Trade Liberalization and Skill Upgrading: Evidence on the Impact of APTA on Chinese Manufacturers*

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Abstract

This paper studies the impact of an Asian trade agreement, APTA, on skill upgrading by Chinese manufacturers. First, we develop a general equilibrium model of trade with heterogeneous firms and endogenous export and employee training decisions to explain firm performance following trade liberalization. Second, we test the theoretical model based on general difference-in-differences estimations, showing that firms in some sectors facing higher reductions in India's tariffs increase investment in on-the-job training faster. The effects of trade openness on export participation and training spending of firms are the largest in the middle range of productivity, which corresponds to our model prediction.

Keywords: trade policies, trade integration, China, manufacturing, human capital investment

JEL Classification: F13, F15, J24, L60, O19

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1 Introduction

China's performance in economic growth is remarkable, and one of the significant contributors is trade openness. After joining the World Trade Organization (WTO) in 2001, China engages further in international trade and attracted more foreign direct investments (FDI). It benefits greatly from trade integration through acting as a leading country of exports, inducing capital inflows and promoting economic growth. Besides the WTO accession, regional trade liberalization such as the Asian Pacific trade agreement (APTA) and Regional Comprehensive Economic Partnership (RCEP) also foster economic development in China. In the meantime, human capital accumulation has improved sharply in China in the past twenty years. For instance, its tertiary school enrollment rate has increased from 7.69% in 2000 to 53.77% in 2018 according to the World Bank. Workers upgrade their skill levels through education or on-the-job training. Our firm level data show a pattern that Chinese new exporters have greater incentives in providing labor training than non-exporters. This indicates that there is a relationship between exports and human capital investment, but is not enough to explain whether expanded export opportunities encourages firms to invest more in human capital for innovation or vice versa. In this paper, we intend to study the effect of trade liberalization (APTA) on export and skill upgrading decisions of Chinese manufacturers theoretically and empirically.

The heterogeneous-firm trade model in Melitz (2003) and Bernard et al. (2003) emphasizes that trade integration reallocates market shares towards exporters who are larger, more productive and more skill- and capital-intensive than non-exporters. In our benchmark model, following the literature, more productive firms find it profitable to pay for the fixed costs of entering the export market, and those with even higher productivity choose to invest in human capital with fixed skill-upgrading costs because firms receiving larger sales are able to provide labor training, which is also consistent with our data pattern. A reduction in trade cost increases export sales and encourages more new entrants in the export market, and then it also induces more firms to invest in human capital and produce skill-intensive products.

Figure 1 (green solid line) reflects that a reduction in India's tariff leads to a boost in exports to the Indian market by Chinese firms. India's average applied effective tariff declines by about 15 percentage points from 2004 to 2007, but the change in the average tariff in the rest of the world (Figure 1's red dashed line) is nearly zero during the same period. Based on this fact, we extend our model to distinguish export destinations—the "main" trading countries with lower and stable trade barriers (the rest of the world) and the less preferential trading partners such as India who impose relatively higher (but declining) tariffs—and then analyze the impacts of trade liberalization on firms' export participation and investment in on-the-job training in the home country (China). Regional trade liberalization policies are expected to boost regional trade and investment, facilitate technology and skill upgrading, and stimulate economic growth. We test the model in the context of a regional trade liberalization episode, APTA, through estimating the impact of the reduction in India's tariffs on firm entry in the export market and labor training provided by firms between 2004 and 2007.

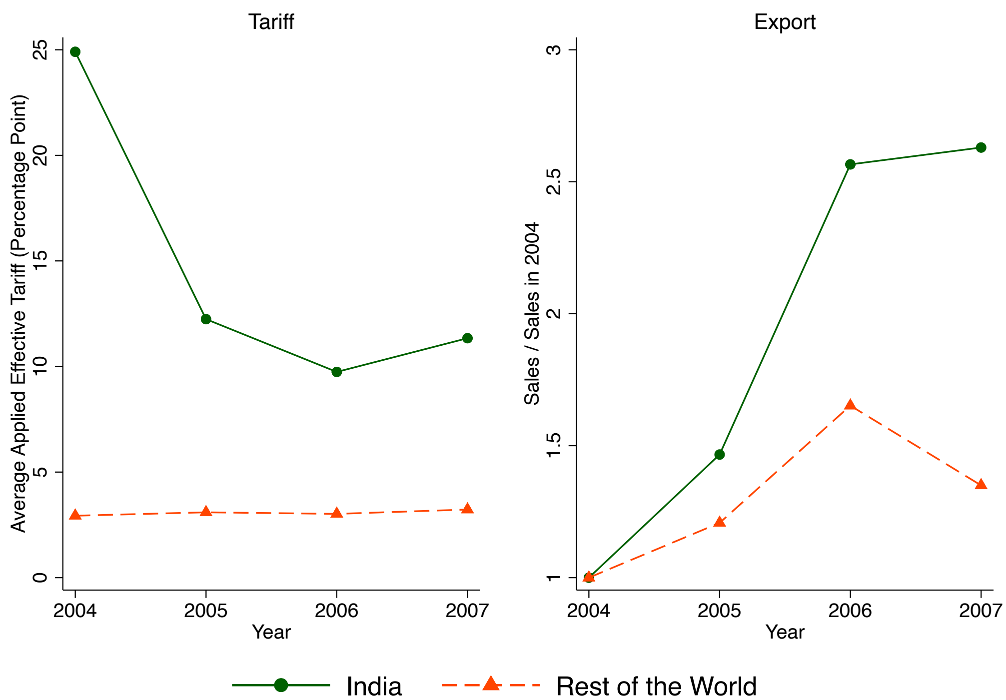

Figure 1: Trends of Tariffs and China's Export Sales (2004–2007)

Notes: The left panel shows the average applied effective tariff China faces when exporting goods to India and the rest of the world; the average for the rest of the world is weighted by the export sales from China to each country. The right panel depicts China's total export sales in each year relative to 2004.

We start our empirical analysis by exploring data patterns. In the first check, we investigate whether the sorting pattern predicted by the benchmark model is consistent with the observed differences between exporters and non-exporters. The model implies that productivity differences produce a sorting of firms in four groups: the least productive firms exit the market (not in data), the low productivity group employs low-skilled workers and serve the domestic market only, the middle group exports but still produces unskilled goods with demand for low-skilled workers, and the most productive firms both export and produce skilled goods through upgrading labor skill levels. Indeed, the data confirm that exporters provide more labor training than non-exporters in 2004. Moreover, new exporters increase investment in human capital faster than continuing exporters during the 2004–2007 liberalization period. It is plausible that new exporters produce more skill-intensive products in order to become more competitive in the foreign market.

In the second data check, we investigate whether the sorting pattern predicted by the extended model is consistent with the observed differences between exporters to main trading partners and exporters to less preferential trading partners. In the extended model, the least productive firms exit the market; the lower-middle group exports unskilled goods to main trading countries; the upper-middle group exports unskilled goods to less preferential trading partners; the high productivity group upgrades labor skills, and only exports skilled goods to main trading countries; the most productive firms are able to both provide labor training and export skilled goods to less preferential trading countries. The extended model assumes that some firms find it more profitable to export skilled goods to main countries than to export unskilled goods to other countries who impose higher trade barriers. This assumption comes directly from the data pattern, as we notice that switching exporters from India to the rest of the world increase training spending per worker faster during 2004–2007. The data pattern also shows that exporters to less preferential trading countries such as India invest more in on-the-job training than those exporting to main countries (the rest of the world) in 2004, except for those who switch destination countries in 2007. In particular, both new and switching exporters to India increase labor training slightly more than continuing, exiting, and never exporters during the regional trade liberalization period.

The data patterns describe above show that there is a coincidence between export participation and skill upgrading but do not address the question of whether trade liberalization induces firms to invest in human capital and produce skill-intensive goods instead of unskilled goods. Thus, we attempt to establish causality by linking exporting and skill upgrading directly to the reduction in India's tariffs for imports from China. This is a direct test of the model where firm decisions to enter the export markets and provide labor training are endogenous. In the meantime, we compare two export destinations imposing different trade costs, and analyze whether exporters switch to another export market following trade liberalization.

First, the benchmark model predicts that the productivity cutoffs to enter the export market and to upgrade labor skills fall more when tariffs fall more. Firms find it easier and more profitable to participate in foreign markets and provide labor training following trade integration. Thus, we estimate the change in the probability that a firm enters the export market as a function of the change in India's tariffs. The average reduction in tariffs (15 percentage pints) increases the probability of entering the export market by 1.55 to 1.88 percentage points from 2004 to 2007. Then, we estimate the change in spending on labor training as a function of the change in tariffs. The average reduction in tariffs increases spending on labor training by 0.11 to 0.13 log points during the same period. The above empirical results are from a sample of selected sectors. In the other sectors, we find that the effect of trade liberalization on export participation is positive but insignificant, and the lower trade costs even decrease spending on training. The different results between selected sectors and other sectors are due to sector heterogeneity in productivity and policy in China. Therefore, some of our empirical findings can go beyond the benchmark model predictions, which indicates a need for model extension.

Next, the extended model predicts that the reduction in tariffs of less preferential trading partners (country o) increases the probability of entering the export markets of both main trading partners (country m) and less preferential trading partners (country o). Meanwhile, lower trade costs induce more spending on labor training provided by exporters to country o, but discourages skill upgrading of exporters to country m as predicted by the extended model. The extended estimation of selected sectors shows that the reduction in India's tariffs induce more export entry in the

Indian market and increase spending on labor training provided by new exporters to India. Consistent with model prediction, new exporters have a larger likelihood to enter the Indian market and new exporters to India induce more investment in on-the-job training following the reduction in India's tariffs.

This paper contributes to the theoretical literature that studies the mechanism of how trade openness affects firms' investment training. The theoretical model in this paper builds on Melitz (2003) and Bustos (2011b).[1] The heterogeneous-firm model offers new insights into the causes and consequences of international trade.[2] There are model specifications that study trade-induced economic outcomes.[3] In the context of human capital adjustment, however, Falvey et al. (2010) build a traditional two-sector Heckscher-Ohlin trade model with skilled and unskilled labor to address when and whether unskilled workers opt for skill upgrading in response to trade liberalization in a skill-abundant country; Van Long et al. (2007) develop a model of firm-specific human capital accumulation, and focus on the decision of workers to accumulate firm-specific skills following trade liberalization. The major differences between our paper and theirs are that 1) we apply the "new" trade theory (heterogeneous-firm model) and 2) we focus on the decision of firms. In terms of studies on China's economy, some papers associate China's economic growth with its human capital accumulation. China has been sustaining the fastest growth for a long period of time after it started economic reform and engaged in global economy. Li et al. (2017) point out that human capital is also an important source and prospect for the future economic growth in China as higher per capita income is positively associated with higher levels of human capital. This paper focuses on the impact of a regional trade liberalization

[1] Bustos (2011a) points out that firms upgrading skills also upgrade technology, and analyze skill upgrading in the context of the employment share of skilled workers. In this paper, firms make skill upgrading decisions through increasing spending in labor training.

[2] Recent literature also incorporates firm dynamics in models of international trade. Burstein and Melitz (2013) generate substantial aggregate-transition dynamics from endogenous shifts in firm-size distribution in response to trade liberalization and find that the responses of trade volumes, innovation, and aggregate output depends on the assumption for firm dynamics, endogenous innovation, and the expected time path of trade liberalization.

[3] For instance, Helpman et al. (2004) highlight the important role of within-sector firm productivity differences in explaining the structure of international trade and FDI with heterogeneous firms.

policy, APTA, on export participation, as well as labor training decisions by Chinese manufacturing firms. Firms' investment in on-the-job training is an important way for skill enhancement, human capital adjustment and product quality improvement in China.

The empirical work presented herein is related to the fields of trade liberalization and manufacturing firms' performance. A wide range of studies have investigated the impacts of trade integration on export market entry, technology adaption, skill upgrading, productivity, wage inequality and other economic outcomes. For instance, Bustos (2011b) empirically analyzes the impact of free trade on export participation and technology upgrading of Argentinian firms. Bas (2012) extends the previous work by also considering skill upgrading with plant-level data from Chile's manufacturing sector. There, however, can be heterogeneity in the trade effect on skill upgrading by export destinations. For example, Yamashita (2008) finds that fragmentation trade with high income countries has a skill downgrading effect, in contrast to skill upgrading among firms with developing East Asian countries, based on a panel dataset covering 52 Japanese manufacturing industries. There are empirical studies about trade adjustment and human capital development of less developed countries, such as India (Edmonds et al., 2010),[4] and Indonesia (Bazzi et al., 2016).[5] Wang (2007) uses data from manufacturing industries in 25 developing countries to study the role of human capital in trade-related technology spillovers. Regarding trade liberalization in China, Brandt et al. (2017) focus on how the WTO accession influences markups and productivity of Chinese manufacturing firms. Our research is closely related to Bustos (2011b). The departure of this paper from the literature is that we introduce two different export markets to discuss firms' export decisions in response to the reduction in one destination's tariffs, and examine how a regional trade liberalization (APTA) affects investment in on-the-job training of Chinese manufacturers.[6]

[4] They examine the impact of India's 1991 trade reform on schooling and child labor. They find that rural India experiences an increase in schooling and decline in child labor, but the rural districts with employment subject to larger changes in final product protection have a relative rise in poverty and smaller improvements in schooling.

[5] They study the role of location-specific human capital and skill transferability in shaping productivity in Indonesia.

[6] In the context of labor training, Liu and Lu (2016) and Huang and Zhuang (2021) apply a large panel data of manufacturing firms in China to investigate the effects of on-the-job training on firm

The rest of the paper is organized as follows. Section 2 presents the benchmark model. Section 3 derives the extended model in which we distinguish two distinct export markets. Section 4 describes trade policies and data sets. Section 5 provides an empirical framework to exam the effects of trade liberalization on export participation and skill upgrading and test the predictions of the baseline and extended models; in particular, section 5.5 makes a discussion about selected and other sectors. Section 6 concludes the whole paper.

2 Benchmark Model

The model is built on Melitz (2003) and Bustos (2011b) to study the impact of trade liberalization on firms' human capital investment decisions. There are two identical countries, and each country has two sectors, the skill-intensive sector s and the unskilled sector u. We consider a monopolistically competitive setup with heterogeneous firm productivity, endogenous skill upgrading decision and endogenous export participation. The least productive firms have to exit the market due to negative profits. Some firms in the middle range of productivity can export to the foreign country even though they are not productive enough to invest in labor training. The most productive firms are able to export and invest in labor training. Precisely, they employ high-skilled labor and produce skill-intensive products.

2.1 Preferences

In each country, there are two sectors, indexed by $i \in (s, u)$, the skill-intensive sector s and unskilled sector u. The preferences of a representative consumer in the home country is give by the following CES function combing skilled and unskilled goods:

$$\max_{y_{s,t}(\omega), y_{u,t}(\omega)} \left[\left(\int_{\omega \in \Omega_u} y_{u,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}\frac{\rho-1}{\rho}} + \left(\int_{\omega \in \Omega_s} y_{s,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

subject to

$$\int_{\omega \in \Omega_u} p_{u,t}(\omega) y_{u,t}(\omega) d\omega + \int_{\omega \in \Omega_s} p_{s,t}(\omega) y_{s,t}(\omega) d\omega = E$$

productivity and wages.

where Ω_i is the mass of varieties available in sector i coming from home and foreign countries, E is the aggregate level of spending, $y_i(\omega)$ and $p_i(\omega)$ are the consumption of good ω and the price of this good respectively, θ is the elasticity of substitution within sector varieties and ρ is the elasticity of substitution between sector varieties.

These preferences generate demand functions in sector u and s, and they are

$$y_u(\omega) = \left(\frac{p_u(\omega)}{P_u}\right)^{-\theta} \frac{P}{P_u} Y = \rho_u(\omega)^{-\theta} \rho_1^{\theta-\rho} Y$$
$$y_s(\omega) = \left(\frac{p_s(\omega)}{P_s}\right)^{-\theta} \frac{P}{P_s} Y = \rho_s(\omega)^{-\theta} \rho_2^{\theta-\rho} Y$$

where the relative prices are defined as $\frac{p_u(\omega)}{P} = \rho_u(\omega)$, $\frac{p_s(\omega)}{P} = \rho_s(\omega)$, $\frac{P_u}{P} = \rho_1$, $\frac{P_s}{P} = \rho_2$ and aggregate consumption good defined as $Y \equiv U$ (utility) and $PY = E$.

The aggregate price index is denoted as

$$P = \left[P_u^{1-\rho} + P_s^{1-\rho}\right]^{\frac{1}{1-\rho}}$$

where $P_u = \left(\int_{\omega\in\Omega} p_u(\omega)^{1-\theta} d\omega\right)^{\frac{1}{1-\theta}}$ and $P_s = \left(\int_{\omega\in\Omega} p_s(\omega)^{1-\theta} d\omega\right)^{\frac{1}{1-\theta}}$ are the prices of unskilled and skilled goods respectively.

2.2 Firm Entry

Firms under monopolistic competition are heterogeneous in their productivity z, and pay a sunk entry cost f_e in units of aggregate consumption good. Following Ghironi and Melitz (2005), the firm entrant draws its productivity z with a Pareto distribution $G(z) = 1 - z^{-\kappa}$ after entering the market. Then, firms can make decisions for exporting and human capital investment. Human capital investment in this paper refers to how much training spending firms are able to provide workers with for skill upgrading.

