Trade Liberalization, Skill Premium, and Productivity: Evidence from Thailand[*]

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Abstract

In this paper, I quantitatively study the effects of trade liberalization on Thailand's skill wage premium and on productivity by using a trade model of monopolistic competition with heterogeneous firms. The estimation is based on a 2003 survey of Thai manufacturing firms. The model reveals that the wage rate of skilled workers is approximately 47% higher than that of unskilled workers. This study shows that trade liberalization results in a tradeoff between productivity and the skill premium. That is, trade liberalization improves productivity but at the expense of a wider gap in the wages of skilled to unskilled workers. I observe a link between productivity and export status and then show that trade liberalization, as a drop in tariffs, drives low-productivity non-exporting firms from the market, replacing them with high-productivity exporting firms. Further, trade liberalization increases the skill wage premium.

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I. Introduction

Since the early 2000s, the Thai government has aggressively pursued trade liberalization. Both tariffs and non-tariff barriers have been reduced. There is a major concern that trade liberalization might affect the labor market and negatively impact skilled employment and wages. Phan (2004), Velde and Morrissey (2004), and Sangkaew and Jayanthakumaran (2013) found that trade liberalization significantly affects the skill wage premium in Thailand. However, none of these studies have specifically quantified the skill wage premium in Thailand. The goal of this study is to estimate the skill premium in Thailand. Moreover, this study shows that trade liberalization results in a tradeoff between productivity and the skill premium. That is, trade liberalization improves productivity but at the expense of a wider gap in the wages of skilled to unskilled workers. It is important for policy makers to be aware of this trade-off in order to optimize the productivity level and the skill premium.

In the decade during 2000-2010, many studies were done that used a trade model with heterogeneous firms to analyze the effect of trade liberalization on skilled employment and the skill premium. For example, Yeaple (2005) proposed a theoretical trade model in which firms choose a technology corresponding to heterogeneous labor differentiated by skill levels. A main feature of his model is that exporting firms using advanced technology with high-skilled labor are productive firms endeavoring to upgrade their production technology. Therefore, these firms demand more skilled workers to work with their advanced technology, resulting in an increase in the skill wage premium. Bustos (2011) built a model based on Yeaple (2005), but firms in her model employ both skilled and unskilled workers. She analyzed the effects of Brazil's tariff reduction on Argentinean firms. She found that the skill premium in Argentinean firms that export their products to Brazil was increased due to the adoption of improved technology following trade reform. Bas (2008) expanded on Yeaple (2005) and Bustos (2011) to explain the increase in the skill premium in Chilean industries during 1990-1999. While the firms in Bustos (2011) used skilled and unskilled workers in fixed proportions, Bas (2008) assumed that skilled and unskilled labor are combined by a CES production function. He found that the skill premium increased in all industries in Chile. Even in unskilled-intensive sectors, firms upgrade their production technology after tariff reform, leading to a higher skill premium. Harringan and Reshef (2011) observed a correlation between skill intensity and technological adoption. Using 1995 firm-level data from Chile, they found that a reduction in trade costs led exporting firms to expand production by using more skilled workers and more advanced technology, and this caused the higher skill premium. Moreover, based on the assumption that countries export products that use their abundant factor, they further showed that the skill premium grows in both skill-abundant and skill-scarce countries. The pattern of an increase in skill premium has occurred in both developing and developed countries. Xiang (2007) and Goldin and Katz (2008) found that technological progress in the U.S. during the 1980s accelerated the demand for skilled labor and raised the U.S. skill premium.

Unlike the studies described above, Bernard, Redding, and Schott (2007) assumed that firms are identical in technologies but different in factor proportions (high-skilled vs. low-skilled workers). Hence, firms that have a comparative advantage experience greater benefits from trade liberalization and employ more high-skilled labor. Thus, the wage gap between high-skilled and low-skilled workers is widening.

While some studies explained the increase in the skill premium through technological adoption following trade liberalization, others claimed that the skill premium increases even without the technological variable. For example, Epifani and Gancia (2008) and Dinopoulos et al. (2011) observed a correlation between economies of scale and skill intensity at the sector and firm level, respectively. The key feature of these studies is that the increase in economies of scale after trade liberalization triggers a greater demand for skilled labor, leading to an increase in the skill premium. Unel (2010) developed a model similar to that of Epifani and Gancia (2008), but introduced heterogeneous firms and a fixed cost of exporting into the framework. Unel (2010) used his model to explain the increase in the skill premium in the U.S.

The literature described above provides evidence that trade liberalization pushes the skill premium up; however, some studies show that a decline in trade costs can decrease the skill premium. For instance, Ekholm and Midelfart (2005), Yavas (2006), and Helpman et al. (2012) demonstrated that when trade costs decrease continuously, the skill premium will go up until it reaches a peak. If trade costs continue to fall, firms demand more skilled workers. However, if they cannot further increase the proportion of skilled to unskilled workers, they expand production by using more unskilled workers. Hence, the skill premium declines.

The remainder of this chapter is organized as follows: Section 2 describes the model used in this study; Section 3 defines the equilibrium of the model; Section 4 describes the data and parameters of the model; Section 5 describes the results of numerical experiments; Section 6 provides concluding remarks.

II. The Model

In this section, I explain the structure of the model used in this study. I develop a trade model of monopolistic competition with heterogeneous firms similar to that of Melitz (2003). The economy is composed of two sectors: the homogeneous agricultural sector and the heterogeneous manufacturing sector. The economy in this model is open and comprised of consumers, producers, and the government. The characteristics of each of these economic agents are described in detail below.

II.1 Consumers

Consumers are differentiated by their skill levels. Some supply their skilled labor (s) to the market, and others supply their unskilled labor (u). Wages vary with skills. I denote a set of consumers by $i \in I\{s,u\}$. Consumers' preferences are governed by the logarithmic CES Dixit-Stiglitz utility function:

$$U = (1-\alpha^i)\log c_0^i + \alpha^i \log\left(\int_{z\in Z} c^i(z)^\eta \, dz\right)^{\frac{1}{\eta}} \tag{1}$$

Here, c_0^i is the consumption of homogeneous goods of consumer i; Z is the set of differentiated manufacturing goods available for consumption in a country; $c^i(z)$ is the consumption of differentiated goods in the set of Z demanded by consumer i, where z is the index for the varieties; α^i is the preference parameters of each consumer group on two private goods where $0 < \alpha^i < 1$; $\varepsilon = \dfrac{1}{1-\eta}$ is the elasticity of substitution between any varieties and is greater than one.

The consumer's budget is composed of three sources: the return to labor (w^i), the share of total profits (π), and the lump-sum transfers (T). Note that the aggregate profits (Π) and the total tax revenues (R) are equally distributed to all consumers. Given their incomes and prices, the representative consumer chooses consumption of homogeneous and differentiated goods c_0^i and $c^i(z)$ to maximize his utility subject to the budget constraint. The aggregate demand for homogeneous goods and differentiated goods is given by

$$C_0 = \sum_{i \in I} c_0^i \text{, where } c_0^i = \frac{(1-\alpha^i)(w^i \bar{l}^i + \pi + T)}{p_0} \tag{2}$$

and

$$C(z) = \sum_{i \in I} c^i(z) \text{, where } c^i(z) = \frac{\alpha^i (w^i \bar{l}^i + \pi + T)}{p(z)^{\frac{1}{1-\eta}} P^{-\frac{\eta}{1-\eta}}} \tag{3}$$

Here, P is the price index and is equal to

$$P = \left(\int_{z \in Z} p(z)^{\frac{-\eta}{1-\eta}} dz \right)^{\frac{-(1-\eta)}{\eta}} \tag{4}$$

II.2 Producers

As explained previously, there are two sectors in the economy. Thus, we have two types of producers. The producers in each sector are described in detail below.

