages: Theory and Evidence from Colombia. Working paper
[37] Flam H, Helpman E. Vertical product differentiation and North-South trade. The American Economic Review. 1987 Dec 1:810-22
[38] Glass AJ, Saggi K. Intellectual property rights and foreign direct investment. Journal of International economics. 2002 Mar 31;56(2):387-410.
[39] Glass AJ, Wu X. Intellectual property rights and quality improvement. Journal of Development Economics. 2007 Mar 31;82(2):393-415.
[40] Grossman GM, Helpman E. Product development and international trade. Journal of political economy. 1989 Dec 1;97(6):1261-83.
[41] Grossman GM, Helpman E. Quality ladders in the theory of growth. The Review of Economic Studies. 1991 Jan 1;58(1):43-61.
[42] Grossman GM, Helpman E. Innovation and growth in the global economy[M]. MIT press; 1993.
[43] Goldberg PK, Pavcnik N. Distributional effects of globalization in developing countries. Journal of economic Literature. 2007 Mar 1;45(1):39-82.
[44] Goldberg P, Khandelwal A, Pavcnik N, Topalova P. Trade liberalization and new imported inputs. The American Economic Review. 2009 May 1;99(2):494-500.
[45] Hallak JC, Sivadasan J. Firms' exporting behavior under quality constraints. National Bureau of Economic Research; 2009 Apr 30.
[46] Hallak JC, Schott PK. Estimating cross-country differences in product quality. The Quarterly Journal of Economics. 2011 Feb 1;126(1):417-74.
[47] Hanson GH, Harrison A. Trade liberalization and wage inequality in Mexico. ILR

Review. 1999 Jan;52(2):271-88.
[48] Hanson GH, Feenstra RC. Intermediaries in entrepôt trade: Hong Kong re-exports of Chinese Goods. National Bureau of Economic Research; 2001 Jan 1.
[49] Haruyama T, Zhao L. Trade and firm heterogeneity in a quality-ladder model of growth. Research Institute for Economics & Business Administration, Kobe University, Discussion Paper. 2008 Apr(223).
[50] Helpman E, Itskhoki O, Redding S. Inequality and unemployment in a global economy. Econometrica. 2010 Jul 1;78(4):1239-83.
[51] Henn C, Papageorgiou C, Spatafora N. Export quality in advanced and developing economies: Evidence from a new dataset. WTO Staff Working Paper; 2015.
[52] Hummels D, Skiba A. Shipping the good apples out? An empirical confirmation of the Alchian-Allen conjecture . Journal of political Economy. 2004 Dec; 112(6): 1384-402.
[53] Hummels D, Klenow PJ. The variety and quality of a nation's exports. The American Economic Review. 2005 Jun 1;95(3):704-23
[54] Imbs J, Méjean I. Trade elasticities. Review of International Economics. 2016 Nov 1.
[55] Johnson RC. Trade and prices with heterogeneous firms. Journal of International Economics. 2012 Jan 31;86(1):43-56.
[56] Kamal F, Lovely ME, Mitra D. Trade liberalization and labor shares in China. Working Paper.2014
[57] Kanbur R, Zhang X. Fifty years of regional inequality in China: a journey through central planning, reform, and openness.Review of development Economics. 2005 Feb 1;9(1):87-106.
[58] Khandelwal A. The long and short (of) quality ladders. The Review of Economic Studies. 2010 Oct 1;77(4):1450-76.
[59] Kremer M. The O-ring theory of economic development. The Quarterly Journal of Economics. 1993 Aug 1;108(3):551-75.
[60] Kugler M, Verhoogen E. Plants and imported inputs: New facts and an interpretation. The American Economic Review. 2009 May 1;99(2):501-7.
[61] Kugler M, Verhoogen E. Prices, plant size, and product quality. The Review of Economic Studies. 2012 Jan 1;79(1):307-39.
[62] Krugman P. Scale economies, product differentiation, and the pattern of trade. The American Economic Review. 1980 Dec 1;70(5):950-9.
[63] Leamer, E.E. In search of Stolper-Samuelson effects on US wages. (No. w5427).

National Bureau of Economic Research.1996
[64] Leamer E.E. What’s the use of factor contents? . Journal of International Economics. 2000 Feb 29;50(1):17-49.
[65] Linder SB. An essay on trade and transformation[M]. Stockholm: Almqvist & Wiksell; 1961.
[66] Lin JY, Wang Y. China's integration with the world: Development as a process of learning and industrial upgrading. 2008; Working Paper
[67] Lileeva A, Trefler D. Improved access to foreign markets raises plant-level productivity for some plants. The Quarterly Journal of Economics. 2010 Aug 1;125(3):1051-99.
[68] Martin J, Mejean I. Low-wage country competition and the quality content of high-wage country exports. Journal of International Economics. 2014 May 31;93(1):140-52.
[69] Manova K, Zhang Z. Export prices across firms and destinations. The Quarterly Journal of Economics. 2012 Jan 12
[70] Manova K, Zhang Z. Multi-product firms and product quality. National Bureau of Economic Research; 2012 Dec 21.
[71] Melitz MJ. The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica. 2003 Nov 1;71(6):1695-725.
[72] Michelacci C, Lopez-Salido D. Technology shocks and job flows. The Review of Economic Studies. 2007 Oct 1;74(4):1195-227.
[73] Pula G, Santabárbara D. Is China climbing up the quality ladder? Estimating cross country differences in product quality using Eurostat's COMEXT trade database . Working paper
[74] Schott PK. Across-product versus within-product specialization in international trade. The Quarterly Journal of Economics. 2004 May 1;119(2):647-78.
[75] Scott AJ. The changing global geography of low-technology, labor-intensive industry: clothing, footwear, and furniture. World Development. 2006 Sep 30;34(9):1517-36.
[76] Xu B, Li W. Trade, technology, and China's rising skill demand . Economics of Transition. 2008 Jan 1;16(1):59-84.
[77] Van Biesebroeck J. Exporting raises productivity in sub-Saharan African manufacturing firms. Journal of International economics. 2005 Dec 31;67(2):373-91
[78] Verhoogen EA. Trade, quality upgrading, and wage inequality in the Mexican manufacturing sector. The Quarterly Journal of Economics. 2008 May 1;123(2):489-530.

[79] Wang Y, Zhao L. Saving good jobs from global competition by rewarding quality and efforts. Journal of International Economics. 2015 Jul 31;96(2):426-34.
[80] Weiss M. Skill-biased technological change: Is there hope for the unskilled? Economics Letters. 2008 Sep 30;100(3):439-41.
[81] Wood A. How trade hurt unskilled workers. The Journal of Economic Perspectives. 1995 Jul 1;9(3):57-80.
[82] Yeaple SR. A simple model of firm heterogeneity, international trade, and wages. Journal of international Economics. 2005 Jan 31;65(1):1-20.