2.3 Production

There is a continuum of firms with heterogeneous productivity z. Let $z \in \Omega$ be a particular variety. Firms endogenously choose to produce unskilled or skilled goods. Firm technology is represented by a total cost function, and the total cost under the unskilled sector is

$$TC_u(z) = f_u + \frac{w_l}{z} y_u(z)$$

where f_u is fixed production costs of the unskilled sector measured in units of aggregate consumption goods, and w_l is the real wage of low-skilled workers. More productive firms can hire high-skilled workers to produce skill-intensive goods with paying higher fixed costs $f_s > f_u$, and deliver lower marginal production costs with $\gamma > 1$ and $\beta \in (0,1)$. w_h is the real wage of high-skilled workers. The total cost of skill-intensive goods is

$$TC_s(z) = f_s + \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma z} y_s(z)$$

The profit maximization of these two sectors yields the following pricing rules of domestic sales:

$$\rho_u^d(z) = \frac{\theta}{\theta-1}\frac{w_l}{z}$$
$$\rho_s^d(z) = \frac{\theta}{\theta-1}\frac{w_h^{\beta} w_l^{1-\beta}}{\gamma z}$$

The two pricing rules of exporting are $\rho_s^x(z) = \tau\rho_s^d(z)$, $\rho_u^x(z) = \tau\rho_u^d(z)$. Hence, $\rho_s^d(z) = \rho_u^d(z)/\lambda$ where $\lambda \equiv \gamma\left(\frac{w_l}{w_h}\right)^{\beta}$.

Profits if producing unskilled goods and only serving the domestic market:

$$\pi_u^d(z) = \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u$$
$$= \frac{r_u^d(z)}{\theta} - f_u$$

where firm revenue $r_u^d(z) = \left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y$.

Profits if producing unskilled goods and exporting:

$$\pi_u^x(z) = (1+\tau^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u - f_x$$
$$= (1+\tau^{1-\theta})\frac{r_u^d(z)}{\theta} - f_u - f_x$$

Exporting is costly, incurring iceberg trade costs τ and fixed exporting costs, f_x, measured in units of aggregate consumption goods.

Profits if producing skill-intensive goods and only serving the domestic market:

$$\pi_s^d(z) = \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\beta} w_l^{1-\beta}}{\gamma z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_s$$
$$= \lambda^{\theta-1}\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi f_u$$

Profits if producing skill-intensive goods and exporting:

$$\begin{aligned}\pi_s^x(z) &= (1+\tau^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\beta}w_l^{1-\beta}}{\gamma z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_s - f_x \\ &= \lambda^{\theta-1}(1+\tau^{1-\theta})\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi f_u - f_x\end{aligned}$$

where $\phi > 1$ and $f_s > f_u$. High productivity firms find it profitable to export skilled goods with incurring higher fixed production costs, ϕf_u.

After learning the idiosyncratic productivity z, firms endogenously choose to produce unskilled or skilled goods. The least productive firms must exit the market if the domestic sales profit is negative, so the exit cutoff z_e is defined as:

$$z_e = \{z|\pi_u^d(z) = 0\}$$

z_x denotes the productivity level above which firms producing unskilled goods and finding export profitable, so

$$z_x = \{z|\pi_u^d(z) = \pi_u^x(z)\}$$

Thus, z_x can be expressed as a function of z_e with the zero profit condition for marginal exporters:

$$z_x = \tau z_e\left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} \tag{1}$$

This condition shows that $z_x > z_e$ as long as $\tau\left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} > 1$.

More productive firms are able to provide training to upgrade workers' skill levels, so they can enter the skill-intensive sector. The productivity cutoff z_s is the cutoff level where firms obtain equal profits from producing unskilled and skilled goods:

$$z_s = \{z|\pi_s^x(z) = \pi_u^x(z)\}$$

The zero profit condition for the marginal firm to produce skill-intensive goods gives the following expression of z_s as a function of z_e:

$$z_s = z_e\left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{1}{\theta-1}} \tag{2}$$

The restriction required for $z_s > z_e$ is $\phi - 1 > (1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)$. Given $\tau\left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}} > 1$, the ratio of z_s and z_x is larger than one:

$$\frac{z_s}{z_x} = \left[\frac{\tau^{1-\theta}(\phi-1)f_u}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)f_x}\right]^{\frac{1}{\theta-1}} > 1$$

In equilibrium, there are four groups of firms. The least productive firms $z < z_e$ exit the market, the low productivity firms $z_e < z < z_x$ are not able to investment in labor training and they only serve the domestic market, the moderate productivity firms $z_x < z < z_s$ also cannot invest in human capital but can export to the foreign market, and the most productive firms $z > z_s$ are able to both export and upgrade skill levels of their workers. The productivity cutoffs in the model $z_s > z_x$ are consistent with the data since some firms find it profitable to export, but not profitable to provide labor training and produce skilled goods.

2.4 Equilibrium

2.4.1 labor Market

The aggregate demand for low-skilled workers under both the unskilled and skill-intensive sectors is:

$$\begin{aligned} L &= L_u + L_s \\ &= \int_{z_e}^{z_x} l_u^d(z)dz + \int_{z_x}^{z_s} l_u^x(z)dz + \int_{z_s}^{\infty} l_s^x(z)dz \end{aligned}$$

The aggregate demand for high-skilled workers under the skill-intensive sector is

$$H = \int_{z_s}^{\infty} h_s^x(z)dz$$

2.4.2 Free Entry

The present value of the average profit flows $\tilde{v} = \sum_{t=0}^{\infty}(1-\delta)^t\tilde{\pi} = \frac{\tilde{\pi}}{\delta}$ and the net value of entry is $v_e = \frac{1}{1-G(z_e)}\tilde{v} - f_e$, so the free entry condition is

$$f_e = (1-G(z_e))\frac{\tilde{\pi}}{\delta} \tag{3}$$

The average profit is $\tilde{\pi} = \tilde{\pi}_u^d + n_x \tilde{\pi}_u^x + n_s \tilde{\pi}_s^x$, where $\tilde{\pi}_u^d$ is the average profit for firms that produce unskilled goods and serve the domestic market only, $n_x \equiv \frac{1-G(z_x)}{1-G(z_e)} = \left(\frac{z_x}{z_e}\right)^{-\kappa}$ is the fraction of firms that export but employ low-skilled labor and produce unskilled goods, $\tilde{\pi}_u^x$ is the average profits for exporters producing unskilled goods, and $n_s \equiv \frac{1-G(z_s)}{1-G(z_e)} = \left(\frac{z_s}{z_e}\right)^{-\kappa}$ is the fraction of exporters providing labor training and produce skilled goods, and $\tilde{\pi}_s^x$ is their average profits.

In Appendix B, we derive the average revenues of surviving firms is

$$\tilde{r} = \theta f_u \left(\frac{\tilde{z}_e}{z_e}\right)^{\theta-1} + n_x \theta f_x \left(\frac{\tilde{z}_x}{z_x}\right)^{\theta-1} + n_s \theta f_u (\phi - 1) \left(\frac{\tilde{z}_s}{z_s}\right)^{\theta-1}.$$

After substituting $\tilde{r}$ into the free entry condition, we obtain

$$z_e = \left(\frac{1}{f_e \delta} \frac{\theta - 1}{\kappa - (\theta - 1)}\right)^{\frac{1}{\kappa}} [f_u + n_x f_x + n_s f_u (\phi - 1)]^{\frac{1}{\kappa}} \tag{4}$$

where $n_x = \left(\frac{z_x}{z_e}\right)^{-\kappa} = \tau \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}}$ and $n_s = \left(\frac{z_s}{z_e}\right)^{-\kappa} = \left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{-\kappa}{\theta-1}}$

Substituting n_x and n_s into equation (4), we get

$$z_e = \Lambda \Phi \tag{5}$$

where $\Lambda \equiv \left(\frac{f_u}{f_e \delta} \frac{\theta-1}{\kappa-(\theta-1)}\right)^{\frac{1}{\kappa}}$ and

$\Phi \equiv \left[1 + \frac{f_x}{f_u} \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} \tau^{-\kappa} + (\phi - 1) \left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}} (1 + \tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}}.$

By substituting the solution for the exit cutoff, we can get a solution for the export and skill upgrading cutoffs below.

$$z_x = \tau \Lambda \Phi \tag{6}$$

$$z_s = \Lambda \Phi \left[\frac{\phi - 1}{(1 + \tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - 1)}\right]^{\frac{1}{\theta-1}} \tag{7}$$

2.5 Trade Liberalization

In this section, we analyze the impact of trade liberalization on export participation and skill upgrading. We find that the reduction in iceberg trade costs increases export profits, inducing more firm to enter the export market and encourage exporters to provide more labor training and produce skilled goods.

Proposition 1. A reduction in iceberg trade costs (τ):

a. increases the equilibrium skill premium, $\frac{\partial \frac{w_h}{w_l}}{\tau} < 0$

b. increases the average profit, $\frac{\partial \tilde{\pi}}{\tau} < 0$

c. increases the exit productivity cutoff, $\frac{\partial z_e}{\tau} < 0$

d. reduces the export productivity cutoff, $\frac{\partial z_x}{\tau} > 0$

e. reduces the skill upgrading cutoff, $\frac{\partial z_s}{\tau} > 0$

Proof: see Appendix B.1.3.

There is an asymmetric effect of trade liberalization since firms are heterogeneous. Market shares are reallocated from the firms producing unskilled goods to the firms providing skilled goods with a reduction in trade costs, which increases the relative demand for skilled labor. This leads to an increase in the skill premium. We also can conclude that trade integration increases firms' revenues, encourages more firms in the middle range of productivity levels to enter the export market, and makes labor training more profitable for productive exporters.

3 Extended Model

3.1 Production

Different from the benchmark model, we assume that the foreign country can be either a main trading partner of the home country, denoted as country m, or a less preferential trading partner of the home country, denoted as country o. The home country and its main trading partner are assumed to impose the most-favored-nation (MFN) tariff, which is the lowest possible tariff a country can assess from another country. The less preferential trading partner imposes larger tariffs. In this section, two export productivity cutoffs are considered to distinguish if the firm can export to only the main country m or both countries o and m. In section 5.5, we regard India as a representative country o because empirically India impose higher tariffs on Chinese products compared to the rest of the world during our study period 2004–2007.

There are two types of iceberg trade costs, $\tau_m < \tau_o$, and fixed export costs, $f_{mx} < f_{ox}$, since trade barriers are lower if the home firms export to country m. Four pricing rules of export are $\rho_s^{mx}(z) = \tau_m \rho_s^d(z)$, $\rho_s^{ox}(z) = \tau_o \rho_s^d(z)$, $\rho_u^{mx}(z) = \tau_m \rho_u^d(z)$ and $\rho_u^{ox}(z) = \tau_o \rho_u^d(z)$.

Profits if producing unskilled goods and only serving the domestic market:

$$\begin{aligned}\pi_u^d(z) &= \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u \\ &= \frac{r_u^d(z)}{\theta} - f_u\end{aligned}$$

Profits if producing unskilled goods and exporting to country m:

$$\begin{aligned}\pi_u^{mx}(z) &= (1+\tau_m^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u - f_{mx} \\ &= (1+\tau_m^{1-\theta})\frac{r_u^d(z)}{\theta} - f_u - f_{mx}\end{aligned}$$

Profits if producing unskilled goods and exporting to country o:

$$\begin{aligned}\pi_u^{ox}(z) &= (1+\tau_o^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_l}{\gamma_u z}\right)^{1-\theta}\rho_1^{\theta-\rho}Y - f_u - f_{ox} \\ &= (1+\tau_o^{1-\theta})\frac{r_u^d(z)}{\theta}\gamma_u^{\theta-1} - f_u - f_{ox}\end{aligned}$$

Profits if producing skill-intensive goods and exporting to country m:

$$\begin{aligned}\pi_s^{mx}(z) &= (1+\tau_m^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\beta}w_l^{1-\beta}}{\gamma_m z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_{ms} - f_{mx} \\ &= \lambda_m^{\theta-1}(1+\tau_m^{1-\theta})\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi_m f_u - f_{mx}\end{aligned}$$

Profits if producing skill-intensive goods and exporting to country o:

$$\begin{aligned}\pi_s^{ox}(z) &= (1+\tau_o^{1-\theta})\frac{1}{\theta}\left(\frac{\theta}{\theta-1}\frac{w_h^{\alpha}w_l^{1-\alpha}}{\gamma_o z}\right)^{1-\theta}\rho_2^{\theta-\rho}Y - f_{os} - f_{ox} \\ &= \lambda_o^{\theta-1}(1+\tau_o^{1-\theta})\frac{r_u^d(z)}{\theta}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \phi_o f_u - f_{ox}\end{aligned}$$

where $f_{ox} > f_{mx}$, $f_{os} > f_{ms} > f_u$, $\alpha > \beta$, $\gamma_o > \gamma_m > \gamma_u > 1$ and $\phi_o > \phi_m > 1$.

Firms with productivity above z_{mx} export to country m (the main trading partner) while they can export to country o if their productivity is above z_{ox}. Thus, these two export productivity cutoffs are

$$z_{mx} = \{z | \pi_u^d(z) = \pi_u^{mx}(z)\} \qquad z_{ox} = \{z | \pi_u^{mx}(z) = \pi_u^{ox}(z)\}$$

The productivity cutoff of producing skill-intensive goods (skill upgrading) is also different from the one in the benchmark model. The highly productive firms find it profitable to provide labor training when trading with country m, and the most productive firms are able to export to country o and invest in human capital; thus the two productivity cutoffs of skill upgrading are

$$z_{ms} = \{z | \pi_u^{ox}(z) = \pi_s^{mx}(z)\} \qquad z_{os} = \{z | \pi_s^{mx}(z) = \pi_s^{ox}(z)\}$$

In equilibrium, firms sort into six different groups: the least productive firms ($z < z_e^{'}$) exit the market, the low productivity firms ($z_e^{'} < z < z_{mx}$) employ low-skilled labor and serve only the home country, the lower-middle productivity firms ($z_{mx} < z < z_{ox}$) employ low-skilled labor and export to country m; the upper-middle productivity firms ($z_{ox} < z < z_{ms}$) export unskilled goods to country o; the high productivity firms ($z_{ms} < z < z_{os}$) export to country m but is able to employ skilled labor, the most productive firms ($z > z_{os}$) can export to country o and provide labor training.

$$z_{mx} = z_e^{'} \tau_m \left(\frac{f_{mx}}{f_u} \right)^{\frac{1}{\theta - 1}} \tag{8}$$

$$z_{ox} = z_e^{'} \left(\frac{f_{ox} - f_{mx}}{((1 + \tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1) f_u} \right)^{\frac{1}{\theta - 1}} \tag{9}$$

$$z_{ms} = z_e^{'} \left[\frac{(\phi_m - 1) f_u + f_{mx} - f_{ox}}{((1 + \tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1 + \tau_o^{1-\theta})\gamma_u) f_u} \right]^{\frac{1}{\theta - 1}} \tag{10}$$

$$z_{os} = z_e^{'} \left[\frac{f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u}{(\lambda_o^{\theta-1}(1 + \tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1 + \tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho} f_u} \right]^{\frac{1}{\theta - 1}} \tag{11}$$

3.2 Equilibrium

3.2.1 Labor Market

The aggregate demand for low-skilled workers in both the unskilled and skill intensive sectors is

$$\begin{aligned} L^{'} &= L_u^{'} + L_s^{'} \\ &= \int_{z_e^{'}}^{z_{mx}} l_u^d(z)dz + \int_{z_{mx}}^{z_{ox}} l_u^{mx}(z)dz + \int_{z_{ox}}^{z_{ms}} l_u^{ox}(z)dz + \int_{z_{ms}}^{z_{os}} l_s^{mx}(z)dz + \int_{z_{os}}^{\infty} l_s^{ox}(z)dz \end{aligned}$$

while the aggregate demand for high-skilled workers in the skill-intensive sector is

$$H^{'} = \int_{z_{ox}}^{z_{ms}} h_s^{mx}(z)dz + \int_{z_{os}}^{\infty} h_s^{ox}(z)dz$$

3.2.2 Free Entry

The numbers of firms exporting unskilled or skilled goods to country m and country o can be derived as: $n_{mx} = \left(\frac{z_{mx}}{z_e^{'}}\right)^{-\kappa}$, $n_{ox} = \left(\frac{z_{ox}}{z_e^{'}}\right)^{-\kappa}$, $n_{ms} = \left(\frac{z_{ms}}{z_e^{'}}\right)^{-\kappa}$ and $n_{os} = \left(\frac{z_{os}}{z_e^{'}}\right)^{-\kappa}$. The average profit is $\tilde{\pi} = \tilde{\pi}_u^d + n_{mx}\tilde{\pi}_u^{mx} + n_{ox}\tilde{\pi}_u^{ox} + n_{ms}\tilde{\pi}_s^{mx} + n_{os}\tilde{\pi}_s^{ox}$, and it can be described in this way:

$$\begin{aligned} \tilde{\pi}^{'} = \frac{\tilde{r}^{'}}{\theta} - f_u - n_{mx}f_{mx} - n_{ox}(f_{ox} - f_{mx}) - n_{ms}((\phi_m - 1)f_u + f_{mx} - f_{ox}) \\ - n_{os}((\phi_o - \phi_m)f_u + f_{ox} - f_{mx}) \end{aligned}$$

Similar to the benchmark model, we can derive the average revenues $\tilde{r}^{'}$ expressed as the productivity cutoffs:

$$\begin{aligned} \tilde{r} = \theta f_u \left(\frac{\tilde{z}_e^{'}}{z_e^{'}}\right)^{\theta-1} + n_{mx}\theta f_{mx}\left(\frac{\tilde{z}_{mx}}{z_{mx}}\right)^{\theta-1} + n_{ox}\theta(f_{ox} - f_{mx})\left(\frac{\tilde{z}_{ox}}{z_{ox}}\right)^{\theta-1} \\ + n_{ms}\theta(f_u(\phi_m - 1) + f_{mx} - f_{ox})\left(\frac{\tilde{z}_{ms}}{z_{ms}}\right)^{\theta-1} + n_{os}\theta(f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u)\left(\frac{\tilde{z}_{os}}{z_{os}}\right)^{\theta-1} \end{aligned}$$

After substituting $\tilde{r}^{'}$ into the free entry condition, we obtain

$$z_e^{'} = \left(\frac{\theta - 1}{\kappa - (\theta - 1)}\frac{1}{\delta f_e}\Psi\right)^{1/\kappa} \tag{12}$$

where $\Psi^{\kappa} = f_u + n_{mx}f_{mx} + n_{ox}(f_{ox} - f_{mx}) + n_{ms}(f_u(\phi_m - 1) + f_{mx} - f_{ox}) + n_{os}(f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u)$.