In the homogeneous sector (y_0), I assume that one unit of unskilled labor is used to produce one unit of output. The constant-returns production function of homogeneous agricultural goods is given by $y_0 = l_0^u$. The homogeneous goods producer minimizes cost by finding l_0^u solve

$$\min w^u l_0^u$$

subject to

$$y_0 = l_0^u$$

Perfect competition in the homogeneous goods sector implies

$$p_0 y_0 - w^u l_0^u = 0$$

In contrast to the agricultural sector, there is a continuum of heterogeneous firms in the manufacturing sector. Each produces a single different variety. I denote a set of producers by $j \in J = \{d, x\}$, where d is the non-exporting firm and x is the exporting firm. Production uses two variable factors: skilled (l_j^s) and unskilled (l_j^u) labor. The labor supply of each type of labor is inelastic and mobile within an industry. They are combined in a constant elasticity of substitution (CES) production function. Following Vannoorenberghe (2011), the production function is governed by

$$y_j(z) = \max\left\{0, \left[(l_j^u)^\rho + z_j^{1-\rho}(l_j^s)^\rho\right]^{\frac{1}{\rho}}\right\} \tag{5}$$

Here, $\sigma = \dfrac{1}{1-\rho}$ is the elasticity of substitution between the two factors of production and is greater than one. Firms are heterogeneous as to the productivity of skilled labor indexed by z. The productivity (z) is drawn by each potential entrant from a Pareto distribution function.[1]

A firm's profit maximization problem relates to two decisions: the optimal amounts of unskilled and skilled labor to employ and the optimal price of goods. Firstly, the cost minimization problem of a firm with efficiency z is

$$\min \sum_{i \in I} w^i l_j^i + f_j$$

subject to

$$\left[(l_j^u)^\rho + z_j^{1-\rho}(l_j^s)^\rho\right]^{\frac{1}{\rho}} = \tau_j y_j$$

Note that,

$$f_j = \begin{cases} \varphi_d & \text{if } j = d \\ \varphi_d + \varphi_x & \text{if } j = x \end{cases} \qquad \text{where } j \in J$$

[1] Foltyn (2007) noted that the Pareto distribution was selected as closed-form expressions for all equilibrium variables can be derived and dominates in applied work (see, for example, Helpman/Melitz/Yeaple (2004) and papers by Baldwin et al.)

Here, w^i is the wage rate for each type of labor. If a firm serves the domestic market, it must pay fixed cost, f_d. If a firm enters a foreign market, it must pay an additional fixed cost, f_x, as well as iceberg trade costs, τ. These costs can be interpreted as either transport costs or tariffs. For one unit of goods to arrive at its destination, firms must produce τ units, where $\tau \geq 1$ units of goods. I assign $\tau_j = (1+t_j)$, where t_j is a tariff rate. Hence, for the domestic firms, $t_d = 0$, and for the exporting firms, $t_x = t > 0$.

The first order conditions of the cost minimization problem yield the following condition:

$$\frac{l_j^s}{l_j^u} = z_j \omega^{-\frac{1}{1-\rho}} \quad \text{for} \quad j \in J \tag{6}$$

Here, $\omega = w^s / w^u$ is the skill premium, where w^s and w^u are the skilled and unskilled wage rates, respectively. The expression implies that the skill intensity defined as the ratio of skilled to unskilled labor (l_j^s / l_j^u) is positively correlated to the productivity, z_j. In other words, the production of more productive firms is more skilled intensive. In contrast, the skill intensity is negatively correlated to the skill premium, ω.

Further, the cost minimization problem yields the total cost function as follows:

$$\Gamma_j(z) = w^u \left(1 + z_j \cdot \omega^{\frac{-\rho}{1-\rho}}\right)^{-\frac{1-\rho}{\rho}} \cdot \tau_j y_j(z) + f_j \quad \text{for} \quad j \in J \tag{7}$$

Second, a firm sets the optimal price to maximize profit as follows:

$$\max_{p_j(\omega)} p_j(z) y_j(z) - w^u \left(1 + z_j \cdot \omega^{\frac{-\rho}{1-\rho}}\right)^{-\frac{1-\rho}{\rho}} \cdot \tau_j y_j(z) - f_j \tag{8}$$

With monopolistic competition, a firm chooses an optimal price by taking the consumer's demand function (3) as given and maximizing (8) with respect to p_j. This yields the pricing decision rule as follows:

$$p_j(z) = \frac{1}{\eta} \cdot w^u \left(1 + z_j \cdot \omega^{\frac{-\rho}{1-\rho}}\right)^{-\frac{1-\rho}{\rho}} \tau_j \tag{9}$$

This is the standard outcome of the monopolist. Monopolistic price is the marginal cost of production multiplied by a markup, $\frac{1}{\eta}$, and the markup is constant due to a constant elasticity ε. According to the assumption of t_j, $\tau_d = 1$, and $\tau_x = \tau > 1$, equation (9) implies that the export price is higher than the domestic price, $p_x(z) = \tau p_d(z)$. This indicates the raised marginal cost τ of choosing export. Note that the marginal costs of production, $m(z)$, is

$$m(z) = w^u \left(1 + z_j \cdot \omega^{\frac{-\rho}{1-\rho}}\right)^{\frac{\rho-1}{\rho}} \tag{10}$$

Equation (10) implies that the marginal cost, $m(z)$, is negatively correlated to the productivity, z. That is, a firm with higher productivity (higher z) will have lower marginal cost, charge a lower price, and thus earn more profits than a firm with lower productivity.

II.3 Equilibrium

Potential entrepreneurs in the heterogeneous manufacturing sector must decide their status in the market. The variables that will determine their status are the productivity cutoff level of being a non-exporting firm (z^*) and the productivity cutoff level of being an exporting firm (z_x^*). The conditions of equilibrium are explained below.

II.3.1 Market Entry Decision and Export Status

There are unrestricted potential entrants into the market, and all firms are identical prior to entry. In my model, the commodities produced by heterogeneous firms are partitioned into two sets: the set of goods produced to sell in the domestic market and the set of goods produced to serve the export market. Therefore, firms face two decisions: (i) operate or exit, and (ii) export or do not export. To enter, firms must first pay a fixed entry cost f_d. I assume that the entry and export decisions are determined after firms know their productivity z, which is drawn from a common distribution $G(z)$.

I assign that the productivity parameter z is a Pareto distribution:

$$G(z) = 1 - \left(\frac{\underline{z}}{z}\right)^{\gamma}$$

I assume that $\underline{z} = 1$, which implies that skilled labor is at least as efficient as unskilled labor. The Pareto probability density function is $g(z) = \gamma z^{-\gamma - 1}$ with support $[1, \infty)$.

After knowing their productivity, firms with low productivity decide to exit and never produce. As shown in Figure 1, I assume that z^* is the productivity cutoff level for entering into the market. Thus, if a firm produces and serves the market, its productivity level must be $z \geq z^*$. Firms with $z < z^*$ immediately exit the market.

Also, there is a productivity cutoff level for being an exporter. If $z_x^* = z^*$, then all firms in the market export. If $z_x^* > z^*$, there is a partition between non-export firms and export firms; firms that lie between z^* and z_x^* serve exclusively in the domestic zone. A firm will produce for export solely if its productivity is $z > z_x^*$.[2] Considering the profit conditions, firms will only operate in the domestic market if $\pi_d(z) \geq 0$, and firms will only choose to export if $\pi_x(z) \geq 0$. Therefore, the cutoff levels can be set at $\pi_d(z^*) \equiv 0$ and $\pi_x(z_x^*) \equiv 0$.