3.3 Trade Liberalization

We have two additional propositions below.

Proposition 2. A reduction in iceberg trade costs of country m (τ_m):

a. increases the average profit, $\frac{\partial \tilde{\pi}'}{\tau_m} < 0$

b. increases the exit productivity cutoff, $\frac{\partial z_e'}{\tau_m} < 0$

c. reduces the productivity cutoff of exporting to country m, $\frac{\partial z_{mx}}{\tau_m} > 0$

d. reduces the skill-upgrading cutoff of exporters to country m, $\frac{\partial z_{ms}}{\tau_m} > 0$

Proof: Please see Appendix B.2.3. Part d is established only when certain conditions are met.

Proposition 3. A reduction in iceberg trade costs of country o (τ_o):

a. increases the average profit, $\frac{\partial \tilde{\pi}'}{\tau_o} < 0$

b. increases the exit productivity cutoff, $\frac{\partial z_e'}{\tau_o} < 0$

c. reduces the productivity cutoff of exporting to country m, $\frac{\partial z_{mx}}{\tau_o} > 0$

d. reduces the productivity cutoff of exporting to country o, $\frac{\partial z_{ox}}{\tau_o} > 0$

e. increases the skill-upgrading productivity cutoff of exporters to country m, $\frac{\partial z_{ms}}{\tau_o} < 0$

f. reduces the skill-upgrading productivity cutoff of exporters to country o, $\frac{\partial z_{os}}{\tau_o} > 0$

Proof: Please see Appendix B.2.4. Parts c and d are established only when certain conditions are met.

4 Trade Policies and Data

4.1 Post-WTO Accession Trade Liberalization in China

Trade liberalization policies undertaken in China after WTO accession are described in this session. First, China joined WTO in 2001 and continued trade liberalization from 2001-2005. For instance, China bounded all tariff lines and the average applied most-favored nation (MFN) rate dropped from 15.6% in 2001 to 9.7% in 2005, with the manufactured goods rate declining from 14.3% to 8.9%, and agricultural products rate decreasing from 23.2% to 14.6% during the same period (Bin, 2015). This indicates that China made a great achievement of import liberalization. Meanwhile, China's industrial goods conquered the global markets after it joined the WTO in 2001. China doubled its share of trade in manufactured goods from 7.9% in 2000 to 17.7% in 2012 (Hilpert, 2014). According to UNCTADStat, its share of global export goods was 3.9% in 2000, and went up to 14.7% in 2020. FDI in China was less restricted after WTO accession, so China became the most important global investment destination. According to the World Bank, the net inflows FDI in China started with 42.1 billion dollars in 2000 and achieved a peak level at 290.9 billion dollars in 2013. Furthermore, China overtook US as the world's leading destination for FDI in 2020.

Next, we describe an important regional trade liberalization—Asian Pacific Trade Agreement (APTA). APTA, previously the Bangkok Agreement, was signed in 1975 and renamed in 2005. Bangladesh, China, India, Lao PDR, Mongolia, Republic of Korea, and Sri Lanka are the current parties. APTA promotes intra-regional trade and contributes to economic development of the seven developing countries through trade and investment liberalization. China acceded APTA in 2001 and endorsed a preferential trade arrangement among developing Asian countries. In 2005, the first Ministerial Council was held in Beijing, China and the third round of negotiation results was implemented in 2006. Trade and tariff data from World Integrated Trade Solution (WITS) between 2004 and 2007 (see Figure 1) shows that India became the most preferential trading partner of China. This paper emphasizes the impact of APTA on exports and human capital investment of Chinese manufactured firms theoretically and empirically. India is selected as a representative country, which imposed much higher tariffs than the rest of the world in 2004, but also reduced trade barriers with China more significantly from 2004 to 2007. More trade agreements among APTA members were made after 2007,[7] which will not be our focus.

[7]A new Asia-Pacific trade deal was created in November 2020. It is a new overarching Regional Comprehensive Economic Partnership (RCEP) Free Trade Agreement (FTA) between 15 Asia-Pacific countries. Its signatories are the 10 members of the Association of Southeast Asian Nations (ASEAN) countries and Japan, Korea, China, Australia and New Zealand. The signing of the RCEP aims to

4.2 Firm-Level Data

We resort to two data sources to construct a balanced panel of manufacturing firms in China. First of all, we obtain data from the Chinese Industrial Enterprises Database (CIED). The CIED is constructed by China's National Bureau of Statistics (CNBS) mainly based on the annual or quarterly reports submitted to local bureau of statistics. The database contains all industrial enterprises that are non-state-owned and "large-scale"[8] or state-owned. In the database, approximately 90% of the enterprises are manufacturing firms, which will be what we focus on in this research. Although the database spans from 1998 to 2013, information about on-the-job training spending (TS), which is our main measure of skill upgrading in the empirical analysis, is only available in 2004–2007, which is exactly the regional trade liberalization period we emphasize. This database has been exploited by economists such as Hsieh and Klenow (2009), Song et al. (2011), Brandt et al. (2017), as well as Huang and Zhuang (2021), who provide more details about this database. From CIED, we also learn about each firm's total sales (which include both domestic and export sales) and number of employees, other than TS.

Second, we collect dis-aggregated information from the China Customs Database (CCD). It provides the data of exports by firm, 8-digit HS product, and destination country. We merge the information from CCD to the CIED according to the firms' names, postal codes, or telephone numbers, following Ruiqin et al. (2019).[9] We then aggregate export data at the 4-digit CIC industry level for each firm-destination country pair (some firms operate in multiple industries domestically and/or globally).

Next, we select the firms in the sectors that are covered by India's consolidated list of concessions of the first 3 rounds of negotiations to APTA member countries and in the 4-digit CIC industries with information on India's tariffs. We ended up

facilitate regional or even world trade and investment further. RCEP connects about 30% of the world's population and output, makes the Asian economies more efficient, and improves technology and solidifies global value chains. China continues to benefit from trade openness.

[8]That is, the main business income of an enterprise was larger than 5 million RMB, and this standard was revised to 20 million RMB in 2011.

[9]The numbers of merged manufacturing enterprises are 52,046 in 2004, 51,026 in 2005, 60,345 in 2006, and 61,749 in 2007. These correspond to 38.1%, 37.7%, 27.8%, and 28.9% of the enterprises in CCD.

with a balanced panel of 110,632 manufacturing firms (operating in 131,460 4-digit CIC industries) in each year from 2004 to 2007. The sample is representative of firms owning establishments with more than 10 employees that can potentially be affected by APTA.

By merging the CIED and CCD data, we can calculate the total sales per employee for each firm, which will be one of our firm-level controls. Moreover, domestic sales can be calculated by subtracting the export sales from total sales. One special feature of the data is that we know each firm's export sales to each destination country, including India—we can therefore learn about whether a firm exports to India or not.

Table A1 in Appendix C contains summary statistics by export status for the main variables of interest for the initial year, 2004.

4.3 Industry-Level Data

In the empirical section we use controls for 4-digit CIC industry characteristics that might be correlated with changes in tariffs. We first obtain average capital and skill intensity in the industry in the United States in the 1980s from the National Bureau of Economic Research (NBER) productivity database (see Appendix C for details). We also use the import demand elasticity and export supply elasticity as estimated by Broda and Weinstein (2006) and Broda et al. (2008).

5 Empirics

In this section we test the theoretical predictions developed in Sections 2 and 3. First, we check whether the sorting pattern of firms into exporting and training predicted by the model is consistent with the observed characteristics of exporters to different countries and non-exporters operating in the same four-digit CIC industry. Second, we test the main predictions of our model: a reduction in export tariffs encourages firm entry in the export market and induces skill upgrading. We focus on the regional trade liberalization (APTA) effect, as we select the sectors covered by India's consolidated list of concessions of the first 3 rounds of negotiations to APTA member countries.

5.1 Within-Industry Patterns in the Data

In the benchmark model, underlying productivity differences produce a sorting of firms into four groups: the least productive firms exit the market (not in data), the low productivity firms produce unskilled goods and serve the domestic market only, the middle ones still produce unskilled goods but also export, and the most productive firms both export and provide labor training for skilled goods production. In this setting, a reduction in trade costs τ increases export profits, inducing more firms in the middle range of the productivity distribution to enter the export market and upgrade workers' skill levels. Figure 2 indicates the effects of trade liberalization for firms in each range of the productivity distribution through reflecting the changes in productivity cutoffs from 2004 to 2007. Precisely speaking, firms with intermediate productivity find it easier to start exporting and the more productive firms also have greater incentives to provide labor training.

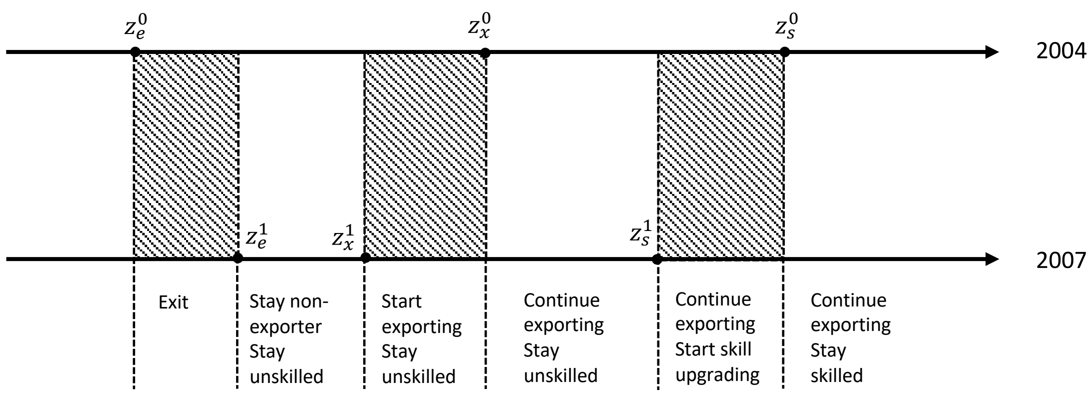

Figure 2: Effect of Lowering Variable Trade Costs: Benchmark Model

In the extended model, we distinguish the trade effects of two export destinations, countries m and o. Country m refers to a main trading partner of the home country, while country o is a less preferential trading partner since it imposes a higher tariff ($\tau_o > \tau_m$). This paper refers to India as a representative country o. In this case, firms sort into six groups: the least productive firms exit the market, the low productivity firms produce unskilled goods and serve the domestic market only, the lower-middle ones still produce unskilled goods but also export to country m, the upper-middle ones export unskilled goods to country o, the high productivity firms are able to provide labor training but export skilled goods to country m, and the most productive firms can export skilled goods to country o. Figure 3 also displays the effect of trade liberalization for firms in each part of the productivity distribution. In particular, as shown by the shaded areas, firms switching export markets from country m to o could continue producing unskilled goods, start skill downgrading, or begin skill upgrading.[10]

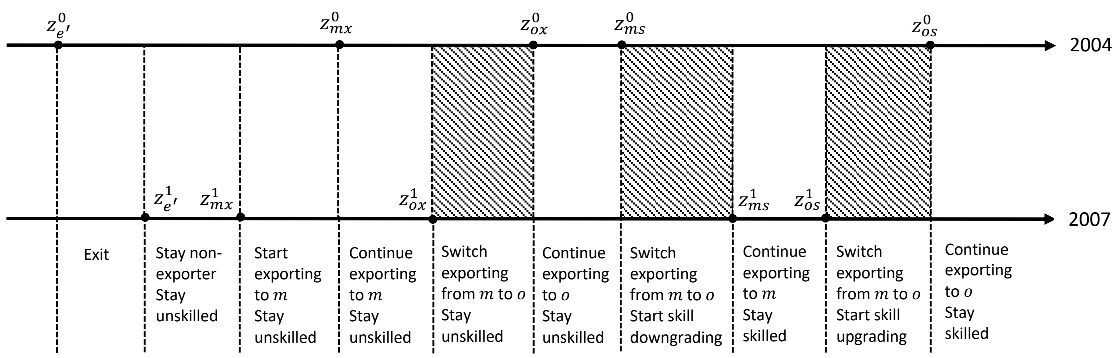

Figure 3: Effect of Lowering Variable Trade Costs: Extended Model

To check whether the sorting patterns depicted in Figures 2 and 3, and the parameter restrictions required to obtain the model are consistent with the data, we follow Bustos (2011b) to divide firms into four groups: continuing exporters, new exporters, exiting exporters and firms serving the domestic market only (never exporters), and compute the differences in characteristics, including sales, employment and training spending per worker, for firms operating within the same four-digit CIC industry.

First, Table 1 indicates that, based on the basic model, all types of exporters have higher sales, employment, and training spending per worker than never exporters in 2004 on average, which mirrors the fact that (potential) exporters are larger, more productive and more skill-intensive. Second, although sales and employment of new exporters are relatively lower than incumbent exporters in 2004, their per capita training spending is higher than continuing exporters on average, preparing them to enter the skill-intensive sector and employ more high-skilled workers. Third, the increase in training spending per worker for continuing exporters are almost zero from 2004 to 2007 (trade liberalization period), but exiting exporters that later serve the

[10] The extended model does not reflect trade-induced switching from country o to m. There should be an exogenous shock that leads to this switching.

Table 1: Differences between different types of exporters and non-exporters in APTA sectors

	Levels in 2004			Changes 2004–2007			Size	
Firm characteristic	Sales	Employment	Training per worker	Sales	Employment	Training per worker	Observations	Firms
Basic model								
New exporters	0.596***	0.505***	0.412***	0.176***	0.146***	0.129***	3,957	3,957
	(0.020)	(0.017)	(0.041)	(0.014)	(0.010)	(0.048)		
Continuing exporters	1.240***	1.027***	0.150***	-0.095***	0.058***	0.011	40,873	20,045
	(0.009)	(0.008)	(0.017)	(0.006)	(0.004)	(0.019)		
Exiting exporters	1.086***	0.852***	0.438***	-0.130***	-0.035***	-0.087*	3,919	3,919
	(0.021)	(0.018)	(0.040)	(0.015)	(0.010)	(0.046)		
Extended model								
New exporters to non-Indian	0.532***	0.462***	0.329***	0.152***	0.132***	0.129**	3,203	3,203
countries (m)	(0.021)	(0.018)	(0.045)	(0.015)	(0.011)	(0.052)		
New exporters to India (o)	0.876***	0.691***	0.769***	0.278***	0.205***	0.128	754	754
	(0.049)	(0.042)	(0.091)	(0.027)	(0.021)	(0.111)		
Continuing exporters to m	1.160***	0.997***	0.047***	-0.113***	0.046***	-0.001	34,448	17,227
	(0.010)	(0.008)	(0.018)	(0.006)	(0.004)	(0.020)		
Continuing exporters to o	1.751***	1.234***	0.813***	-0.024*	0.102***	0.015	2,200	1,831
	(0.032)	(0.026)	(0.058)	(0.014)	(0.011)	(0.063)		
Switching exporters from m to o	1.562***	1.131***	0.594***	0.061***	0.163***	0.080	2,971	2,379
	(0.029)	(0.024)	(0.049)	(0.012)	(0.010)	(0.054)		
Switching exporters from o to m	1.545***	1.157***	0.435***	-0.165***	0.014	0.140*	1,254	1,082
	(0.042)	(0.034)	(0.071)	(0.020)	(0.016)	(0.078)		
Exiting exporters to m	0.997***	0.794***	0.338***	-0.140***	-0.044***	-0.080	3,348	3,348
	(0.022)	(0.019)	(0.043)	(0.016)	(0.011)	(0.049)		
Exiting exporters to o	1.618***	1.194***	1.032***	-0.072**	0.015	-0.129	571	571
	(0.053)	(0.045)	(0.104)	(0.031)	(0.023)	(0.124)		
Observations	131,460	131,460	131,460	131,460	131,460	131,460		
Firms	110,632	110,632	110,632	110,632	110,632	110,632		

Notes: (1) Robust standard errors are in parentheses. (2) Exporter premia are estimated from a regression of the form $\ln Y_{ij} = \alpha_1 \text{Type } 1_{ij} + \alpha_2 \text{Type } 2_{ij} + ... + I_j + \varepsilon_{ij}$ where i indexes firms, and j indexes four-digit CIC industries; the reference category relative to which differences are estimated is non-exporters; I are industry dummies, and Y is the firm characteristic for which the differences are estimated. (3) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (4) Some continuing and switching exporters operated in multiple industries.

domestic market only reduce labor training.[11] On the contrary, new exporters have the largest average increases in sales, employment, and training spending per worker compared to never exporters. These results indicate that new exporters benefit more from trade liberalization and has greater incentives in human capital investment. It is intuitive that new exporters might demand more high-skilled workers in order to become more competitive in the foreign market.

In terms of the extended model, we distinguish two export markets, country m and o. Exporters to India have higher sales, employment, and training spending per worker in 2004 than those exporting to non-Indian countries (except for those who switch destinations) as shown in Table 1, which is consistent with the model setting that firms exporting to India are more productive, conditional on skill level. Moreover, firms switching from non-India to Indian markets in 2004 have slightly higher training spending per worker than those doing the converse, which shows that more of them started to produce high-skilled products earlier. From 2004 to 2007, there is a larger decline in India's tariffs and a greater increase in exports to India compared to those of other countries (Figure 1). Therefore, new exporters targeting Indian markets have even larger average increases in sales and employment than those targeting non-Indian markets. However, interestingly, new exporters targeting India have a slightly less significant average increase in training spending per worker than those targeting non-Indian countries. This is probably due to the fact that they have already spent more in training their workers in 2004 before changes in trade costs τ_o, or there could be sector heterogeneity. Moreover, continuing exporters targeting non-Indian markets had even lower average increases in sales and employment than those targeting India, although their increases in average per capita training spending were almost the same. Additionally, there are firms switching export destinations during the same period. Table 1 shows that the trade liberalization period coincides with a slightly higher increase in training pending per worker among firms who switch export markets from country o to m, which supports our model assumption that some firms could find it more profitable to export skilled goods to country m than to export unskilled goods to country o who imposes higher (but declining) trade barriers. For

[11]Based on the number of industry-level observations and the number of distinct firms, we can see that only continuing exporters operate in multiple industries, while exiting and new exporters both operated in a single industry.

firms who switch destinations from m to o, the increase in per capita training is not so significant. This result is actually also in line with the model in some way, as two shading areas in Figure 3 imply that these firms either start skill downgrading or continue producing unskilled goods. Thus, the average effect of labor training could be ambiguous.

The pattern in the Table 1 shows that there is coincidence between entry in the export market and skill upgrading, and the performance of exporters targeting the Indian market differs from other firms, but we cannot establish whether it is better export opportunities that induce human capital investment or vice versa, or whether both are caused by a third factor. The next empirical exercise is to establish causality by linking exporting and skill upgrading directly to the reduction in India's tariffs for imports from China.

5.2 The Impact of the APTA: Identification Strategy

After China joined APTA in 2001, a reduction in India's tariffs for imports from China across four-digit CIC industries leads to changes in Chinese firms' entry in the export market and skill upgrading. There are two features of the source of identification that make it exogenous with respect to these two outcomes of interest. First, the tariff reductions were constantly adjusted and negotiated among APTA members during 2004 and 2007. In our data, the average tariff facing manufacturing firms in the sectors covered by APTA decreases from about 28.59 percentage points in 2004 to 13.43 percentage points in 2007. These tariff reductions are not likely to be determined by any individual firm in a specific country. Second, the 2004 simple average effectively applied (AHS) import tariff of India for China was close to those of the rest of the world.[12] Import tariffs of India are unlikely to be targeted to industry characteristics particular to China. Share of India's imports from China was 6.11% in 2004, but rose to 11.24% in 2007, since India's average tariff declined by more than a half during the same period.

[12] According to WITS, the simple average AHS tariffs of India for China and the world are 28.78 and 28.57 percentage points respectively in 2004. In terms of the simple average MFN tariff, the 2004 tariff rates of India are 28.78 percentage points for China and 29.51 percentage points for the world.

The reverse causality problem may not be a concern, but India's initial tariff structure is surely not random. India's trade policy is correlated with some industry characteristics, so omitting them could lead to a source of bias. Hence, we estimate all the equations in first differences to eliminate constant industry characteristics. Still, India's tariffs could capture some omitted industry-level time-varying variable if industries with different initial characteristics are on different trends. In order to further address this issue, we include in the first-differenced equations sector dummies to control for unobserved sector trends, and also include four-digit CIC level controls for industry characteristics such as import demand elasticity, export supply elasticity, and capital and skill intensity.

We use the India's tariffs to measure the effect of increased export opportunities on export participation and skill upgrading, but these influences might be correlated with changes in China's tariffs. Thus, we control for the changes in China's tariffs with respect to the world between 2004 and 2007, as well as the changes in China's tariffs with respect to India.[13]

Under the benchmark model, the reduction in India's tariffs induces entry in the export market and skill upgrading for firms in the middle range of the productivity distribution rather than affects the least and most productive groups. The extended model also predicts that firms in the middle or upper-middle range have a higher likelihood of exporting, switching export destinations and starting skill downgrading or upgrading following trade integration. To study these heterogeneous effects of firm productivity, we use firm size relative to the four-digit CIC industry mean in 2004 as a proxy for initial productivity and divide firms into quartiles. In the next section, we discuss the empirical results of how the reduction in India's tariffs affects each quartile of the firm size distribution through emphasizing export entry and skill upgrading decisions, and compare them with our theoretical findings.

5.3 Export Markets Entry Decision

In this section, we intend to recover the signs of the partial derivatives of interest in the model of the export markets entry choices described by equations (6), as well as (8) and (9). To do so, we estimate a linearized version of the entry models and access

[13]Both final goods and intermediate inputs tariffs are controlled.

the economic significance of the estimated coefficients. We first describe estimation of the average effect of a reduction in India's tariffs on entry in the export market for all firms. Next, we distinguish the export markets, comparing non-Indian countries with India.

Consistent with the benchmark model, we empirically analyze the export entry decision using an index model:

$$EX_{ijst}^{k} = \begin{cases} 1 & \text{if } \beta_{\tau^{ex}}^{k}\tau_{jt}^{ex} + \alpha_{st}^{k} + \mu_{i}^{k} + \epsilon_{ijst}^{k} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{13}$$

where i indexes firms; j indexes four-digit CIC industries; s indexes sectors; t indexes years from 2004 to 2007; τ_{jt}^{ex} are India's tariffs that vary across four-digit CIC industries and time; α_{st}^{k} are sector dummies that capture time-varying sector features; μ_{i}^{k} are firm fixed effects capturing unobserved constant heterogeneity including firm heterogeneity z defined in the model and other characteristics affecting productivity cutoffs; EX_{ijst}^{k} is a dummy that captures firms' export decisions to any partner or India. When $k = 0$, firms can either be exporters or non-exporters; EX_{ijst}^{0} takes the value of 1 if a firm exports to any country in the world in year t and 0 otherwise. If $k = 1$, the firm is an exporter; $EX_{ijst}^{1} = 1$ when the firm exports to India (and potentially other counrties at the same time), and $EX_{ijst}^{1} = 0$ if the firm exports only to non-Indian countries.

5.3.1 First-Differenced Specification

We take first differences to eliminate time-invariant plant and sector heterogeneity, and obtain

$$\Delta EX_{ijst}^{0} = \beta_{\tau^{ex}}^{0}\Delta\tau_{jt}^{ex} + \Delta\alpha_{st}^{0} + \Delta\epsilon_{ijst}^{0} \tag{14}$$

In the meantime, we control for changes in China's import tariffs for both outputs and inputs with respect to the world and India ($\Delta\tau_{jt}^{im}$), the firm characteristics in the initial year (2004) such as the number of workers and sales per worker (z_{ij2004}), and four-digit industry characteristics like the import demand and export supply elasticities, skill and capital intensity in the United States (c_j).[14] Hence, we have the

[14]We calculate elasticities sand intensity following Broda and Weinstein (2006) and Broda et al. (2008).

Table 2: Entry in the export markets stratified by sector group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sample of selected sectors. Dependent variable: year-over-year change in export status								
ΔIndia's tariffs	-0.124***	-0.125***	-0.120***	-0.104***	-0.103**	-0.112***	-0.104***	-0.103***
	(0.032)	(0.031)	(0.034)	(0.038)	(0.040)	(0.031)	(0.032)	(0.033)
ΔChina's tariffs w.r.t. world								
Outputs			yes	yes	yes			
Inputs				yes	yes			
ΔChina's tariffs w.r.t. India								
Outputs						yes	yes	yes
Inputs							yes	yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level controls		yes	yes	yes	yes	yes	yes	yes
Industry controls					yes			yes
Observations	91,869	91,869	91,869	91,869	91,869	91,869	91,869	91,869
R^2	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Panel B: Sample of other sectors. Dependent variable: year-over-year change in export status								
ΔIndia's tariffs	-0.014	-0.014	-0.011	-0.016	-0.016	-0.012	-0.015	-0.015
	(0.015)	(0.015)	(0.017)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Observations	302,511	302,511	302,511	302,511	302,511	302,511	302,511	302,511
R^2	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Panel C: Sample of selected sectors. Dependent variable: export status in the current year								
ΔIndia's tariffs	-0.147***	-0.147***	-0.143***	-0.127***	-0.116***	-0.135***	-0.128***	-0.116***
	(0.036)	(0.036)	(0.038)	(0.042)	(0.043)	(0.036)	(0.036)	(0.036)
Export status in the	0.933***	0.932***	0.932***	0.932***	0.931***	0.932***	0.932***	0.931***
previous year	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
R^2	0.884	0.884	0.884	0.884	0.884	0.884	0.884	0.884
Panel D: Sample of baseline non-exporters in selected sectors. Dependent variable: export status in the current year								
ΔIndia's tariffs	-0.128***	-0.126***	-0.122***	-0.121***	-0.090**	-0.127***	-0.120***	-0.092***
	(0.038)	(0.039)	(0.039)	(0.043)	(0.035)	(0.039)	(0.038)	(0.031)
Export status in the	0.729***	0.726***	0.726***	0.726***	0.725***	0.726***	0.726***	0.725***
previous year	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)	(0.021)	(0.021)	(0.020)
Observations	60,273	60,273	60,273	60,273	60,273	60,273	60,273	60,273
R^2	0.317	0.318	0.318	0.318	0.319	0.318	0.318	0.319

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include number of employees and sales per worker, all measured in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) In panels B and D, remaining controls are the same as in the corresponding column in panel A. (6) In panel C, controls and number of observations are the same as in the corresponding column in panel A. (7) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (8) Selected sectors include 14 manufacturing sectors as follows: "wood processing and wood, bamboo, rattan, palm and grass products" (No. 32), "coatings, inks, pigments and similar products" (No. 42), "daily chemical products" (No. 45), "rubber products" (No. 48), "plastic products" (No. 49), "brick, stone and other building materials" (No. 52), "boilers and prime movers" (No. 64), "metal processing machines" (No. 65), "mining, metallurgy, and special equipment for construction" (No. 69), "special machines for agriculture, forestry, animal husbandry and fishery" (No. 71), "ship and floating devices" (No. 75), "household electric and non-electric appliances" (No. 80), "instrumentation" (No. 88), and "cultural and office machines" (No. 89).

following equation:

$$\Delta EX_{ijst}^0 = \beta_{\tau^{ex}}^0 \Delta\tau_{jt}^{ex} + \beta_{\tau^{im}}^0 \Delta\tau_{jt}^{im} + \beta_z^0 Z_{ij2004} + \beta_c^0 c_j + \Delta\alpha_{st}^0 + \Delta\epsilon_{ijst}^0 \tag{15}$$

Estimation of equation (14) is reported in column 1 of Table 2, and the regression coefficients including other controls (equation 15) are shown in columns 2 to 8. From panel A of Table 2, we find that a reduction in India's tariffs increases the likelihood of entry in the export market for the sample of selected sectors. For instance, columns 5 and 8 indicate that the probability of firm entry in the export market increases by 1.55 percentage points when the average reduction in India's tariffs is around 15 percentage points from 2004 to 2007. This empirical result is consistent with the model prediction that a reduction in trade costs increases firm profit and encourages export participation. Interestingly, only certain sectors show a significant relationship between trade openness and export participation by Chinese firms, and the coefficients are not statistically significant for other sectors as shown in panel B of Table 2. Due to sector heterogeneity, there are some limitations of the model, which may not be able to distinguish firm performance (in particular, export decisions) in different sectors after trade liberalization. The different results in panels A and B imply that diverse trade policies could be necessary to further encourage exports because of the heterogeneous features across sectors.

5.3.2 Lagged-Dependent Variable

To check for robustness, we implement two more exercises. First, current export decisions might be influenced by lagged export status because of sunk export costs. Therefore, we control the export status in the previous year and estimate the equation in levels with the following regression:

$$EX_{ijst}^0 = \beta_{\tau^{ex}}^0 \Delta\tau_{jt}^{ex} + \gamma^0 EX_{ijs,t-1}^0 + \alpha_{st}^0 + \epsilon_{ijst}^0 \tag{16}$$

The second check is to create a sample of baseline non-exporters under selected sectors and estimate the equation (16) that is restricted to non-exporters in 2004. This estimation highlights the effects of changing tariffs on initial non-exporters as we notice that trade liberalization between 2004 and 2007 has a greater positive impact on sales, employment and labor training of new exporters in Table 1. The estimates in panels C and D of Table 2 are very close to the coefficients of changes in India's tariffs in panel A. This implies that our estimated results of the export entry decision are fairly robust.

5.3.3 Export Decision by Quartile of the Firm Size Distribution

The benchmark model predicts that lower trade costs induce entry in the export market for firms with intermediate productivity levels since a reduction in trade costs decreases the export productivity cutoff z_x. More precisely, as depicted by Figure 2, the export productivity cutoff in 2007 (z_x^1) is much lower than the initial cutoff (z_x^0). Firms with productivity in the range $z_x^1 < z < z_x^0$ become exporters following trade liberalization. The less productive firms still stay out of the market or serve domestic market only and the most productive firms continue exporting. Empirically, we estimate the impact of the change in India's tariffs on each quartile of the initial firm size distribution with the following equation:

$$\Delta EX_{ijst}^0 = \sum_{n=1}^{4} \beta_{\tau^{ex},n}^0 (\Delta\tau_{jt}^{ex} \times Q_{ij,n}) + \sum_{n=1}^{4} \delta_n^0 Q_{ij,n} + \beta_{\tau^{im}}^0 \Delta\tau_{jt}^{im} + \Delta\alpha_{st}^0 + \Delta\epsilon_{ijst}^0 \quad (17)$$

where n is each of the four quartiles of the firm size distribution and $Q_{ij,n}$ are dummy variables being 1 when firm i belongs to quartile n. Columns 1 to 9 of Table 3 show that the effect of the reduction in India's tariffs on firm entry in the export market is significant in the last three quartiles of the firm size distribution, while firms in the fourth quartile ($\beta_{\tau^{ex},4} = -0.17$) actually receive larger influences from changing in tariffs than those in the second ($\beta_{\tau^{ex},2} = -0.11$) and third quartiles ($\beta_{\tau^{ex},3} = -0.13$) within the selected sectors. Columns 4 to 6 present estimation of the above equation in levels controlling for lagged export status. The point estimates of $\beta_{\tau^{ex},n}$ are a bit larger, but still have the same pattern. Additionally, the estimated results of the sample of non-exporters in 2004 are smaller than those of the full sample, and the impacts of trade costs on the third and fourth quartiles are more significant compared to the first and second quartiles. In particular, the point estimates of $\beta_{\tau^{ex},3}$ in columns 4 and 7 imply that the the average decline in India's tariffs (15 percentage points) increases the probability to participate in the export market by 2.13 percentage points for all firms in the selected sectors and 1.64 percentage points for the sample of non-exporters in 2004.

All coefficients ($\beta_{\tau^{ex},n}$) are negative within the selected sectors (columns 1 to 9) though some firms in the first quartile are not always statistically significant. This suggests that some firms in the first quartile are less likely to be induced to export with a reduction in India's tariffs, which is consistent with the model prediction. Nevertheless, the firm size distribution may not be a good measure of firm productivity and the export productivity cutoffs could differ across industries, which explains the significance of the fourth quartile.

Overall, most of firms in the first quartile are still below the productivity threshold of exports after liberalization, while firms in the middle range (second and third quartiles) of the size distribution are more likely to be induced to enter in the export market. However, the empirical findings show that firms in the fourth quartile have the largest incentive to enter the export market as the absolute value of $\beta_{\tau^{ex},4}$ is the biggest in each column of selected sectors. This result is not in line with the model prediction that the most productive firms would always export regardless of tariffs. Besides the initial firm size not being a perfect measure, some relevant policies in China could help explain this finding. Former Chinese leader Hu Jintao encouraged large-scale enterprises to participate the export market and implemented the the Eleventh Five-Year Plan in 2006. In particular, the chapter 11 of the Eleventh Five-Year Plan includes goals to revitalize manufacturing of major technical equipment, strengthen the shipbuilding industry and improve the performance of the automotive industry. Therefore, this policy can explain why more firms in the fourth quartiles enter the export market during the trade-integration period.

Even though the impact of trade liberalization on other sectors is not significant on average as shown in panel B of Table 2, the export decision of the fourth quartile of the firm size distribution is significantly and negatively affected by trade costs with point estimates around -0.05 presented in columns 10–12 of Table 3. This suggests that the 15 percentage point decline in India's tariffs also increases the probability of firms in the fourth quartile to enter in the export market by 0.75 percentage points in other sectors from 2004 to 2007. Thus, trade liberalization induces more entry in the export market for moderately productive firms (consistent with the benchmark model) only within certain specific sectors.