II.3.2 Factor Market Clearing

In the heterogeneous manufacturing sector, there is a constant mass of incumbents denoted by n. The factor market equilibrium is governed by

$$\bar{l}^u = \underbrace{n\left[\int_{z^*}^{\infty} l_d^u(z)g(z)dz + \int_{z_x^*}^{\infty} l_x^u(z)g(z)dz\right]}_{l^u(z)} + l_0^u \tag{11}$$

$$\bar{l}^s = \underbrace{n\left[\int_{z^*}^{\infty} l_d^s(z)g(z)dz + \int_{z_x^*}^{\infty} l_x^s(z)g(z)dz\right]}_{l^s(z)} \tag{12}$$

$$\overline{F} = n[(1 - G(z^*))f_d + (1 - G(z_x^*))f_x] \tag{13}$$

Here, I denote $\overline{F}$ as the total fixed costs. The cost minimization problem yields the demand for unskilled and skilled labor as follows:

$$l_j^u(z) = \tau_j y_j(z)\left(1 + z_j \cdot \omega^{\frac{\rho}{\rho-1}}\right)^{-\frac{1}{\rho}} \tag{14}$$

$$l_j^s(z) = z\omega^{\frac{1}{\rho-1}}\tau_j y_j(z)\left(1 + z_j \cdot \omega^{\frac{\rho}{\rho-1}}\right)^{-\frac{1}{\rho}} \tag{15}$$

By using the aggregate demand function from (3) and the pricing decision rule from (9), the condition (14) and (15) can be written as

[2] Note that, as of the manufacturing industry survey, there is a question regarding the proportion of a firm's outputs that are exported to foreign markets. In my study, I select only firms reporting that 100% of their outputs are exported. As a result, I can definitively partition firms into those that serve the domestic market and those that serve the foreign market.

$$l_j^u(z) = \eta^{\frac{1}{1-\eta}} \tau_j^{-\frac{\eta}{1-\eta}} (1 + z\omega^{\frac{\rho}{\rho-1}})^{\frac{\eta-\rho}{\rho-\rho\eta}} P^{\frac{\eta}{1-\eta}} E w^{u^{-\frac{1}{1-\eta}}} \tag{16}$$

$$l_j^s(z) = z\omega^{\frac{1}{\rho-1}} \eta^{\frac{1}{1-\eta}} \tau_j^{-\frac{\eta}{1-\eta}} (1 + z\omega^{\frac{\rho}{\rho-1}})^{\frac{\eta-\rho}{\rho-\rho\eta}} P^{\frac{\eta}{1-\eta}} E w^{u^{-\frac{1}{1-\eta}}} \tag{17}$$

where $E \equiv \sum_{i=\{s,u\}} \alpha^i (w^i \bar{l}^i + \pi + T)$ or the aggregate expenditures of the heterogeneous sector.

As described previously, the profit at the cutoff level is zero (hereafter referred to as the zero cutoff profit (ZCP) condition). The ZCP condition is one of the conditions used to identify the unique z^*. In turn, the equilibrium z^* can be used to determine the export productivity z_x^*.

The profit condition of a firm producing to serve the market $j \in J$ is governed by

$$\pi_j(z) = p_j(z) y_j(z) - w^u \left(1 + z_j \cdot \omega^{\frac{-\rho}{1-\rho}}\right)^{-\frac{1-\rho}{\rho}} \cdot \tau_j y_j(z) - f_j \tag{18}$$

At the cutoff level $(\pi_d(z^*) \equiv 0 \text{ and } \pi_x(z_x^*) \equiv 0)$, equation (18) can be rewritten as

$$\left[p_d(z^*) - w^u \left(1 + z^* \cdot \omega^{\frac{-\rho}{1-\rho}}\right)^{-\frac{1-\rho}{\rho}} \right] \cdot y_d(z^*) = f_d \tag{19}$$

$$\left[p_x(z_x^*) - w^u \left(1 + z_x^* \cdot \omega^{\frac{-\rho}{1-\rho}}\right)^{-\frac{1-\rho}{\rho}} \cdot \tau \right] \cdot y_x(z_x^*) = f_x \tag{20}$$

Firms with $z < z^*$ will exit the market and do not employ any labor. The condition $\pi_d(z^*) = 0$ implies the state of indifference between producing or not producing. Also, a firm chooses to export only if it earns nonnegative profits in the foreign market, $\pi_x(z) \geq 0$. Hence, the cutoff level z_x^* is determined at the breakeven point where the firm is indifferent in profits between selling in the domestic and selling in the foreign market and $\pi_x(z_x^*) \equiv 0$.

According to the goods market clearing condition, $y_d(z^*) \equiv c_d(z^*)$ and $y_x(z_x^*) \equiv c_x(z_x^*)$. Consequently, using (3), (9), and (10), equations (19) and (20) can be rewritten as

$$f_d m(z_x^*)^{\frac{-\eta}{1-\eta}} = f_x \tau^{\frac{\eta}{1-\eta}} m(z^*)^{\frac{-\eta}{1-\eta}} \tag{21}$$

As in Melitz (2003), I assume that $\tau^{\frac{\eta}{1-\eta}} f_x > f_d$ to ensure the partition between non-exporter and exporter that is $z_x^* > z$.

To compute equilibrium (z^*, ω), I construct equation (22) from the labor market clearing conditions (11) and (12). I rearrange (21) to obtain (23). The tuple (z^*, ω), as shown in Figure 2, must exist and be unique in order to show the labor market equilibrium and the breakeven point for the indifference between exporting and not exporting. Note that equation (13) implies the relationship between z^* and z_x^*.

$$\frac{l^u(z)}{l^s(z)} = \frac{\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz + \tau^{1-\varepsilon}\int_{z_x^*(z^*)}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz}{\int_{z^*}^{\infty} z\omega^{-\sigma}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz + \tau^{1-\varepsilon}\int_{z_x^*(z^*)}^{\infty} z\omega^{-\sigma}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz} \tag{22}$$

$$\frac{f_x}{f_d} = \left(\frac{1+z_x^*(z^*)\omega^{1-\sigma}}{1+z^*\omega^{1-\sigma}}\right)^{\frac{\varepsilon-1}{\sigma-1}} \tau^{1-\varepsilon} \tag{23}$$

I simplify the equations by using ε and σ instead of η and ρ, respectively. Equation (22) is the ratio of the two labor market clearing conditions, and equation (23) is the indifference condition of the export cutoff level. I assume that $\overline{F} \leq nf_d$ and $\varepsilon \geq \sigma$[3] to guarantee the existence of a unique equilibrium (see Vannoorenberghe (2011) for more details).

III. Definition of Equilibrium

The equilibrium for this economy is identified by a set of the endogenous variable generated in the model economy. That is, the prices of differentiated goods $\hat{p}(z)$ for each productivity level z; the prices of homogeneous goods $\hat{p}_0$; the skill wage premium $\hat{\omega} = \frac{\hat{w}^s}{\hat{w}^u}$, where $\hat{w}^s$ and $\hat{w}^u$ are the return to skilled and unskilled labors, respectively; a consumption plan for consumers $\left(\{\hat{c}(z)\}, \{\hat{c}_0\}\right)$; a production plan for the homogeneous goods producers $\left(\hat{y}_0, \hat{l}_0^u\right)$; a production plan for the heterogeneous goods producers $\left(\hat{y}(z), \hat{l}^s(z), \hat{l}^u(z)\right)$ for each productivity level z; aggregate profits $\hat{\Pi}$; total tax revenues $\hat{R}$; a cutoff productivity level z^* such that firms with $z < z^*$ immediately exit the industry and firms with $z > z^*$ operate in the market; a cutoff level z_x^* is the breakeven point where firms are indifferent between being non-exporter and exporter, such that given the tariffs t:

(i) The consumption plan $\left(\{\hat{c}(z)\}, \hat{c}_0\right)$ solves the utility maximization problem of consumers.