Table 3: Entry in the export market by quantile of the firm size distribution and sector group

Sample	Selected sectors									Other sectors		
	Full sample						Baseline non-exporters			Full sample		
Dependent variable	Change in status			Status in the current year			Status in the current year			Change in status		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ΔIndia's tariffs												
× first size quartile	-0.070*	-0.054	-0.050	-0.079**	-0.064	-0.060	-0.060*	-0.059	-0.060*	0.016	0.015	0.014
	(0.036)	(0.042)	(0.036)	(0.039)	(0.046)	(0.040)	(0.036)	(0.040)	(0.036)	(0.016)	(0.015)	(0.014)
× second size quartile	-0.113***	-0.095**	-0.095**	-0.124***	-0.107**	-0.107**	-0.084**	-0.082**	-0.083**	0.001	-0.001	-0.001
	(0.035)	(0.041)	(0.037)	(0.039)	(0.047)	(0.042)	(0.038)	(0.041)	(0.038)	(0.015)	(0.016)	(0.015)
× third size quartile	-0.126***	-0.107***	-0.107***	-0.142***	-0.124***	-0.124***	-0.109***	-0.107***	-0.107***	-0.016	-0.018	-0.016
	(0.033)	(0.041)	(0.034)	(0.037)	(0.044)	(0.038)	(0.034)	(0.039)	(0.035)	(0.019)	(0.020)	(0.020)
× fourth size quartile	-0.169***	-0.150***	-0.149***	-0.194***	-0.176***	-0.175***	-0.162***	-0.160***	-0.160***	-0.051**	-0.054**	-0.051**
	(0.040)	(0.048)	(0.038)	(0.041)	(0.048)	(0.039)	(0.041)	(0.047)	(0.041)	(0.021)	(0.022)	(0.022)
ΔChina's tariffs w.r.t. world		yes			yes			yes			yes	
ΔChina's tariffs w.r.t. India			yes			yes			yes			yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Firm-level controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Industry controls		yes	yes		yes	yes		yes	yes		yes	yes
Observations	91,869	91,869	91,869	91,869	91,869	91,869	60,273	60,273	60,273	302,511	302,511	302,511
R^2	0.004	0.004	0.005	0.884	0.884	0.884	0.320	0.320	0.320	0.005	0.005	0.005

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include dummies for the second, third, and fourth quartile of the firm-size distribution in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) Controls for changes in China's tariffs with respect to the world and India include both output and input tariffs. (6) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.

5.4 Skill Upgrading Decision

In this section, we focus on the skill upgrading decisions made by firms. The decision of providing labor training is described in equations (7), (10) and (11). Following the estimation of equation (15), in addition to India's tariffs, we control for China's import tariffs regarding outputs and inputs, four-digit CIC industry characteristics, sector dummies and plant fixed effects; thus, the level of investment in on-the-job training can be expressed as:

$$\log TS_{ijst} = \beta_{\tau^{ex}} \tau_{jt}^{ex} + \beta_{\tau^{im}} \tau_{jt}^{im} + \alpha_{st} + \mu_i + \epsilon_{ijst} \tag{18}$$

where TS denotes a firm's spending of labor training; τ_{jt}^{im} are China's import tariffs, which also affect firm revenues and skill upgrading decisions.

5.4.1 First-Differenced Estimation

Similarly, we estimate equation (18) in first differences to eliminate constant plant and sector heterogeneity:

$$\Delta \log TS_{ijst} = \beta_{\tau^{ex}} \Delta\tau_{jt}^{ex} + \beta_{\tau^{im}} \Delta\tau_{jt}^{im} + \Delta\alpha_{st} + \Delta\epsilon_{ijst} \tag{19}$$

Panel A of Table 4 indicates that trade liberalization between 2004 and 2007 induces more investment in on-the-job training by manufacturing firms in selected sectors. In particular, columns 5 and 8 of panel A with inclusion of additional controls shows that the 15 percentage point decline in India's tariffs increases labor training provided by firms by about 0.11 to 0.13 log points. When trade costs become lower, the productive firms earn greater revenues, so they have higher incentives to increase human capital investment and produce skill-intensive products more.

Nevertheless, there are reverse findings in other sectors from panel B of Table 4 with average point estimates around 0.15 (a 0.02 log point reduction in training spending occurs when India's tariffs drop by 15 percentage points). In these sectors, firms reduce labor training even though trade barriers decline. There could be several reasons. First, the productivity (not directly observed) of more firms in these sectors may fall between z_{ms}^0 and z_{ms}^1 in Figure 3, so the reduction in India's tariffs may not affect their export participation (not specific to any country) as shown by Table 2, but can cause skill downgrading. Second, the local government may finance labor

Table 4: Investment in on-the-job training stratified by sector group and initial export status

Dependent variable: year-over-year change in log(training spending)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sample of selected sectors.								
ΔIndia's tariffs	-0.854***	-0.854***	-0.903***	-0.796**	-0.753*	-0.859***	-0.883***	-0.842***
	(0.304)	(0.304)	(0.325)	(0.397)	(0.409)	(0.316)	(0.311)	(0.320)
ΔChina's tariffs w.r.t. world								
Outputs			yes	yes	yes			
Inputs				yes	yes			
ΔChina's tariffs w.r.t. India								
Outputs						yes	yes	yes
Inputs							yes	yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level controls		yes	yes	yes	yes	yes	yes	yes
Industry controls					yes			yes
Observations	91,869	91,869	91,869	91,869	91,869	91,869	91,869	91,869
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Panel B: Sample of other sectors.								
ΔIndia's tariffs	0.140*	0.139*	0.144*	0.145*	0.141	0.142*	0.152*	0.148*
	(0.081)	(0.081)	(0.083)	(0.086)	(0.086)	(0.082)	(0.085)	(0.085)
Observations	302,511	302,511	302,511	302,511	302,511	302,511	302,511	302,511
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Panel C: Sample of baseline non-exporters in selected sectors.								
ΔIndia's tariffs	-0.810**	-0.804**	-0.818**	-0.778*	-0.683	-0.820**	-0.908***	-0.824**
	(0.324)	(0.324)	(0.344)	(0.443)	(0.441)	(0.339)	(0.325)	(0.320)
Observations	60,273	60,273	60,273	60,273	60,273	60,273	60,273	60,273
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Panel D: Sample of baseline exporters in selected sectors.								
ΔIndia's tariffs	-0.917	-0.915	-1.018	-0.931	-1.096	-0.878	-0.889	-1.050
	(0.788)	(0.785)	(0.851)	(0.869)	(0.900)	(0.805)	(0.805)	(0.833)
Observations	31,596	31,596	31,596	31,596	31,596	31,596	31,596	31,596
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include number of employees and sales per worker, all measured in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) In panels B, C, and D, remaining controls are the same as in the corresponding column in panel A. (6) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.

training when trade barriers are high, but reduce fiscal support when trade barriers become lower. Findings from panels A and B imply that sector heterogeneity in productivity and policy plays a role in affecting skill upgrading decisions following trade integration. The theoretical model explains trade-induced investment in on-the-job training within some sectors, while providing a possibility of skill downgrading in other sectors where firms are around the cutoff of switching destination countries due to an increase in skill upgrading productivity cutoff in country m.

In terms of the sample of non-exporters in 2004 in selected sectors, the estimation in panel C of Table 4 implies that skill upgrading in response to a reduction in India's tariff is still positive but less precise. The estimated coefficients for the sample of exporters in 2004 in selected sectors are also insignificant as presented in panel D. One possible explanation is that some continuing exporters switch to the Indian market due to an increase in skill upgrading productivity cutoff in non-Indian countries and no longer produce high-skill products, and some exiting exporters no longer demand high-skill workers when serving the domestic market only.[15]

5.4.2 Skill Upgrading Decision by Quartile of the Firm Size Distribution

The benchmark model predicts that lower trade costs encourage firms operating in the range $z_s^1 < z < z_s^0$ to provide more labor training, since a reduction in trade costs decreases the skill upgrading productivity cutoff z_s. As shown in Figure 2, these firms are in the middle range of the productivity distribution, and they invest more in human capital following trade liberalization. The least and the most productive firms wouldn't change their decisions of labor skill upgrading in response to trade openness. Empirically, we estimate the impact of the change in India's tariffs on each quartile of the initial firm size distribution with the following equation:

$$\Delta \log TS_{ijst} = \sum_{n=1}^{4} \beta_{\tau^{ex},n}(\Delta\tau_{jt}^{ex} \times Q_{ij,n}) + \sum_{n=1}^{4} \delta_n Q_{ij,n} + \beta_{\tau^{im}}\Delta\tau_{jt}^{im} + \Delta\alpha_{st} + \Delta\epsilon_{ijst} \quad (20)$$

where n is each of the four quartiles of the firm size distribution and $Q_{ij,n}$ are dummy variables being 1 when firm i belongs to quartile n. Columns 1–3 of Table 5 show that the effect of the reduction in India's tariffs on investment in on-the-job training

[15]Although not shown in Table 2, the effect of trade liberalization on entry in the export market is less statistically significant (although larger) in the sample of baseline exporters.

is significant in the first three quartiles of the firm size distribution for the full sample of selected sectors. Trade liberalization has a relatively larger impact on the skill upgrading decision of firms in the second quartile. For instance, the 15 percentage point reduction in India's tariffs from 2004 to 2007 increases spending on training of firms in the second quartile by 0.18 log points, while firms in the first and third quartiles increase labor training by only about 0.14 log points. As the model predicts that firms with productivity in the middle range are sensitive to changes in trade costs, so the reduction in the tariffs positively affects skill upgrading decisions of firms in the second and third quartiles.

One question is: why firms in the low or lower-middle range of the size distribution choose to increase human capital investment after liberalization? The benchmark model cannot match this empirical result. One possible reason is that Chinese local governments protect some smaller domestic firms and state-owned enterprises. The less productive firms could receive subsidies from governments or benefit from new regulations, so that they can follow their high productive competitors to provide more labor training and employ more high-skilled workers during the liberalization period, especially among those who are encouraged to "go out" (a famous slogan from the Chinese government during that period).

In terms of the sample of initial non-exporters and the sample of initial exporters in 2004, the trade-integration effect on labor training by firms in the first quartile is very similar to the findings in panels C and D of Table 4. Regardless of the initial export status, the effect of the reduction in tariffs on the fourth quartile is less precisely estimated. It is consistent with the model prediction that the most productive firms ($z > z_s$) still find it profitable to provide labor training even when the India's tariffs are lower.

The point estimates in other sectors are positive but not significant for the first and third quartiles as shown in columns 10–12 of Table 5. The reduction in tariffs induces a statistically significant reduction in spending on labor training in the fourth quartile of the firm size distribution. Precisely, the 15 percentage point decline in India's tariffs from 2004 to 2007 reduces spending on training by about 0.07 log points for firms in the fourth quartile. Some of these large firms may actually be in the range $z^1_{mx} < z < z^1_{ms}$ in Figure 3, as initial firm size may not be a perfect measure

Table 5: Investment in on-the-job training by quantile of the firm size distribution, sector group, and initial export status

Dependent variable: year-over-year change in log(training spending)												
Sample	Selected sectors									Other sectors		
	Full sample			Baseline non-exporters			Baseline exporters			Full sample		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ΔIndia's tariffs												
× first size quartile	-0.977***	-0.913**	-0.992***	-1.065***	-0.999**	-1.117***	-0.860	-0.895	-0.845	0.015	0.018	0.022
	(0.338)	(0.416)	(0.344)	(0.330)	(0.419)	(0.330)	(0.904)	(0.981)	(0.919)	(0.126)	(0.129)	(0.129)
× second size quartile	-1.222***	-1.153**	-1.246***	-1.045**	-0.972*	-1.117***	-1.838**	-1.857*	-1.824**	-0.100	-0.092	-0.086
	(0.380)	(0.478)	(0.386)	(0.403)	(0.523)	(0.407)	(0.877)	(0.959)	(0.897)	(0.097)	(0.101)	(0.101)
× third size quartile	-0.924***	-0.854**	-0.953***	-0.650*	-0.573	-0.740**	-1.537*	-1.560*	-1.511*	0.088	0.097	0.104
	(0.332)	(0.427)	(0.335)	(0.352)	(0.469)	(0.351)	(0.846)	(0.938)	(0.875)	(0.116)	(0.122)	(0.120)
× fourth size quartile	-0.168	-0.099	-0.195	0.048	0.124	-0.051	-0.420	-0.432	-0.388	0.476***	0.485***	0.493***
	(0.343)	(0.420)	(0.354)	(0.338)	(0.423)	(0.353)	(0.866)	(0.952)	(0.884)	(0.173)	(0.179)	(0.176)
ΔChina's tariffs w.r.t. world		yes			yes			yes			yes	
ΔChina's tariffs w.r.t. India			yes			yes			yes			yes
Sector FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Firm-level controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Industry controls		yes	yes		yes	yes		yes	yes		yes	yes
Observations	91,869	91,869	91,869	60,273	60,273	60,273	31,596	31,596	31,596	302,511	302,511	302,511
R^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include dummies for the second, third, and fourth quartile of the firm-size distribution in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) Controls for changes in China's tariffs with respect to the world and India include both output and input tariffs. (6) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.

of productivity. As a result, trade liberalization may both encourage the large firms to export and downgrade skill level on average. Interestingly, trade liberalization induces more labor training of firms in the second quartile in these other sectors with $\beta_{\tau^{ex},2}$ equal to about -0.09.

From the findings in Table 3 and Table 5, trade liberalization induces a significant increase in both the probability of export participation and spending on labor training by firms in the second and third quartiles in selected sectors, which is consistent with the benchmark model prediction. Results based on other sectors and for other quartiles are partially explained by our extended model. In the next section, we attempt to extend our empirical analysis to focus more on the extended model, and make some further discussions including sector characteristics and specific policies or regulations in China to understand those empirical results.

5.5 Extension

Recall that the data pattern shows that India's tariffs are much higher than those of other countries, but the reduction in India's tariffs is much more drastic between 2004 and 2007. Thus, we build the extended model that distinguishes two different export destinations, countries m and o in order to highlight the effect of trade liberalization on exporters to the Indian market or other foreign markets. Next, we estimate two similar first-differenced models as in subsections 5.3.3 and 5.4.2, but analyze the export destination decisions of new exporters and the skill upgrading decisions of new exporters to the Indian market.

Rewriting equation (13) when $k = 1$ yields:

$$EX^1_{ijst} = \begin{cases} 1 & \text{if exporting to India} \\ 0 & \text{if exporting to non-Indian countries} \end{cases}$$

Figure 3 shows that more continuing exporters switch to India and new exporters are more likely to enter the Indian market after India's tariffs are reduced. Meanwhile, within-industry patterns in the data (Table 1) shows that new exporters have the largest increase in sales and training per worker from 2004 to 2007. Hence, to estimate the equation (21), we select the sample of firms who do not export in 2004 but become exporters in 2007.

$$\Delta EX_{ijst}^1 = \sum_{n=1}^{4} \beta_{\tau^{ex},n}^1 (\Delta \tau_{jt}^{ex} \times Q_{ij,n}) + \sum_{n=1}^{4} \delta_n^1 Q_{ij,n} + \beta_{\tau^{im}}^1 \Delta \tau_{jt}^{im} + \Delta \alpha_{st}^1 + \Delta \epsilon_{ijst}^1 \quad (21)$$

Table 6: Entry in the India export market and investment in on-the-job training

Sample	Selected sectors New exporters			Selected sectors New exporters to India		
Dependent variable	Change in status of exporting to India			log(training spending)		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔIndia's tariffs						
× first size quartile	-1.721***	-1.723***	-1.888***	-8.054	-15.082*	-3.714
	(0.484)	(0.562)	(0.522)	(6.791)	(8.015)	(5.745)
× second size quartile	-1.533***	-1.555***	-1.676***	-13.208*	-20.970**	-10.031
	(0.486)	(0.555)	(0.512)	(7.591)	(8.530)	(6.596)
× third size quartile	-1.450***	-1.471**	-1.522***	-11.187	-18.683**	-7.860
	(0.485)	(0.565)	(0.502)	(7.409)	(8.943)	(5.681)
× fourth size quartile	-1.600***	-1.615***	-1.654***	-15.153	-23.569**	-12.200*
	(0.533)	(0.603)	(0.549)	(9.079)	(10.006)	(7.083)
ΔChina's tariffs w.r.t. world		yes			yes	
ΔChina's tariffs w.r.t. India			yes			yes
Sector FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Firm-level controls	yes	yes	yes	yes	yes	yes
Industry controls		yes	yes		yes	yes
Observations	2,475	2,475	2,475	489	489	489
R^2	0.025	0.026	0.028	0.035	0.061	0.054

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include dummies for the second, third, and fourth quartile of the firm-size distribution in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (6) New exporters and new exporters to India are defined in Table 1. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.

Columns 1–3 of Table 6 present the estimated results of equation (21). Coefficients in each quartile of size distribution are statistically significant. In particular, the 15 percentage point decline in India's tariffs increases the probability of entering the Indian market for new exporters in the high productivity group (fourth quartile) by 24.23 percentage points. Furthermore, the empirical results of exporting to India in Table 6 are consistent with the extended model prediction as there are three shaded areas located in different ranges of productivity levels in Figure 3, representing that firms in each range of productivity levels could find it more profitable to export to India.

Next, recall that some firms switch export destinations from country m to o and start to produce unskilled or skilled goods after trade liberalization (Figure 3). To investigate the skill upgrading decisions made by new exporters to India, we estimate equation (20) again with the sample of non-exporters in 2004 and exporters to India in 2007.

In column 5 of Table 6, trade liberalization is shown to have significantly positive effects on skill upgrading of new exporters targeting India in the last three quartiles. Although firm size may not be a perfect measure of productivity, this reflects that new exporters targeting India with a size above the medium level actually start to increase investment in on-the-job training when trade costs are lower. The absolute value of the coefficient of the fourth quartile is the largest potentially due to the fact that the most productive new exporters to India are more capable of increasing labor training. Precisely, column 5 of Table 6 presents that a 15 percentage point reduction in trade costs from 2004 to 2007 leads to a 3.54 log point increase in labor training provided by the new exporters to India in the fourth quartile. The absolute value of the coefficient of second quartile is smaller, but still larger than that of the third quartile. These results are in line with the pattern in Figure 3 as some firms in the middle range of productivity levels continue to produce unskilled products or reduce spending on labor training.

5.6 Mechanism

Empirically, the reduction in the tariffs induces more firm entry in the export market and increase spending on labor training in the second and third quartiles of the firm size distribution (in selected sectors) based on the previous tables, which indicates that firms in the middle range of the productivity distribution greatly benefit from trade liberalization. The model mechanism implies that firms gain higher revenues when trade costs are lower, so they find it more profitable to export and have greater incentives in skill upgrading, mirroring the reduction in productivity cutoffs of export and skill upgrading. In this section, we provide evidence that how trade integration between China and India affect China's export sales to India and domestic sales.

Table 7: Export sales to India and domestic sales of new exporters to India in selected sectors

Dependent variable	Change in log(export sales to India)			Change in log(domestic sales)		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔIndia's tariffs	-40.851***	-41.207***	-43.108**			0.016
	(13.352)	(13.727)	(17.650)			(1.577)
ΔChina's tariffs w.r.t. India						
Output		yes		0.302	0.521	0.518
				(0.862)	(1.995)	(1.984)
Input		yes			-1.515	-1.517
					(14.819)	(14.862)
ΔChina's tariffs w.r.t. world			yes			
Sector FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Firm-level controls	yes	yes	yes	yes	yes	yes
Industry controls		yes	yes		yes	yes
Observations	489	489	489	489	489	489
R^2	0.141	0.154	0.153	0.063	0.071	0.071

Notes: (1) Standard errors are clustered at the 4-digit CIC industry level. (2) Δ denotes the year-over-year change in a variable during the period 2004–2007. (3) Firm-level controls include number of employees and sales per worker, all measured in the initial year (2004). (4) Industry controls include import demand elasticity, export supply elasticity, skill intensity, and capital intensity in the United States. (5) ***, **, * denote significance level at 1%, 5%, and 10%, respectively. (6) New exporters to India are defined in Table 1. (7) Selected sectors include 14 manufacturing sectors mentioned in Table 2.

5.6.1 Export Sales to India

We select the sample of firms who do not export in 2004 but become new exporters to India in 2007. We find that the reduction in India's tariffs increases China's export sales to India as reported by columns 1–3 of Table 7 following the previous estimation method. When we control for the change of China's import tariffs with respect to India, the 15 percentage point reduction in India's tariffs leads to an increase in export sales to India by about 6.18 log points. This exercise produces consistent results, and mainly reflects changes of export sales of new exporters to India. The coefficients are large in magnitude because we analyze the export sales at the firm level instead of the industry level. The firm level data can help emphasize how a small group of firms respond to changes in trade costs.

5.6.2 Domestic Sales

Our theoretical model also shows that the reduction in trade costs leads to a decline in domestic sales and causes more low productivity firms to exit the market. However, trade costs are symmetric for two countries in the model, which cannot be easily matched to the data. In fact, India's tariffs differ from China's tariffs. The empirical evidence under columns 4–6 of Table 7 suggests that the decline in China's tariffs with respect to India could result in lower domestic sales with point estimates from 0.30–0.52. However, these results are not significant. This is probably due to the fact that China as a developing country has a rapid growth rate, as well as a large population. For instance, GDP annual growth rate in China increased from 10% in 2004 to 14% in 2007.[16] Chinese firms increase export sales a lot following trade openness, and also can maintain a great amount of domestic sales even if there are more imported varieties.

5.7 Discussion

In this section, we attempt to understand why firms in certain sectors would enter in the export markets and invest more in on-the-job training following trade liberalization, while others would not. The theoretical benchmark model can only explain some empirical findings, while others can result from special sector characteristics or policies targeting certain industries. Due to sector heterogeneity in productivity and policy, trade liberalization has positive impacts on firms' decisions of export entry and skill upgrading in only some selected sectors, including manufacturers of "ship and floating devices".

First, some large-scale manufacturing companies in China such as pharmaceutical, home appliances and electronics manufacturers, have their own universities for labor training, so their labor training procedures are canonical and their training decision might not be sensitive to changes in trade costs. Second, industry characteristics and certain policies could determine whether some industries have comparative advantage or sustainable competition in the foreign market. We pick the shipbuilding industry from selected sectors and the textile industry from other sectors to understand their different responses to the regional trade liberalization.

Textile Industry. According to an investigation report from the CNBS[17], the labor-intensive textile industry used to have a strong advantage in terms of labor costs, but it

[16]Data source: World Bank national accounts data, and OECD National Accounts data files.

[17]The first China Industrial Security Forum was held in 2006. It reported the domestic environment of China's textile industry from 1997 to 2005.

is offset by low labor productivity. Compared with China's main competitors in Asia, its labor costs gradually lose the advantage. In 2002, the average wage level in China's textile industry reached 1.12 times that of India. Moreover, the production technology of spinning machinery is relatively mature, while the production technology of weaving and sewing machinery is relatively backward. Due to low productivity levels and less advanced technologies, some firms in the textile industry are less competitive in the export market, and find it not profitable to participate in exports or increase labor training even if trade costs are very low. This explains why they are not sensitive to changes in tariffs. Instead, they could have a higher investment in on-the-job training when tariffs are high and when they could receive protection or subsidies from the government.

Shipbuilding Industry. China engages in foreign trade further after joining the WTO and APTA in 2001. In particular, China's total volume of imports and exports increased by 23.2% and the export of mechanical and electrical products and high-tech products increased by 32.0% and 31.8% respectively, from 2004 to 2005.[18] Meanwhile, the Eleventh Five-Year-Plan was announced in 2006, which encourages large-scale enterprises such as shipbuilding or auto-car firms to enter the export market. In 2020, China was still the world's largest shipbuilding market, accounting for 43.08% of total shipbuilding volume in the world. Shipbuilding industry is one of the selected sectors in the empirical studies. Shipbuilding firms are more productive and likely to fall in the second or the third quartiles of the firm size distribution. They should be sensitive to changes in trade costs. Besides, they actually receive supports in the export market after the government implements the Eleventh Five-Year-Plan. Thus, the reduction in tariffs still have significantly positive impacts on their export entry decisions.

6 Conclusion

The evidence from selected sectors reported in this paper suggests that a reduction of trade costs can help reduce the export productivity cutoff and increases profits for exporters, resulting in more export participation and more spending in labor training.

[18] These data were reported at the Fourth Session of China's Tenth National Congress in 2006.

According to the model implication and empirical results, the positive impact of trade liberalization on firms in the middle range of productivity levels is the largest. Due to sector heterogeneity and specific policies targeting to some other sectors, the empirical findings in other sectors revert. As expanded export opportunities positively affect firm performance in selected sectors, it is important to implement trade policies targeting to certain industries, including regional or multilateral trade liberalizations. More export participation leads to more investment in on-the-job training, which increases labor skill levels and improves product quality in the long term.

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Appendices

A Additional Figures

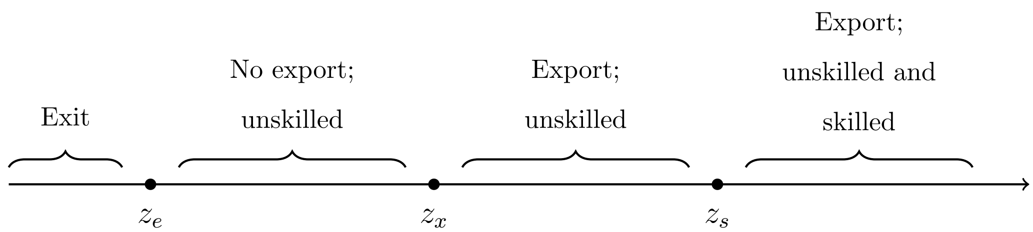

Figure A1: Productivity Cutoffs under the Benchmark Model

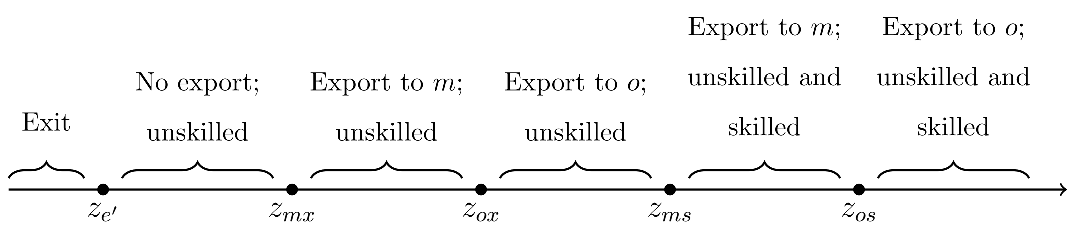

Figure A2: Productivity Cutoffs under the Extended Model

B More Details of the Theoretical Model

B.1 Benchmark Model

B.1.1 Total Cost Function

Per-period fixed export cost f_x and iceberg trade cost τ are required for exporters, thus the total costs for firms that export under the unskilled and skilled sector are respectively

$$TC_u(z) = f_u + f_x + \frac{w_l}{z} y_u^d(z) + \tau \frac{w_l}{z} y_u^x(z)$$

$$TC_s(z) = f_s + f_x + \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma z} y_s^d(z) + \tau \frac{w_h^{\beta} w_l^{1-\beta}}{\gamma z} y_s^x(z)$$

B.1.2 Average Profit and Revenue

The average profit $\tilde{\pi} = \tilde{\pi}_u^d + n_x \tilde{\pi}_x^d + n_s \tilde{\pi}_s^x$, where

$$\tilde{\pi}_u^d = \frac{1}{1-G(z_e)} \int_{z_e}^{z_x} z^{\theta-1} g(z) dz$$
$$\tilde{\pi}_u^x = \frac{1}{1-G(z_e)} \int_{z_x}^{z_s} z^{\theta-1} g(z) dz$$
$$\tilde{\pi}_s^x = \frac{1}{1-G(z_e)} \int_{z_s}^{\infty} z^{\theta-1} g(z) dz$$

The average profit also can be describe in this way: $\tilde{\pi} = \frac{\tilde{r}}{\theta} - f_u - n_x f_x - n_s(\phi - 1) f_u$. The average revenues of surviving firms is

$$\begin{aligned}
\tilde{r} &= \int_{z_e}^{z_x} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz + \int_{z_x}^{z_s} r_u^x(z) \frac{g(z)}{1-G(z_e)} dz + \int_{z_s}^{\infty} r_s^x(z) \frac{g(z)}{1-G(z_e)} dz \\
&= \int_{z_e}^{z_x} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz + (1+\tau^{1-\theta}) \int_{z_x}^{z_s} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz \\
&\quad + \lambda^{\theta-1}(1+\tau^{1-\theta}) \int_{z_s}^{\infty} r_d^x(z) \frac{g(z)}{1-G(z_e)} dz \\
&= \int_{z_e}^{z_x} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz + \int_{z_x}^{z_s} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz + \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz \\
&\quad + \tau^{1-\theta} \int_{z_x}^{z_s} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz + \tau^{1-\theta} \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz \\
&\quad + \left[\lambda^{\theta-1}(1+\tau^{1-\theta}) \left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - 1 - \tau^{1-\theta} \right] \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz \\
&= \int_{z_e}^{\infty} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz \\
&\quad + \tau^{1-\theta} \int_{z_x}^{\infty} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz \\
&\quad + (1+\tau^{1-\theta}) \left(\lambda^{\theta-1} \left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - 1 \right) \int_{z_s}^{\infty} r_u^d(z) \frac{g(z)}{1-G(z_e)} dz
\end{aligned}$$

Using the zero profit condition, we get $r_u^d(z) = \theta f_u \left(\frac{z}{z_e}\right)^{\theta-1}$. We define $\tilde{z}_j^{\theta-1} = \int_{z_j}^{\infty} z_j \frac{g(z)}{1-G(z_j)} dz$ where $j \in (e, x, s)$, and we derive that both z_x and z_s can be a function of z_e, so

$$\tilde{r} = \theta f_u \left(\frac{\tilde{z}_e}{z_e}\right)^{\theta-1} + n_x \theta f_x \left(\frac{\tilde{z}_x}{z_x}\right)^{\theta-1} + n_s \theta f_u(\phi - 1) \left(\frac{\tilde{z}_s}{z_s}\right)^{\theta-1}$$

Since

$$
\begin{aligned}
\left(\frac{\tilde{z}_j}{z_j}\right)^{\theta-1} &= \int_{z_j}^{\infty} \left(\frac{z}{z_j}\right)^{\theta-1} \frac{g(z)}{1-G(z_j)} dz \\
&= z_j^{\kappa+1-\theta} \frac{\kappa z_j^{\theta-1-\kappa}}{\kappa-(\theta-1)} \\
&= \frac{\kappa}{\kappa-(\theta-1)}
\end{aligned}
$$

We get $\tilde{r} = \frac{\theta\kappa}{\kappa-(\theta-1)} [f_u + n_x f_x + n_s f_u(\phi-1)]$. After substituting $\tilde{r}$ into the free entry condition, we obtain

$$
f_e = \frac{z_e^{-\kappa}}{\delta} \frac{\theta-1}{\kappa-(\theta-1)} [f_u + n_x f_x + n_s f_u(\phi-1)]
$$

Substituting n_x and n_s,

$$
\begin{aligned}
z_e =& \left(\frac{1}{f_e\delta} \frac{\theta-1}{\kappa-(\theta-1)}\right)^{\frac{1}{\kappa}} [f_u + n_x f_x + n_s f_u(\phi-1)]^{\frac{1}{\kappa}} \\
=& \left(\frac{1}{f_e\delta} \frac{\theta-1}{\kappa-(\theta-1)}\right)^{\frac{1}{\kappa}} \times \\
& \left[f_u + f_x \tau^{-\kappa} \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} + f_u(\phi-1) \left(\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}} \\
=& \Lambda \left[1 + \frac{f_x}{f_u} \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} \tau^{-\kappa} + (\phi-1) \left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}} (1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}} \\
=& \Lambda\Phi
\end{aligned}
$$

where $\Lambda \equiv \left(\frac{f_u}{f_e\delta} \frac{\theta-1}{\kappa-(\theta-1)}\right)^{\frac{1}{\kappa}}$ and

$$
\Phi = \left[1 + \frac{f_x}{f_u} \left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} \tau^{-\kappa} + (\phi-1) \left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}} (1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}}.
$$

B.1.3 Trade Liberalization

Skill Premium:

$$\frac{R_u}{R_s} = \frac{\int_{z_e}^{z_x} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_x}^{z_s} r_u^x(z)\frac{g(z)}{1-G(z_e)}dz}{\int_{z_s}^{\infty} r_s(z)\frac{g(z)}{1-G(z_e)}dz}$$
$$= \frac{1}{\lambda^{\theta-1}(1+\tau^{\theta-1})}$$

As τ has a positive effect on λ, $\frac{\partial R_u}{\partial R_s} > 0$. The reduction in trade costs increase the relative revenues of firms producing skilled goods, so the demand for skilled labor increases. This leads to a higher equilibrium skill premium.

Next, a reduction in trade costs increases the share of firms producing skilled good, $\frac{\partial n_s}{\partial \tau} < 0$.

Proof:

τ has a direct negative effect on n_s, but an indirect positive effect through λ since the reduction in tariffs increases the skill premium reducing the cost advantage of firms producing skilled goods. Nevertheless, the direct effect must dominate. To prove this: we suppose it was not the case, n_s falls as trade costs fall. However, we derive that $\frac{\partial R_s}{\partial R_u} > 0$, which is a contraction.

Average Profit:

Given $\tilde{\pi} = \frac{\theta-1}{\kappa-(\theta-1)}\left[f_u + n_x f_x + n_s f_u(\phi-1)\right] = \frac{\theta-1}{\kappa-(\theta-1)}\Phi^\kappa$, $\frac{\partial\tilde{\pi}}{\partial\tau} = \frac{\theta-1}{\kappa-(\theta-1)}\frac{\partial\Phi^\kappa}{\partial\tau}$.

$$\frac{\partial\Phi^\kappa}{\partial\tau} = -\kappa\frac{f_x}{f_u}\left(\frac{f_x}{f_u}\right)^{\frac{-\kappa-1}{\theta-1}}\tau^{-\kappa}$$
$$-(\theta-1)\frac{\kappa}{\theta-1}(\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}(1+\tau^{1-\theta})^{\frac{\kappa-\theta+1}{\theta-1}}\tau^{-\theta} < 0$$

Since $\theta > 1$ and $\kappa > (\theta-1)$, we get $\frac{\partial\tilde{\pi}}{\partial\tau} < 0$.

Exit productivity cutoff:

Since $z_e = \Lambda\Phi$ and $\frac{\partial\Phi^\kappa}{\partial\tau} < 0$, we get $\frac{\partial z_e}{\partial\tau} < 0$.

Export productivity cutoff:

Since $z_x = \tau\Lambda\Phi$,

$$\frac{\partial z_x}{\partial\tau} = \left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}}\Lambda\Phi + \left(\frac{f_x}{f_u}\right)^{\frac{1}{\theta-1}}\Lambda\frac{\partial\Phi\tau}{\partial\tau}$$

Given $\Phi\tau = \left[\tau^\kappa + \frac{f_x}{f_u}\left(\frac{f_x}{f_u}\right)^{\frac{-\kappa}{\theta-1}} + \tau^\kappa(\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\right]^{\frac{1}{\kappa}}$

$$\frac{\partial \Phi\tau}{\partial \tau} = (\Phi\tau)^{1/\kappa-1}\left[\tau^{\kappa-1} + \Xi(\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}\right]$$

where $\Xi \equiv \tau^{\kappa-1}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}} - \tau^{\kappa-\theta}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}-1} = \tau^{\kappa-1}(1+\tau^{1-\theta})^{\frac{\kappa}{\theta-1}}\left(1-\frac{\tau^{1-\theta}}{(1+\tau^{1-\theta})}\right)$

As $\frac{\tau^{1-\theta}}{(1+\tau^{1-\theta})} < 1$, $\Xi > 0$. Then, $\frac{\partial \Phi\tau}{\partial \tau} > 0$ and all other terms are positive, thus $\frac{\partial z_x}{\partial \tau} > 0$.