(ii) The production plan $\left(\hat{y}(z), \hat{l}^u(z), \hat{l}^s(z)\right)$ solves the cost minimization problem of the heterogeneous goods producers.

(iii) Given the direct demand function $\hat{c}(z)$ derived from the consumer's problem, the firm in heterogeneous sector chooses $\hat{p}(z)$ to solve the profit maximization problem for each productivity level z.

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[3] This condition implies that it is easy for the consumer to substitute between any two differentiated goods. However, in production, it is not easy to substitute an unskilled labor for a skilled labor.

(iv) The production plan $\left(\hat{y}_0, \hat{l}_0^u\right)$ solves the cost minimization problem of the homogeneous goods producers and satisfies the zero-profit condition.

(v) The goods markets clear:

$$\hat{c}_{0,d} = \hat{y}_{0,d}$$

$$\int_{z^*}^{\infty} \hat{c}(z)dz + \int_{z_x^*(z^*)}^{\infty} \hat{c}(z)dz = \int_{z^*}^{\infty} \hat{y}(z)dz + \int_{z_x^*(z^*)}^{\infty} \hat{y}(z)dz$$

(vi) The labor markets clear:

$$\bar{l}^u = n\left[\int_{z^*}^{\infty} \hat{l}_d^u(z)g(z)dz + \int_{z_x^*}^{\infty} \hat{l}_x^u(z)g(z)dz\right] + \hat{l}_0^u$$

$$\bar{l}^s = n\left[\int_{z^*}^{\infty} \hat{l}_d^s(z)g(z)dz + \int_{z_x^*}^{\infty} \hat{l}_x^s(z)g(z)dz\right]$$

(vii) The government collects tariff revenues and transfer to the consumer as a lump sum transfer:

$$\hat{R} = t\int_{z_x^*(z^*)}^{\infty} \hat{p}(z)\hat{c}(z)dz$$

(viii) The trade balance condition holds:

$$\int_{z^*}^{\infty} \hat{p}(z)\left(\hat{y}(z) - \hat{c}(z)\right)dz = \int_{z_x^*(z^*)}^{\infty} \hat{p}(z)\hat{c}(z)dz$$

IV. Data

In this section, I describe the variables and data used in this study. The firm-level data is drawn from the 2003 Thailand manufacturing industry survey conducted by the National Statistical Office (NSO). The survey covers information on establishments such as form of legal organization, registered capital, and period of operation. Additionally, there is information on the cost of production, the proportion of products exported, the number of workers engaged, and remuneration. Table 2 provides the parameters used in this study. The sources for these parameters are explained below.

To find γ for Thai firm data, I summarize a sample of 5,212 Thai firms in 2003. I follow Luttmer (2010) to set the size distribution of firms. I order them by size $S_{(1)} \geq ... \geq S_{(n)}$ where S is the size of the firm's employment. I draw a Zipf's plot where the firm with the largest size has log(rank) = ln(1) and the firm with the smallest size has log(rank) = ln(5,212). A Pareto shape, γ, is determined by ordinary least square (OLS) regression in log-log coordinates where the dependent variable is the log of the number of firms and the independent variable is the log of employment size. I summarize Thailand firm size distribution in Table 1, which shows that the number of firms declines when the employment size goes up. There is only one firm in the size category of 10,000 or more employees. The Thai firm data show that the tail index of the Pareto distribution is 0.93:

$$\ln(\text{number of firms with size} = S) = 0.68 - 0.93\ln(\text{employment size, } S) \qquad R^2 = 0.8$$

However, the value of γ must be greater than 2 to guarantee a finite mean. I thus assume that γ is equal to 2.5. I follow Vannoorenberghe (2011) such that for firms with large z, the distribution converges to a Pareto distribution $\gamma(\sigma-1)/(\varepsilon-1)$, and thus, I impose $\gamma = 2.5(\varepsilon-1)/(\sigma-1) = 3.88.$

The 2003 survey of Thai manufacturing firms shows that the ratio of total unskilled to skilled labor used in the manufacturing sector is $\frac{\bar{l}^s}{\bar{l}^u} = \frac{830{,}531\,\text{persons}}{463{,}782\,\text{persons}} = 1.79$. To obtain values for fixed costs, I use the data from the Thailand Board of Investment. To form a business, all companies must pay a registration fee of US$184.31 per US$33,512.06 of registered capital, and the maximum registration fee is set at US$9,215.81. Foreign businesses must pay an alien business license fee ranging between US$1,340.48 and US$16,756.03.[4] Foreign businesses must pay approximately 2.8 times more than domestic businesses $\left(\frac{9{,}215.81+16{,}756.03}{9{,}215.81}=2.8\right)$. I therefore assume that $f_d = 1$ and $f_x = 2.8$.

V. Results and Numerical Experiments

In this section, I apply the parameters from Table 2 to the model and quantify the skill premium for the Thai economy. Additionally, I analyze the effect of trade liberalization on the skill premium. I set $f_d = 1$ without loss of generality. I calibrate $\overline{F}/n = 0.9$ for Thailand, which results in a skill premium of 1.47, close to the value estimated by Kohpaiboon and Jongwanich (2013).[5]

Figure 3 illustrates the correlation between productivity and skill intensity. The model predicts that firms with $1.3 \le z \le 1.53$ are domestic firms, whereas firms with $z \ge 1.53$ are exporting firms. Given this result, the model estimates that 4% of total firms are exporting firms closed to data (from the survey, 5% of total firms are firms serving only the export market). Higher skill intensity yields higher productivity, and the productivity of exporting firms is higher than that of non-exporting firms.

By following the total differentiation of (22) and (23), I analyze the effects of tariff reduction on the skill premium. The results are provided below.

PROPOSITION 1: *A decline in the variable costs (tariff) of trade unambiguously increases the skill premium.*

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[4] For more information, see http://www.boi.go.th/index.php?page=typical_costs_of_starting_and_operating_a_business, retrieved June 12, 2014.

[5] Kohpaiboon, and Jongwanich (2013) found that wage compensation for white collar workers is 38-43% higher than that for blue collar workers.

Multiple factors are responsible for an increase in the skill premium. First, a decrease in the tariff rate induces existing exporting firms to expand their production. Since they are productive and skill-intensive firms, they demand more skilled workers. Second, due to the fixed labor supply, there is a reallocation of workers among firms, and firms with low productivity exit the market. The release of unskilled workers from the low-productive domestic firms and the declining demand for unskilled workers raises the skill premium (ω). In addition, trade liberalization attracts the initially non-exporting firms to enter the export market. Suppose that the trade cost is initially expensive so that only high productive firms can export. This results in more demand for skilled workers and a higher skill premium. In contrast, if the trade cost is initially low, even the unskilled-intensive firms can enter the foreign market and the wage for unskilled workers can go up, resulting in a lower skill premium. However, the effects from the expansion of production of initially exporting firms and the exit of low productive firms are dominant. Therefore, the skill premium unambiguously rises when tariff rates go down.

VI. Concluding Remarks

This study estimates the skill premium in Thailand and analyzes the impacts of trade liberalization on the skill premium. I quantify the skill premium using a model of monopolistic competition with heterogeneous firms and two factors of production: skilled and unskilled labor. In addition, I analyze the effects of a decrease in the tariff rate and a decline in the fixed exporting cost on the skill premium.