Skill upgrading productivity cutoff:

Since $z_s = z_e\left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{1}{\theta-1}} = \Lambda\Phi\left[\frac{\phi-1}{(1+\tau^{1-\theta})(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right]^{\frac{1}{\theta-1}}$,

$$\begin{aligned}\Phi^\kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} =& (1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} \\ &+ (1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}\left(\frac{f_x}{f_u}\right)^{1-\frac{\kappa}{\theta-1}}\tau^\kappa \\ &+ (\phi-1)\left(\frac{\phi-1}{(\lambda^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}-1)}\right)^{\frac{-\kappa}{\theta-1}}\end{aligned}$$

$$\begin{aligned}\frac{\partial \Phi^\kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}}{\partial \tau} =& \kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} \times \\ &\left[(1+\tau^{1-\theta})^{-1}\tau^{-\theta}\left(1+\left(\frac{f_x}{f_u}\right)^{1-\frac{\kappa}{\theta-1}}\tau^\kappa\right) - \left(\frac{f_x}{f_u}\right)^{1-\frac{\kappa}{\theta-1}}\tau^{-\kappa-1}\right]\end{aligned}$$

As $\kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}} > 0$, the sign of $\frac{\partial \Phi^\kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}}{\partial \tau}$ depends on the second term. We can derive that $\frac{\partial \Phi^\kappa(1+\tau^{1-\theta})^{\frac{-\kappa}{\theta-1}}}{\partial \tau} > 0$ as long as $\tau^{\theta-1}f_x > f_u$. Then $\frac{\partial z_s}{\partial \tau} > 0$ as all terms are positive.

B.2 Extended Model

B.2.1 Total cost and Price

$$TC_u^d(z) = f_u + \frac{w_l}{z}y_u^d(z)$$

$$TC_u^{mx}(z) = f_u + f_{mx} + \frac{w_l}{z}y_u^d(z) + \tau_m\frac{w_l}{z}y_u^{mx}(z)$$

$$TC_u^{ox}(z) = f_u + f_{ox} + \frac{w_l}{\gamma_u z} y_u^d(z) + \tau_o \frac{w_l}{\gamma_u z} y_u^{ox}(z)$$

$$TC_s^{mx}(z) = f_{ms} + f_{mx} + \frac{w_h^\beta w_l^{1-\beta}}{\gamma_m z} y_s^{md}(z) + \tau_m \frac{w_h^\beta w_l^{1-\beta}}{\gamma_m z} y_s^{mx}(z)$$

$$TC_s^{ox}(z) = f_{os} + f_{ox} + \frac{w_h^\alpha w_l^{1-\alpha}}{\gamma_o z} y_s^{od}(z) + \tau_o \frac{w_h^\alpha w_l^{1-\alpha}}{\gamma_o z} y_s^{ox}(z)$$

where $f_{ox} > f_{mx}$, $f_{os} > f_{ms} > f_u$, $\alpha > \beta$ and $\gamma_o > \gamma_m > \gamma_u > 1$.

The profit maximization of both sectors yields the following pricing rules of domestic sales:

$$\begin{aligned}
\rho_u^{md}(z) &= \frac{\theta}{\theta - 1} \frac{w_l}{z} \\
\rho_u^{od}(z) &= \frac{\theta}{\theta - 1} \frac{w_l}{\gamma_u z} \\
\rho_s^{md}(z) &= \frac{\theta}{\theta - 1} \frac{w_h^\beta w_l^{1-\beta}}{\gamma_m z} \\
\rho_s^{od}(z) &= \frac{\theta}{\theta - 1} \frac{w_h^\alpha w_l^{1-\alpha}}{\gamma_o z}
\end{aligned}$$

The four pricing rules of exporting are $\rho_u^{mx}(z) = \tau_m \rho_u^{md}(z)$, $\rho_u^{ox}(z) = \tau_o \rho_u^{od}(z)$, $\rho_s^{mx}(z) = \tau_m \rho_s^{md}(z)$, $\rho_s^{ox}(z) = \tau_o \rho_s^{od}(z)$. Hence, $\rho_s^{md}(z) = \rho_u^{md}(z)/\lambda_m$ where $\lambda_m = \gamma_m \left(\frac{w_l}{w_h}\right)^\beta$; $\rho_s^{od}(z) = \rho_u^{od}(z)/\lambda_o$ where $\lambda_o = \gamma_o \left(\frac{w_l}{w_h}\right)^\alpha$.

B.2.2 Average Profit and Revenue

The average profit $\tilde{\pi}' = \tilde{\pi}_u^{d'} + n_{mx}\tilde{\pi}_u^{mx} + n_{ox}\tilde{\pi}_u^{ox} + n_{ms}\tilde{\pi}_s^{mx} + n_{os}\pi_s^{ox}$, where

$$\begin{aligned}
\tilde{\pi}_u^{d'} &= \frac{1}{1 - G(z_e')} \int_{z_e'}^{z_{mx}} z^{\theta-1} g(z) dz \\
\tilde{\pi}_u^{mx} &= \frac{1}{1 - G(z_e')} \int_{z_{mx}}^{z_{ox}} z^{\theta-1} g(z) dz \\
\tilde{\pi}_u^{ox} &= \frac{1}{1 - G(z_e')} \int_{z_{ox}}^{z_{ms}} z^{\theta-1} g(z) dz \\
\tilde{\pi}_s^{mx} &= \frac{1}{1 - G(z_e')} \int_{z_{ms}}^{z_{os}} z^{\theta-1} g(z) dz \\
\tilde{\pi}_s^{ox} &= \frac{1}{1 - G(z_e')} \int_{z_{os}}^{\infty} z^{\theta-1} g(z) dz
\end{aligned}$$

The average profit also can be describe in this way:

$$\begin{aligned}\tilde{\pi}^{'} =& \frac{\tilde{r}^{'}}{\theta} - (1-n_{ms})f_u - n_{mx}f_{mx} - n_{ox}(f_{ox} - f_{mx}) - n_{ms}(\phi_m f_u + f_{mx} - f_{ox}) \\ & - n_{os}(\phi_o f_u - \phi_m f_u + f_{ox} - f_{mx}) \\ =& \frac{\tilde{r}^{'}}{\theta} - f_u - n_{mx}f_{mx} - n_{ox}(f_{ox} - f_{mx}) - n_{ms}((\phi_m - 1)f_u + f_{mx} - f_{ox}) \\ & - n_{os}((\phi_o - \phi_m)f_u + f_{ox} - f_{mx})\end{aligned}$$

The average revenues of surviving firms is

$$\begin{aligned}\tilde{r}^{'} =& \int_{z_e}^{z_{mx}} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_{mx}}^{z_{ox}} r_u^{mx}(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_{ox}}^{z_{ms}} r_u^{ox}(z)\frac{g(z)}{1-G(z_e)}dz \\ & + \int_{z_{ms}}^{z_{os}} r_s^{ms}(z)\frac{g(z)}{1-G(z_e)}dz + \int_{z_{os}}^{\infty} r_s^{os}(z)\frac{g(z)}{1-G(z_e)}dz \\ =& \int_{z_e}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\ & + \tau_m^{1-\theta}\int_{z_{mx}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\ & + ((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - 1 - \tau_m^{1-\theta})\int_{z_{ox}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\ & + \left[(1+\tau_m^{1-\theta})\lambda_m^{\theta-1}\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u^{\theta-1}\right]\int_{z_{ms}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz \\ & + \left[\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho} - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta})\left(\frac{\rho_2}{\rho_1}\right)^{\theta-\rho}\right]\int_{z_{os}}^{\infty} r_u^d(z)\frac{g(z)}{1-G(z_e)}dz\end{aligned}$$

We derive that z_{mx}, z_{ox}, z_{ms} and z_{ox} can be a function of $z_e^{'}$, so

$$\begin{aligned}\tilde{r}^{'} =& \theta f_u\left(\frac{\tilde{z}_e^{'}}{z_e^{'}}\right)^{\theta-1} + n_{mx}\theta f_{mx}\left(\frac{\tilde{z}_{mx}}{z_{mx}}\right)^{\theta-1} + n_{ox}\theta(f_{ox} - f_{mx})\left(\frac{\tilde{z}_{ox}}{z_{ox}}\right)^{\theta-1} \\ & + n_{ms}\theta(f_u(\phi_m - 1) + f_{mx} - f_{ox})\left(\frac{\tilde{z}_{ms}}{z_{ms}}\right)^{\theta-1} \\ & + n_{os}\theta(f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u)\left(\frac{\tilde{z}_{os}}{z_{os}}\right)^{\theta-1}\end{aligned}$$

Given $\left(\frac{\tilde{z}_j}{z_j}\right)^{\theta-1} = \frac{\kappa}{\kappa-(\theta-1)}$ and the free entry condition, we get

$$z_e^{'} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\Psi\right)^{1/\kappa}$$

$$
\begin{aligned}
\Psi^\kappa =& f_u + n_{mx} f_{mx} + n_{ox}(f_{ox} - f_{mx}) \\
&+ n_{ms}(f_u(\phi_m - 1) + f_{mx} - f_{ox}) + n_{os}(f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u) \\
=& f_u + f_{mx}\tau_m^{-\kappa}\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}} + (f_{ox} - f_{mx})\left(\frac{f_{ox} - f_{mx}}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - 1 - \tau_m^{1-\theta})f_u}\right)^{\frac{-\kappa}{\theta-1}} \\
&+ (f_u(\phi_m - 1) + f_{mx} - f_{ox}) \\
&\times \left[\frac{((\phi_m - 1)f_u + f_{mx} - f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u^{\theta-1})f_u}\right]^{\frac{-\kappa}{\theta-1}} \\
&+ (f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u) \\
&\times \left[\frac{f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho} f_u}\right]^{\frac{-\kappa}{\theta-1}} \\
=& f_u + f_{mx}\tau_m^{-\kappa}\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}} + (f_{ox} - f_{mx})^{\frac{-\kappa}{\theta-1}} A + (f_u(\phi_m - 1) + f_{mx} - f_{ox}) B^{\frac{-\kappa}{\theta-1}} \\
&+ (f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u) C^{\frac{-\kappa}{\theta-1}}
\end{aligned}
$$

where $A \equiv (1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - 1 - \tau_m^{1-\theta}$, $B \equiv \frac{((\phi_m-1)f_u + f_{mx} - f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u^{\theta-1})f_u}$ and $C \equiv \frac{f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho} f_u}$.

B.2.3 Changes in Trade Costs to Country m

Average Profit:

Given $\tilde{\pi}' = \frac{\theta-1}{\kappa-(\theta-1)}\Psi^\kappa$, $\frac{\partial\tilde{\pi}'}{\partial\tau_m} = \frac{\theta-1}{\kappa-(\theta-1)}\frac{\partial\Psi^\kappa}{\partial\tau_m}$.

$$
\begin{aligned}
\frac{\partial\Psi^\kappa}{\partial\tau_m} = -\kappa f_{mx}\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}}\tau_m^{-\kappa-1} + \kappa A^{\frac{\theta-1-\kappa}{\theta-1}} f_u \tau_m^{-\theta} - \kappa B^{\frac{\theta-1-\kappa}{\theta-1}} f_u \lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_m^{-\theta} \\
+ \kappa C^{\frac{\theta-1-\kappa}{\theta-1}} f_u \lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_m^{-\theta}
\end{aligned}
$$

Since $f_{mx} > f_u$, $\left(\frac{f_{mx}}{f_u}\right)^{\frac{-\kappa}{\theta-1}}\tau_m^{-\kappa} > A$, $\tau_m^{-1} > \tau_m^{-\theta}$ and $B > C$, $\frac{\partial\Psi^\kappa}{\partial\tau_m} < 0$. Thus, $\frac{\partial\tilde{\pi}'}{\partial\tau_m} < 0$.

Exit productivity cutoff:

$$
z_e' = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\Psi\right)^{1/\kappa}
$$

Thus, $\frac{\partial z_e^{'}}{\partial \tau_m} < 0$

Export Productivity Cutoff, Country m:

$$z_{mx} = \left(\frac{\theta - 1}{\kappa - (\theta - 1)} \frac{1}{\delta f_e} \right)^{1/\kappa} \left[\frac{1}{n_{mx}} f_u + f_{mx} + \frac{n_{ox}}{n_{mx}} (f_{ox} - f_{mx}) + \frac{n_{ms}}{n_{mx}} (f_u(\phi_m - 1) \right.$$
$$\left. + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{mx}} (f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u) \right]$$

Proof:

(1)

$$\frac{1}{n_{mx}} = \left(\frac{z_{mx}}{z_e^{'}} \right)^{\kappa} = \left(\tau_m \left(\frac{f_{mx}}{f_u} \right)^{\frac{1}{\theta - 1}} \right)^{\kappa}$$

When τ_m falls, $\frac{1}{n_{mx}}$ goes down.

(2)

$$\frac{n_{ox}}{n_{mx}} = \left(\frac{z_{mx}}{z_{ox}} \right)^{\kappa} = \left(\frac{f_{mx}}{f_{ox} - f_{mx}} \right)^{\frac{\kappa}{\theta - 1}} \left[\tau_m^{\theta - 1} (\gamma_u^{\theta - 1} (1 + \tau_o^{1 - \theta}) - \tau_m^{1 - \theta} - 1) \right]^{\frac{\kappa}{\theta - 1}}$$

Let $D \equiv \tau_m^{\theta - 1} (\gamma_u^{\theta - 1} (1 + \tau_o^{1 - \theta}) - \tau_m^{1 - \theta} - 1)$

$$\frac{\partial \frac{n_{ox}}{n_{mx}}}{\partial \tau_m} = \left(\frac{f_{mx}}{f_{ox} - f_{mx}} \right)^{\frac{\kappa}{\theta - 1}} \kappa D^{\frac{\kappa}{\theta - 1} - 1} \tau_m \theta \left(\gamma_u^{\theta - 1} (1 + \tau_o^{1 - \theta}) - 1 \right) > 0$$

Since $\gamma_u^{\theta - 1} (1 + \tau_o^{1 - \theta}) > 1$, $\frac{n_{ox}}{n_{mx}}$ falls when τ_m drops.

(3)

$$\begin{aligned}
\frac{n_{ms}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{ms}} \right)^{\kappa} \\
&= \left(\frac{f_{mx}}{(\phi_m - 1) f_u + f_{mx} - f_{ox}} \right)^{\frac{\kappa}{\theta - 1}} \times \\
&\quad \left[\tau_m^{\theta - 1} ((1 + \tau_m^{1 - \theta}) \lambda_m^{\theta - 1} (\rho_2 / \rho_1)^{\theta - \rho} - (1 + \tau_o^{1 - \theta}) \gamma_u^{\theta - 1}) \right]^{\frac{\kappa}{\theta - 1}} \\
&= \left(\frac{f_{mx}}{(\phi_m - 1) f_u + f_{mx} - f_{ox}} \right)^{\frac{\kappa}{\theta - 1}} \times \\
&\quad \left[\frac{1 + \tau_m^{1 - \theta}}{\tau_m^{1 - \theta}} \lambda_m^{\theta - 1} (\rho_2 / \rho_1)^{\theta - \rho} - \frac{1 + \tau_o^{1 - \theta}}{\tau_m^{1 - \theta}} \gamma_u^{\theta - 1} \right]^{\frac{\kappa}{\theta - 1}}
\end{aligned}$$

When τ_m falls, $\tau_m^{1-\theta}$ increases, $\frac{1+\tau_m^{1-\theta}}{\tau_m^{1-\theta}}$ decreases and λ_m also decreases. Thus, $\frac{n_{ms}}{n_{mx}}$ falls.

(4)

$$\begin{aligned}\frac{n_{os}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{os}}\right)^{\kappa} \\ &= \left(\frac{f_{mx}}{f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u}\right)^{\frac{\kappa}{\theta-1}} \times \\ &\quad \left[(\tau_m^{\theta-1}(\lambda_o^{\theta-1} - \lambda_m^{\theta-1}) + \tau_m^{\theta-1}\lambda_o^{\theta-1}\tau_o^{\theta-1} - \lambda_m^{\theta-1})(\rho_2/\rho_1)^{\theta-\rho}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $(\lambda_o^{\theta-1} - \lambda_m^{\theta-1}) > 0$, $\frac{n_{os}}{n_{mx}}$ decreases with a lower τ_m.

Therefore,

- $\tau_m \downarrow \Rightarrow \frac{1}{n_{mx}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{ox}}{n_{mx}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{ms}}{n_{mx}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{os}}{n_{mx}} \downarrow$,

We show that $\frac{\partial z_{mx}}{\partial \tau_m} > 0$.

Skill Upgrading Productivity Cutoff, Country m

$$\begin{aligned}z_{ms} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa} &\left[\frac{1}{n_{ms}} f_u + \frac{n_{mx}}{n_{ms}} f_{mx} + \frac{n_{ox}}{n_{ms}}(f_{ox} - f_{mx}) + (f_u(\phi_m - 1)\right. \\ &\left. + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{ms}}(f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u)\right]\end{aligned}$$

Proof:

(1)

$$\begin{aligned}\frac{1}{n_{ms}} &= \left(\frac{z_{ms}}{z_e}\right)^{\kappa} \\ &= \left[\frac{(\phi_m - 1) f_u + f_{mx} - f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u) f_u}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\theta > 1$ and $\kappa > \theta - 1$, $\frac{1}{n_{ms}}$ falls when τ_m decreases.