The analysis shows that, in Thailand, the wage for skilled workers is 47% higher than that for unskilled workers $(\omega = 1.47)$. Furthermore, I find that a decrease in tariff rates increases the skill premium. In further research, the model could be extended to include additional productivity cutoff levels, such as those of being a domestic only firm, a firm serving both domestic and foreign markets, and a firm serving only foreign markets. Furthermore, the model could be applied to other ASEAN countries so that the skill premium and the fixed cost of doing business of each country could be compared.

Appendices

Appendix A: Figures

Figure 1: Market entry decision and export status

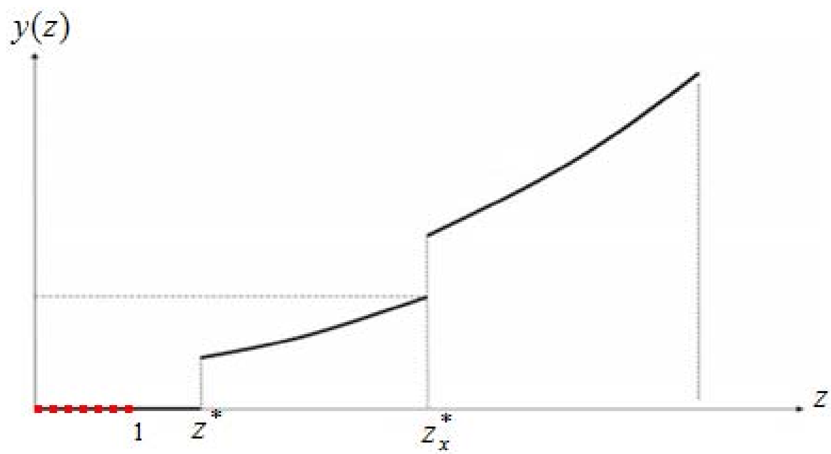
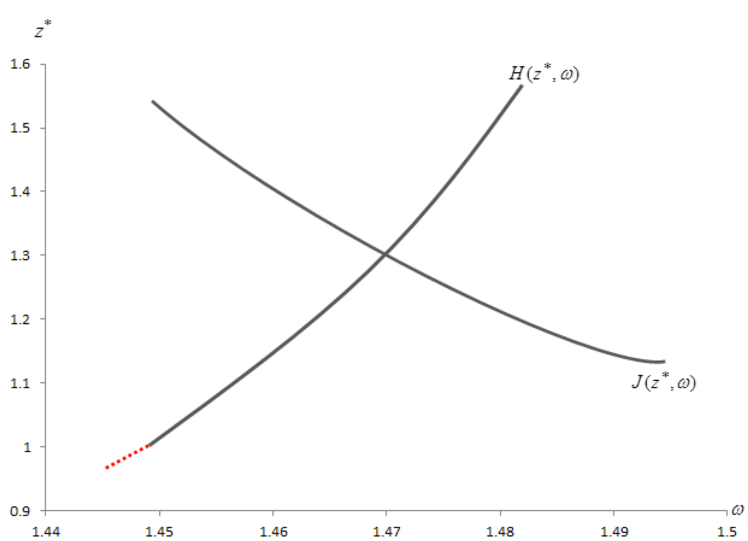
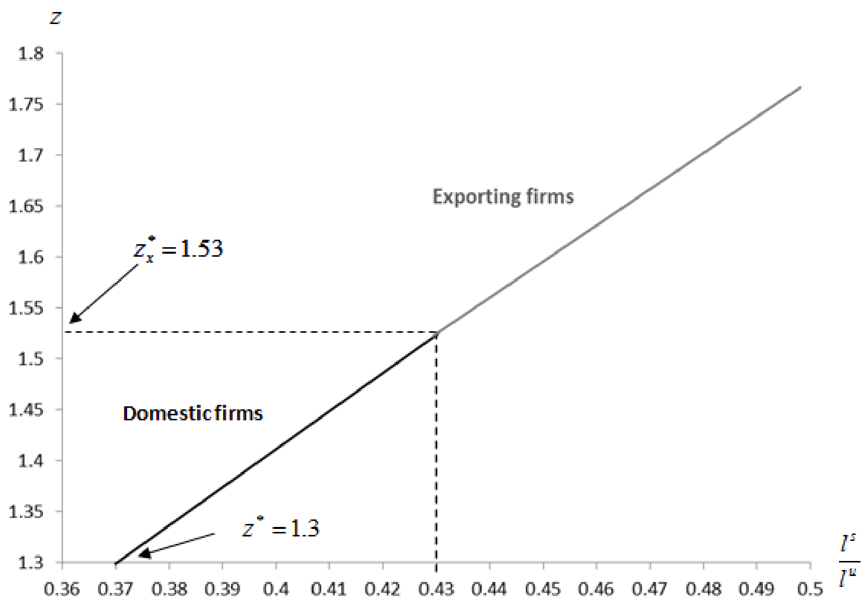


Figure 2: The equilibrium



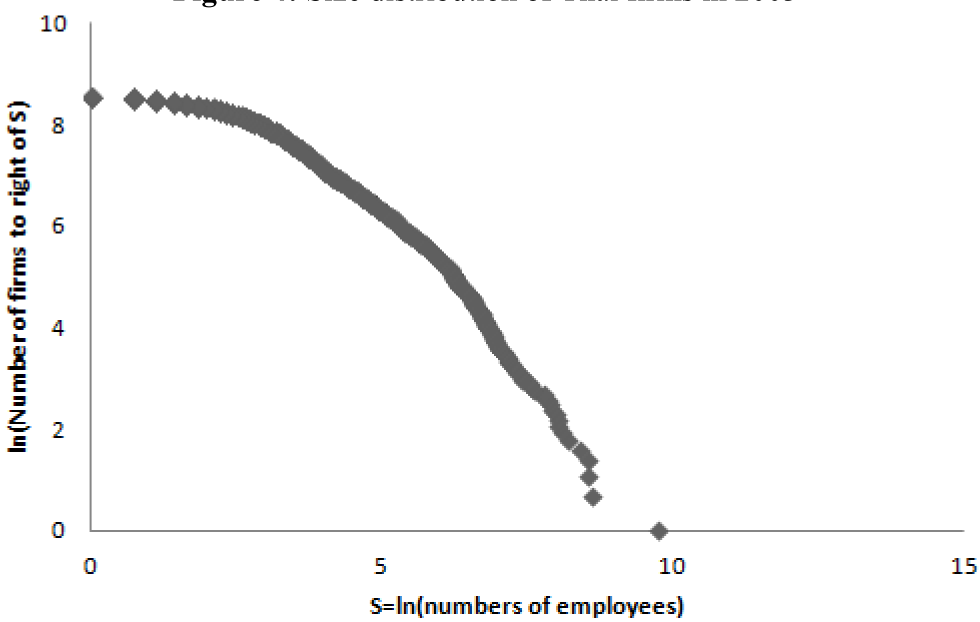
Source: Own calculation

Figure 3: Correlation between productivity and skill intensity



Source: Own calculation

Figure 4: Size distribution of Thai firms in 2003



Source: Own calculation

Appendix B: Tables

Table 1: Thailand firm size distribution, 2003

Size class	Number of firms
1-20	2,473
21-50	1,448
51-100	548
101-250	418
251-500	175
501-1,000	104
1,000-2,500	33
2,501-5,000	10
5,001-10,000	2
10,000 up	1

Source: Own calculation from the 2003 Thailand manufacturing industry survey

Table 2: Parameters for Thailand, 2003

Symbol	Description	Value	Source
n	Total number of firms	5,212	National Statistical Office, 2003
ε	The elasticity of substitution between varieties	4.53	Kancs, 2010
σ	The elasticity of substitution between skilled and unskilled labor	3.27	Thangavelu and Chongvilaivan, 2011
$\bar{l}^u$	Total unskilled labor supply	830,531[1/]	National Statistical Office, 2003
$\bar{l}^s$	Total skilled labor supply	463,782	National Statistical Office, 2003
γ	Pareto distribution parameter when z goes large*	3.88	A tail index of the size distribution of firms
t	The tariff rate	13%	WTO, 2003
f	The fixed cost of being non-exporting firm	1	Normalization
f_x	The fixed cost of being exporting firm	2.8	BOI, 2014
$\bar{F}/n$	The stock of capital	0.9	To match the skill premium = 1.47

Note: [1/]The summation of unskilled operating workers and other employees from Thai 2003 manufacturing industry survey.