(2)

When τ_m falls, $\frac{n_{ms}}{n_{mx}}$ decreases; thus $\frac{n_{mx}}{n_{ms}}$ increases.

(3)

$$\begin{aligned}\frac{n_{ox}}{n_{ms}} &= \left(\frac{z_{ms}}{z_{ox}}\right)^{\kappa} \\ &= \left[\frac{(\phi_m - 1)f_u + f_{mx} - f_{ox}}{f_{ox} - f_{mx}} \frac{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\tau_m \downarrow \Rightarrow \tau_m^{1-\theta} \uparrow$, $\frac{n_{ox}}{n_{ms}}$ falls with a lower τ_m.

(4)

$$\begin{aligned}\frac{n_{os}}{n_{ms}} &= \left(\frac{z_{ms}}{z_{os}}\right)^{\kappa} \\ &= \left[\frac{(\phi_m - 1)f_u + f_{mx} - f_{ox}}{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u} \frac{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Since $\tau_m \downarrow \Rightarrow \tau_m^{1-\theta} \uparrow$, $\frac{n_{os}}{n_{ms}}$ falls with a lower τ_m.

Therefore,

- $\tau_m \downarrow \Rightarrow \frac{1}{n_{ms}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{mx}}{n_{ms}} \uparrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{ox}}{n_{ms}} \downarrow$
- $\tau_m \downarrow \Rightarrow \frac{n_{os}}{n_{ms}} \downarrow$,

We can get $\frac{\partial z_{ms}}{\partial \tau_m} > 0$ when the second effect $\frac{n_{mx}}{n_{ms}}$ is dominated by the other three effects.

B.2.4 Changes in Trade Costs to Country o

Average Profit:

Given $\tilde{\pi}' = \frac{\theta-1}{\kappa-(\theta-1)}\Psi^{\kappa}$, $\frac{\partial \tilde{\pi}'}{\partial \tau_o} = \frac{\theta-1}{\kappa-(\theta-1)}\frac{\partial \Psi^{\kappa}}{\partial \tau_o}$.

$$\frac{\partial \Psi^\kappa}{\partial \tau_o} = -\kappa A^{\frac{\theta-1-\kappa}{\theta-1}} f_u \gamma_u^{\theta-1} \tau_o^{-\theta} + \kappa B^{\frac{\theta-1-\kappa}{\theta-1}} f_u \gamma_u^{\theta-1} \tau_o^{-\theta} - \kappa C^{\frac{\theta-1-\kappa}{\theta-1}} f_u \lambda_o^{\theta-1} (\rho_2/\rho_1)^{\theta-\rho} \tau_o^{-\theta}$$

As $A > B$, $\frac{\partial \Psi^\kappa}{\partial \tau_o} < 0$ and then, $\frac{\partial \tilde{\pi}'}{\partial \tau_o} < 0$.

Exit Productivity Cutoff:

Similarly, $\frac{\partial z_e'}{\partial \tau_o} < 0$.

Export Productivity Cutoff, Country o:

$$z_{ox} = \left(\frac{\theta-1}{\kappa-(\theta-1)} \frac{1}{\delta f_e} \right)^{1/\kappa} \left[\frac{1}{n_{ox}} f_u + \frac{n_{mx}}{n_{ox}} f_{mx} + (f_{ox} - f_{mx}) \right.$$
$$\left. + \frac{n_{ms}}{n_{ox}} (f_u(\phi_m - 1) + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{ox}} (f_{ox} - f_{mx} + (\phi_o - \phi_m) f_u) \right]$$

Proof:

(1)

$$\frac{1}{n_{ox}} = \left(\frac{z_{ox}}{z_e} \right)^\kappa = \left[\frac{f_{ox} - f_{mx}}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1) f_u} \right]^{\frac{\kappa}{\theta-1}}$$

Since $\theta > 1$ and $\kappa > \theta - 1$, $\frac{1}{n_{ox}}$ falls when τ_o decreases.

(2)

$$\frac{n_{mx}}{n_{ox}} = \left(\frac{z_{ox}}{z_{mx}} \right)^\kappa = \left(\frac{f_{ox} - f_{mx}}{f_{mx}} \right)^{\frac{\kappa}{\theta-1}} \left[\frac{(\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) - \tau_m^{1-\theta} - 1)}{\tau_m^{\theta-1}} \right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{mx}}{n_{ox}}$ increases with a lower τ_o.

(3)

$$\frac{n_{ms}}{n_{ox}} = \left(\frac{z_{ox}}{z_{ms}} \right)^\kappa = \left[\frac{f_{ox} - f_{mx}}{(\phi_m - 1) f_u + f_{mx} - f_{ox}} \frac{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)} \right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{ms}}{n_{ox}}$ falls with a lower τ_o.

(4)

$$\begin{aligned}\frac{n_{os}}{n_{ox}} &= \left(\frac{z_{ox}}{z_{os}}\right)^{\kappa} \\ &= \left[\frac{f_{ox}-f_{mx}}{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}\frac{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})-\lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}}{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1}-\tau_m^{1-\theta}-1)}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

Let $E \equiv (\lambda_o^{\theta-1}(1+\tau_o^{1-\theta})-\lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}$ and $F \equiv ((1+\tau_o^{1-\theta})\gamma_u^{\theta-1}-\tau_m^{1-\theta}-1)$.

$$\frac{\partial \frac{n_{os}}{n_{ox}}}{\tau_o} = \left[\frac{f_{ox}-f_{mx}}{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}\right]^{\frac{\kappa}{\theta-1}} \kappa \frac{-\lambda_o^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_o^{-\theta}F-\gamma_u^{\theta-1}\tau_o^{-\theta}E}{F^2}$$

Since $-\lambda_o^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho}\tau_o^{-\theta}F-\gamma_u^{\theta-1}\tau_o^{-\theta}E<0$ and other terms are positive, $\frac{\partial \frac{n_{os}}{n_{ox}}}{\tau_o}<0$.

Hence,

- $\tau_o \downarrow \Rightarrow \frac{1}{n_{ox}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{mx}}{n_{ox}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ms}}{n_{ox}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{os}}{n_{ox}} \uparrow$,

$\frac{\partial z_{ox}}{\partial \tau_o}>0$ if and only if the total effects of τ_o on $\frac{1}{n_{ox}}$ and $\frac{n_{ms}}{n_{ox}}$ dominate the other two effects.

Skill Upgrading Productivity Cutoff, Country o:

$$\begin{aligned}z_{os} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa} &\left[\frac{1}{n_{os}}f_u+\frac{n_{mx}}{n_{os}}f_{mx}+\frac{n_{ox}}{n_{os}}(f_{ox}-f_{mx})\right. \\ &\left.+\frac{n_{ms}}{n_{os}}(f_u(\phi_m-1)+f_{mx}-f_{ox})+(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\right]\end{aligned}$$

Proof:

(1)

$$\frac{1}{n_{os}} = \left(\frac{z_{os}}{z_e}\right)^{\kappa}$$
$$= \left[\frac{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{1}{n_{os}}$ falls with a lower τ_o.

(2)

$$\frac{n_{mx}}{n_{os}} = \left(\frac{z_{os}}{z_{mx}}\right)^{\kappa}$$
$$= \left[\frac{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u}{f_{mx}} \frac{\tau_m^{1-\theta}}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{mx}}{n_{os}}$ falls with a lower τ_o.

(3)

As $\frac{\partial \frac{n_{os}}{n_{ox}}}{\tau_o} < 0$, $\frac{n_{ox}}{n_{os}}$ decreases if τ falls.

(4)

$$\frac{n_{ms}}{n_{os}} = \left(\frac{z_{os}}{z_{ms}}\right)^{\kappa}$$
$$= \left[\frac{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u}{(\phi_m - 1)f_u + f_{mx} - f_{ox}} \frac{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}f_u}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{ms}}{n_{os}}$ falls with a lower τ_o.

Hence,

- $\tau_o \downarrow \Rightarrow \frac{1}{n_{os}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{mx}}{n_{os}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ox}}{n_{os}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ms}}{n_{os}} \downarrow$,

We prove that $\frac{\partial z_{os}}{\partial \tau_o} > 0$.

Export Productivity Cutoff, Country m:

$$z_{mx} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\left[\frac{1}{n_{mx}}f_u + f_{mx} + \frac{n_{ox}}{n_{mx}}(f_{ox}-f_{mx}) + \frac{n_{ms}}{n_{mx}}(f_u(\phi_m-1) + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{mx}}(f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u)\right]$$

Proof:

(1)

$$\frac{1}{n_{mx}} = \left(\frac{z_{mx}}{z_e'}\right)^{\kappa} = \left(\tau_m\left(\frac{f_{mx}}{f_u}\right)^{\frac{1}{\theta-1}}\right)^{\kappa}$$

τ_o has no effects on $\frac{1}{n_{mx}}$.

(2)

$$\frac{n_{ox}}{n_{mx}} = \left(\frac{z_{mx}}{z_{ox}}\right)^{\kappa} = \left(\frac{f_{mx}}{f_{ox}-f_{mx}}\right)^{\frac{\kappa}{\theta-1}}\left[\tau_m^{\theta-1}(\gamma_u^{\theta-1}(1+\tau_o^{1-\theta}) - \tau_m^{1-\theta}-1)\right]^{\frac{\kappa}{\theta-1}}$$

When τ_o falls, $\tau_0^{1-\theta}$ increases and $\frac{n_{ox}}{n_{mx}}$ goes up.

(3)

$$\begin{aligned}\frac{n_{ms}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{ms}}\right)^{\kappa}\\ &= \left(\frac{f_{mx}}{(\phi_m-1)f_u+f_{mx}-f_{ox}}\right)^{\frac{\kappa}{\theta-1}} \times\\ &\quad \left[\tau_m^{\theta-1}((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u^{\theta-1})\right]^{\frac{\kappa}{\theta-1}}\\ &= \left(\frac{f_{mx}}{(\phi_m-1)f_u+f_{mx}-f_{ox}}\right)^{\frac{\kappa}{\theta-1}} \times\\ &\quad \left[\frac{1+\tau_m^{1-\theta}}{\tau_m^{1-\theta}}\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - \frac{1+\tau_o^{1-\theta}}{\tau_m^{1-\theta}}\gamma_u^{\theta-1}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

When τ_o falls, $\tau_o^{1-\theta}$ increases; thus $\frac{n_{ms}}{n_{mx}}$ falls.

(4)

$$\begin{aligned}\frac{n_{os}}{n_{mx}} &= \left(\frac{z_{mx}}{z_{os}}\right)^{\kappa}\\ &= \left(\frac{f_{mx}}{f_{ox}-f_{mx}+(\phi_o-\phi_m)f_u}\right)^{\frac{\kappa}{\theta-1}} \times\\ &\quad \left[(\tau_m^{\theta-1}(\lambda_o^{\theta-1}-\lambda_m^{\theta-1}) + \tau_m^{\theta-1}\lambda_o^{\theta-1}\tau_o^{\theta-1} - \lambda_m^{\theta-1})(\rho_2/\rho_1)^{\theta-\rho}\right]^{\frac{\kappa}{\theta-1}}\end{aligned}$$

When τ_o falls, $\tau_o^{\theta-1}$ falls and $\frac{n_{os}}{n_{mx}}$ goes down.

Therefore,

- $\tau_o \downarrow \Rightarrow \frac{n_{ox}}{n_{mx}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ms}}{n_{mx}} \downarrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{os}}{n_{mx}} \downarrow$.

A reduction in τ_o decreases z_{mx} when the impact of τ_o on $\frac{n_{ox}}{n_{mx}}$ is dominated by the other two effects.

Skill Upgrading Productivity Cutoff, Country m:

$$z_{ms} = \left(\frac{\theta-1}{\kappa-(\theta-1)}\frac{1}{\delta f_e}\right)^{1/\kappa}\left[\frac{1}{n_{ms}}f_u + \frac{n_{mx}}{n_{ms}}f_{mx} + \frac{n_{ox}}{n_{ms}}(f_{ox}-f_{mx}) + (f_u(\phi_m-1)\right.$$
$$\left. + f_{mx} - f_{ox}) + \frac{n_{os}}{n_{ms}}(f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u)\right]$$

Proof:

(1)

$$\frac{1}{n_{ms}} = \left(\frac{z_{ms}}{z_e}\right)^{\kappa} = \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)f_u}\right]^{\frac{\kappa}{\theta-1}}$$

When τ_o falls, $\tau_o^{1-\theta}$ increases and $\frac{1}{n_{ms}}$ goes up.

(2)

When τ_o falls, $\frac{n_{ms}}{n_{mx}}$ decreases; thus $\frac{n_{mx}}{n_{ms}}$ increases.

(3)

$$\frac{n_{ox}}{n_{ms}} = \left(\frac{z_{ms}}{z_{ox}}\right)^{\kappa} = \left[\frac{(\phi_m-1)f_u + f_{mx} - f_{ox}}{f_{ox}-f_{mx}}\frac{((1+\tau_o^{1-\theta})\gamma_u^{\theta-1} - \tau_m^{1-\theta} - 1)}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{ox}}{n_{ms}}$ increases with a lower τ_o.

(4)

$$\frac{n_{os}}{n_{ms}} = \left(\frac{z_{ms}}{z_{os}}\right)^{\kappa}$$
$$= \left[\frac{(\phi_m - 1)f_u + f_{mx} - f_{ox}}{f_{ox} - f_{mx} + (\phi_o - \phi_m)f_u} \frac{(\lambda_o^{\theta-1}(1+\tau_o^{1-\theta}) - \lambda_m^{\theta-1}(1+\tau_m^{1-\theta}))(\rho_2/\rho_1)^{\theta-\rho}}{((1+\tau_m^{1-\theta})\lambda_m^{\theta-1}(\rho_2/\rho_1)^{\theta-\rho} - (1+\tau_o^{1-\theta})\gamma_u)}\right]^{\frac{\kappa}{\theta-1}}$$

Since $\tau_o \downarrow \Rightarrow \tau_o^{1-\theta} \uparrow$, $\frac{n_{os}}{n_{ms}}$ rises with a lower τ_o.

Therefore,

- $\tau_o \downarrow \Rightarrow \frac{1}{n_{ms}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{mx}}{n_{ms}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{ox}}{n_{ms}} \uparrow$
- $\tau_o \downarrow \Rightarrow \frac{n_{os}}{n_{ms}} \uparrow$,

We derive that $\frac{z_{ms}}{\tau_o} < 0$.

C Data Description

C.1 Computation of Input Tariffs

We computed input tariffs for each 4-digit CIC industry in a similar way as Amiti and Konings (2007) and Bustos (2011b). The input tariff for each industry is computed as weighted average of the tariffs of all inputs used, where the weights are based on the cost share of each input, according to the following formula:

$$\tau_{jt}^{im} = \sum_i w_{ij} \times \tau_{it}^{im} \text{ where } w_{ij} = \frac{a_{ij}}{\sum_i a_{ij}} \tag{A.1}$$

where j indexes the 4-digit CIC industry for which the input tariff is computed; i indexes the 4-digit CIC industry producing the input, and t indexes time. w_{ij} denotes the cost share of each input i in the production of output j, and a_{ij} is total expenditure in input i by industry j. These expenditure shares include both domestic and imported inputs. We estimated a_{ij} based on China's input-output (I-O) table in 2007. The data are aggregated at the sector level, and we use the same value for all the industries in the same sector.

C.2 Proxy for Initial Productivity

In the model, heterogeneity is given by labor productivity holding skill level constant, which is not directly observed in the data. As a proxy for initial productivity, we use initial firm size in terms of employment relative to the 4-digit industry average.

C.3 Measures of Capital and Skill Intensity

Average capital and skill intensity in the industry in the United States in the 1980s is obtained from the NBER productivity database. The measure of capital intensity is capital (real equipment plus real structures) per worker, and the measure of skill intensity is the ratio of non-production to production workers in the industry.

C.4 Summary Statistics

Table A1: Summary Statistics of Variables of Interest in 2004

Variables	All	Exporters	Non-exporters	Observations	Firms
Employment	361.055	691.605	190.219	131,460	110,632
	[1806.685]	[2867.222]	[785.306]		
Total sales	160.362	373.104	50.412	131,460	110,632
	[1826.812]	[3061.618]	[426.793]		
Export share of sales, Exports>0		0.028		23,964	44,792
		[0.048]			
1{Export to India}, Exports>0		0.090		23,964	44,792
		[0.286]			
1{TS>0}	0.443	0.466	0.432	131,460	110,632
	[0.497]	[0.499]	[0.495]		
Total training spending	43.139	82.403	22.846	131,460	110,632
	[432.506]	[639.843]	[266.359]		
Total training spending, TS>0	97.279	176.890	52.899	58,296	48,525
	[645.421]	[928.517]	[403.346]		
Training spending per worker	111.912	117.462	109.044	131,460	110,632
	[591.856]	[561.849]	[606.766]		
Training spending per worker, TS>0	252.367	252.149	252.488	58,296	48,525
	[868.612]	[802.307]	[903.476]		
Observations	131,460	44,792	86,668		
Firms	110,632	23,964	86,668		

Standard deviations in brackets. Employment in number of workers, sales in millions of 2004 RMB yuan, total training spending in thousands of 2004 RMB yuan, and training spending per capita in 2004 RMB yuan.