Appendix C: Proofs

The existing and unique value of (z^*, ω) is determined by the two equilibrium conditions: the conditions of variable production costs and the condition of fixed production cost. Those are,

$$B(z^*,\omega) \equiv \int_{z^*}^{\infty} (1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz + \tau^{1-\varepsilon} \int_{z_X^*(z^*)}^{\infty} (1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz \tag{A.1}$$

$$D(z^*,\omega) \equiv \int_{z^*}^{\infty} z\omega^{-\sigma} (1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz + \tau^{1-\varepsilon} \int_{z_X^*(z^*)}^{\infty} z\omega^{-\sigma} (1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz \tag{A.2}$$

$$J(z^*,\omega) \equiv \left(\frac{1+z_x^*\omega^{1-\sigma}}{1+z^*\omega^{1-\sigma}} \right)^{\frac{\varepsilon-1}{\sigma-1}} - \frac{f_x}{f_d}\tau^{\varepsilon-1} \tag{A.3}$$

Equations (A.1), (A.2), and (A.3) are total unskilled labor, total skilled labor, and total fixed costs in the manufacturing sector, respectively. To prove that the value of (z^*, ω) is existing and unique, I require two main functions establishing a positive and a negative relationship between w and z^*. I assign $H(z^*,\omega) \equiv \frac{B(z^*,\omega)}{D(z^*,\omega)}$ and $J(z^*,\omega) \equiv \left(\frac{1+z_x^*\omega^{1-\sigma}}{1+z^*\omega^{1-\sigma}} \right)^{\frac{\varepsilon-1}{\sigma-1}} - \frac{f_x}{f_d}\tau^{\varepsilon-1}$. Next, I have to prove that sets $H(z^*,\omega)$ set up the positive relationship between w and z^* while $J(z^*,\omega)$ establishes the negative relationship between ω and z^*.

1. **Proof**: $H(z^*,\omega)$ establishes a continuous positive relationship between z^* and ω. That is, $\frac{\partial H(z^*,\omega)}{\partial z^*} < 0$ and $\frac{\partial H(z^*,\omega)}{\partial \omega} > 0$.

1.1 We want to show that $\frac{\partial H(z^*,\omega)}{\partial z^*} < 0$.

$$\frac{\partial H(z^*,\omega)}{\partial z^*} D^2 = D\frac{\partial B(z^*,\omega)}{\partial z^*} - B\frac{\partial D(z^*,\omega)}{\partial z^*} \tag{A.4}$$

Consider $\dfrac{\partial B(z^*,\omega)}{\partial z^*}$

$$\frac{\partial B(z^*,\omega)}{\partial z^*} = -(1+z^*\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z^*) - \tau^{1-\varepsilon}(1+z_x^*\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z_x^*)\frac{dz_x^*}{dz^*} \tag{A.5}$$

Consider $\dfrac{\partial D(z^*,\omega)}{\partial z^*}$

$$\frac{\partial D(z^*,\omega)}{\partial z^*} = -z^*\omega^{-\sigma}(1+z^*\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z^*) - \tau^{1-\varepsilon} z_x^*\omega^{-\sigma}(1+z_x^*\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z_x^*)\frac{dz_x^*}{dz^*} \tag{A.6}$$

Substitute (A.5) and (A.6) into (A.4), we obtain

$$\frac{\partial H(z^*,\omega)}{\partial z^*}D^2 = \left(Bz^*\omega^{-\sigma} - D\right)\left(1+z^*\omega^{1-\sigma}\right)^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z^*) + \left(Bz_x^*\omega^{-\sigma} - D\right)\tau^{1-\varepsilon}\left(1+z_x^*\omega^{1-\sigma}\right)^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z_x^*)\frac{dz_x^*}{dz^*} \tag{A.7}$$

From (13), we have

$$g(z_x^*)\, f_x dz_x^* = -g(z^*)\, f_d\, dz^* \tag{A.8}$$

Substitute (A.8) into (A.7), we obtain

$$\frac{\partial H(z^*,\omega)}{\partial z^*}D^2 = \left(Bz^*\omega^{-\sigma} - D\right)\left(1+z^*\omega^{1-\sigma}\right)^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z^*) - g(z^*)\left(Bz_x^*\omega^{-\sigma} - D\right)\tau^{1-\varepsilon}\left(1+z_x^*\omega^{1-\sigma}\right)^{\frac{\varepsilon-\sigma}{\sigma-1}}\frac{f_d}{f_x} \tag{A.9}$$

Substitute (23) into (A.9) and rearrange, hence

$$\frac{\partial H}{\partial z^*}D^2 = g(z^*)\left(1+z^*\omega^{1-\sigma}\right)^{\frac{\varepsilon-1}{\sigma-1}}\left[\frac{\left(Bz^*\omega^{-\sigma} - D\right)}{\left(1+z^*\omega^{1-\sigma}\right)} - \frac{\left(Bz_x^*\omega^{-\sigma} - D\right)}{\left(1+z_x^*\omega^{1-\sigma}\right)}\right] \tag{A.10}$$

A sufficient condition for $\dfrac{\partial H(z^*,\omega)}{\partial z^*}$ to be negative is the partitioning between the non-exporters (z^*) and the exporters (z_x^*). Note that $z^* < z_x^*$, so $\left(Bz^*\omega^{-\sigma} - D\right)$ is negative and less than

$\left(Bz_x^*\omega^{-\sigma} - D\right)$. Also, $\left(1 + z^*\omega^{1-\sigma}\right) < \left(1 + z_x^*\omega^{1-\sigma}\right)$. As a result, $\dfrac{\left(Bz^*\omega^{-\sigma} - D\right)}{\left(1 + z^*\omega^{1-\sigma}\right)}$ is negative and smaller than $\dfrac{\left(Bz_x^*\omega^{-\sigma} - D\right)}{\left(1 + z_x^*\omega^{1-\sigma}\right)}$ yielding $\dfrac{\partial H(z^*, \omega)}{\partial z^*} < 0$.

1.2 We want to show that $\dfrac{\partial H(z^*, \omega)}{\partial \omega} > 0$.

$$\frac{\partial H(z^*, \omega)}{\partial \omega} D^2 = D\frac{\partial B(z^*, \omega)}{\partial \omega} - B\frac{\partial D(z^*, \omega)}{\partial \omega} \tag{A.11}$$

Consider $\dfrac{\partial B(z^*, \omega)}{\partial \omega}$

$$\begin{aligned}\frac{\partial B(z^*, \omega)}{\partial \omega} &= -(\varepsilon - \sigma)\omega^{-\sigma}\int_{z^*}^{\infty}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1} zg(z)dz \\ &\quad - \tau^{1-\varepsilon}(\varepsilon - \sigma)\omega^{-\sigma}\int_{z_X^*}^{\infty}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1} zg(z)dz\end{aligned} \tag{A.12}$$

Consider $\dfrac{\partial D(z^*, \omega)}{\partial \omega}$

$$\frac{\partial D(z^*, \omega)}{\partial \omega} = \int_{z^*}^{\infty} \underbrace{\frac{\partial}{\partial \omega} z\omega^{-\sigma}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz}_{=q} + \tau^{1-\varepsilon}\int_{z_X^*}^{\infty} \underbrace{\frac{\partial}{\partial \omega} z\omega^{-\sigma}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz}_{=q} \tag{A.13}$$

Find q

$$q = \frac{\partial}{\partial \omega} z\omega^{-\sigma}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} dG(z)$$

$$q = z\omega^{-\sigma}\frac{\varepsilon - \sigma}{\sigma - 1}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1} z(1-\sigma)\omega^{-\sigma} g(z)dz + (1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} g(z)dz(-\sigma)z\omega^{-\sigma-1} \tag{A.14}$$

Substitute (A.14) into (A.13), we obtain

$$\frac{\partial D(z^*, \omega)}{\partial \omega} \equiv -(\varepsilon - \sigma)\omega^{-\sigma}\int_{z^*}^{\infty}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1} z^2\omega^{-\sigma} g(z)dz - \sigma\omega^{-1}\int_{z^*}^{\infty}(1 + z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}} z\omega^{-\sigma} g(z)dz \tag{A.15}$$

$$-\tau^{1-\varepsilon}(\varepsilon-\sigma)\omega^{-\sigma}\int_{z_x^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1}z^2\omega^{-\sigma}g(z)dz-\tau^{1-\varepsilon}\sigma\omega^{-1}\int_{z_x^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz$$

Substitute (A.12) and (A.15) into (A.11), we obtain

$$\frac{\partial H(z^*,\omega)}{\partial\omega}D^2\equiv$$

$$\begin{aligned}
&-D(\varepsilon-\sigma)\omega^{-\sigma}\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1}zg(z)dz+B(\varepsilon-\sigma)\omega^{-\sigma}\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1}z^2\omega^{-\sigma}g(z)dz\\
&+B\sigma\omega^{-1}\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz-D\tau^{1-\varepsilon}(\varepsilon-\sigma)\omega^{-\sigma}\int_{z_X^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1}zg(z)dz\\
&+B\tau^{1-\varepsilon}(\varepsilon-\sigma)\omega^{-\sigma}\int_{z_X^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1}z^2\omega^{-\sigma}g(z)dz+B\tau^{1-\varepsilon}\sigma\omega^{-1}\int_{z_X^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz
\end{aligned}\tag{A.16}$$

Let $\kappa(z)\equiv(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}-1}g(z)$, (A.16) becomes

$$\frac{\partial H(z^*,\omega)}{\partial\omega}D^2\equiv$$

$$-D(\varepsilon-\sigma)\omega^{-\sigma}\int_{z^*}^{\infty}\kappa(z)zdz+B(\varepsilon-\sigma)\omega^{-\sigma}\int_{z^*}^{\infty}\kappa(z)z^2\omega^{-\sigma}dz+B\sigma\omega^{-1}\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz$$

$$-D\tau^{1-\varepsilon}(\varepsilon-\sigma)\omega^{-\sigma}\int_{z_X^*}^{\infty}\kappa(z)zdz+B\tau^{1-\varepsilon}(\varepsilon-\sigma)\omega^{-\sigma}\int_{z_X^*}^{\infty}\kappa(z)z^2\omega^{-\sigma}dz$$

$$+B\tau^{1-\varepsilon}\sigma\omega^{-1}\int_{z_X^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz$$

$$\frac{\partial H(z^*,\omega)}{\partial\omega}D^2\equiv$$

$$\left(B(\varepsilon-\sigma)\omega^{-\sigma}\int_{z^*}^{\infty}\kappa(z)z^2\omega^{-\sigma}dz-D(\varepsilon-\sigma)\omega^{-\sigma}\int_{z^*}^{\infty}\kappa(z)zdz\right)+B\sigma\omega^{-1}\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz$$

$$\left(+ B\tau^{1-\varepsilon}(\varepsilon-\sigma)\omega^{-\sigma}\int_{z_X^*}^{\infty}\kappa(z)z^2\omega^{-\sigma}dz - D\tau^{1-\varepsilon}(\varepsilon-\sigma)\omega^{-\sigma}\int_{z_X^*}^{\infty}\kappa(z)zdz \right)$$

$$+ B\tau^{1-\varepsilon}\sigma\omega^{-1}\int_{z_X^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz$$

$$\frac{\partial H(z^*,\omega)}{\partial\omega}D^2 \equiv$$

$$(\varepsilon-\sigma)\omega^{-\sigma}\left(B\int_{z^*}^{\infty}\kappa(z)z^2\omega^{-\sigma}dz - D\int_{z^*}^{\infty}\kappa(z)zdz \right) + \underbrace{B\sigma\omega^{-1}\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz}_{=a}$$

$$+ (\varepsilon-\sigma)\omega^{-\sigma}\left(B\tau^{1-\varepsilon}\int_{z_x^*}^{\infty}\kappa(z)z^2\omega^{-\sigma}dz - D\tau^{1-\varepsilon}\int_{z_x^*}^{\infty}\kappa(z)zdz \right) \tag{A.17}$$

$$\underbrace{+ B\tau^{1-\varepsilon}\sigma\omega^{-1}\int_{z_X^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz}_{=b}$$

Rearrange terms a and b, we obtain

$$a+b = B\frac{\sigma}{\omega}\left(\underbrace{\int_{z^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz + \tau^{1-\varepsilon}\int_{z_X^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}z\omega^{-\sigma}g(z)dz}_{=D(z^*,\omega)} \right) \tag{A.18}$$

Substitute a and b from (A.18) into (A.17), we obtain

$$\frac{\partial H(z^*,\omega)}{\partial\omega}D^2 \equiv \frac{\sigma}{\omega}BD + (\varepsilon-\sigma)\omega^{-\sigma}\left[B\omega^{-\sigma}\int_{z^*}^{\infty}\kappa(z)z^2dz - D\int_{z^*}^{\infty}\kappa(z)zdz \right] \tag{A.19}$$

$$+(\varepsilon-\sigma)\omega^{-\sigma}\left[B\tau^{1-\varepsilon}\omega^{-\sigma}\int_{z_x^*}^{\infty}\kappa(z)z^2dz-D\tau^{1-\varepsilon}\int_{z_x^*}^{\infty}\kappa(z)zdz\right]$$

We want to show that the expression above is positive. Obviously, $\frac{\sigma}{\omega}BD$ is strictly positive and $(\varepsilon-\sigma)\omega^{-\sigma}$ is positive due to the assumption $\varepsilon>\sigma$. In the brackets, $\omega^{-\sigma}$ is positive. We need to verify that

$$\left[B\int_{z^*}^{\infty}\kappa(z)z^2dz-D\int_{z^*}^{\infty}\kappa(z)zdz\right]+\left[B\tau^{1-\varepsilon}\int_{z_X^*}^{\infty}\kappa(z)z^2dz-D\tau^{1-\varepsilon}\int_{z_X^*}^{\infty}\kappa(z)zdz\right]\geq 0 \tag{A.20}$$

Use $\kappa(z)$ to rewrite B and D, then we have

$$B(z^*,\omega)\equiv\int_{z^*}^{\infty}\kappa(z)dz+\tau^{1-\varepsilon}\int_{z_X^*}^{\infty}\kappa(z)dz \tag{A.21}$$

and

$$D(z^*,\omega)\equiv\omega^{-\sigma}\left(\int_{z^*}^{\infty}\kappa(z)zdz+\tau^{1-\varepsilon}\int_{z_X^*}^{\infty}\kappa(z)zdz\right) \tag{A.22}$$

Let $\overline{\kappa}(x)=\int_{x}^{\infty}\kappa(z)dz$, $\overline{\kappa}_1(x)=\int_{x}^{\infty}\kappa(z)zdz$, and $\overline{\kappa}_2(x)=\int_{x}^{\infty}\kappa(z)z^2dz$ and use (A.21) and (A.22), we rewrite (A.20) as

$$\begin{aligned}&\left(\overline{\kappa}(z^*)+\tau^{1-\varepsilon}\overline{\kappa}(z_x^*)\right)\overline{\kappa}_2(z^*)-\left(\overline{\kappa}_1(z^*)+\tau^{1-\varepsilon}\overline{\kappa}_1(z_x^*)\right)\overline{\kappa}_1(z^*)+\left(\overline{\kappa}(z^*)+\tau^{1-\varepsilon}\overline{\kappa}(z_x^*)\right)\tau^{1-\varepsilon}\overline{\kappa}_2(z_x^*)\\&-\left(\overline{\kappa}_1(z^*)+\tau^{1-\varepsilon}\overline{\kappa}_1(z_x^*)\right)\tau^{1-\varepsilon}\overline{\kappa}_1(z_x^*)\end{aligned} \tag{A.23}$$

$$\begin{aligned}&\overline{\kappa}(z^*)\overline{\kappa}_2(z^*)+\tau^{1-\varepsilon}\overline{\kappa}(z_x^*)\overline{\kappa}_2(z^*)-(\overline{\kappa}_1(z^*))^2-\tau^{1-\varepsilon}\overline{\kappa}_1(z_x^*)\overline{\kappa}_1(z^*)+\tau^{1-\varepsilon}\overline{\kappa}(z^*)\overline{\kappa}_2(z_x^*)\\&+\tau^{2-2\varepsilon}\overline{\kappa}(z_x^*)\overline{\kappa}_2(z_x^*)-\tau^{1-\varepsilon}\overline{\kappa}_1(z^*)\overline{\kappa}_1(z_x^*)-\tau^{2-2\varepsilon}(\overline{\kappa}_1(z_x^*))^2\end{aligned} \tag{A.24}$$

$$\bar{\kappa}(z^*)\bar{\kappa}_2(z^*) - (\bar{\kappa}_1(z^*))^2 + \tau^{2-2\varepsilon}\left(\bar{\kappa}(z_x^*)\bar{\kappa}_2(z_x^*) - (\bar{\kappa}_1(z_x^*))^2\right)$$
$$+\tau^{1-\varepsilon}\left(\bar{\kappa}(z_x^*)\bar{\kappa}_2(z^*) + \bar{\kappa}(z^*)\bar{\kappa}_2(z_x^*) - 2\bar{\kappa}_1(z^*)\bar{\kappa}_1(z_x^*)\right) \geq 0 \tag{A.25}$$

Apply the Cauchy-Schwarz inequality to the first line of (A.25), we have

$$\int \kappa(z) z dz = \int \kappa(z)^{\frac{1}{2}} \kappa(z)^{\frac{1}{2}} z dz \leq \left(\int \kappa(z) dz\right)^{\frac{1}{2}} \left(\int \kappa(z) z^2 dx\right)^{\frac{1}{2}} \tag{A.26}$$

Hence, $(\bar{\kappa}_1(z))^2 \leq \bar{\kappa}(z)\bar{\kappa}_2(z)$. As a result, the first line of (A.25) is positive. Analogously, the second line of (A.25) would also be positive if $z^* = z_x^*$.

2. **Proof**: $J(z^*, w)$ establishes a continuous negative relationship between z^* and ω. That is, $\frac{\partial J(z^*,\omega)}{\partial z^*} < 0$ and $\frac{\partial J(z^*,\omega)}{\partial \omega} < 0$.

2.1 We want to show that $\frac{\partial J(z^*,\omega)}{\partial z^*} < 0$.

$$\frac{\partial J(z^*,\omega)}{\partial z^*} = \frac{1-\varepsilon}{\sigma-1}\omega^{1-\sigma}\frac{(1+z_x^*\omega^{1-\sigma})^{\frac{\varepsilon-1}{\sigma-1}}}{(1+z^*\omega^{1-\sigma})^{\frac{\varepsilon-1}{\sigma-1}+1}}\left[1+\frac{(1+z^*\omega^{1-\sigma})}{(1+z_x^*\omega^{1-\sigma})}\frac{g(z^*)f_d}{g(z_x^*)f_x}\right] < 0 \tag{A.27}$$

Since $(1-\varepsilon)$ is negative, $\frac{\partial J(z^*,\omega)}{\partial z^*}$ is negative.

2.2 We want to show that $\frac{\partial J(z^*,\omega)}{\partial \omega} < 0$.

$$\frac{\partial J(z^*,\omega)}{\partial \omega} = \frac{(\varepsilon-1)\omega^{-\sigma}}{(1+z^*\omega^{1-\sigma})(1+z_x^*\omega^{1-\sigma})}\left(\frac{1+z_x^*\omega^{1-\sigma}}{1+z^*\omega^{1-\sigma}}\right)^{\frac{\varepsilon-1}{\sigma-1}}\left(z^* - z_x^*\right) < 0 \tag{A.28}$$

The sufficient condition for $\frac{\partial J(z^*,\omega)}{\partial \omega} < 0$ is that there is partitioning between non-exporters and exporters $(z^* < z_x^*)$.

To determine how the skill premium, ω, responds to a change in trade costs, τ and f_x, I use Cramer's rule on the following system

$$\frac{\partial J(z^*,\omega)}{\partial \omega}\frac{d\omega}{d\Xi}+\frac{\partial J(z^*,\omega)}{\partial z^*}\frac{dz^*}{d\Xi}=-\frac{\partial J(z^*,\omega)}{\partial \Xi}$$

$$\frac{\partial H(z^*,\omega)}{\partial \omega}\frac{d\omega}{d\Xi}+\frac{\partial H(z^*,\omega)}{\partial z^*}\frac{dz^*}{d\Xi}=-\frac{\partial H(z^*,\omega)}{\partial \Xi}$$

Hence,

$$\frac{d\omega}{d\Xi}=\frac{\frac{\partial J(z^*,\omega)}{\partial z^*}\frac{\partial H(z^*,\omega)}{\partial \Xi}-\frac{\partial J(z^*,\omega)}{\partial \Xi}\frac{\partial H(z^*,\omega)}{\partial z^*}}{\frac{\partial J(z^*,\omega)}{\partial \omega}\frac{\partial H(z^*,\omega)}{\partial z^*}-\frac{\partial J(z^*,\omega)}{\partial z^*}\frac{\partial H(z^*,\omega)}{\partial \omega}} \tag{A.29}$$

where $\Xi\in\{\tau, f_x\}$

Proof of Proposition 1

From the proof of uniqueness and existence, the dominator of (A.29) is positive. The sign of $\frac{d\omega}{d\tau}$ thus relies on the sign of the numerator.

$$\frac{\partial H(z^*,\omega)}{\partial \tau}=\frac{\varepsilon-1}{D^2}\tau^{-\varepsilon}\int_{z_x^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}(B\omega^{-\sigma}z-D)g(z)dz$$

$$\frac{\partial J(z^*,\omega)}{\partial \tau}=(1-\varepsilon)\frac{f_x}{f_d}\tau^{\varepsilon-2}$$

Therefore, the sign of $\frac{d\omega}{d\tau}$ is defined as

$$\begin{aligned}\Delta\equiv\Theta\int_{z_x^*}^{\infty}(1+z\omega^{1-\sigma})^{\frac{\varepsilon-\sigma}{\sigma-1}}(Bz\omega^{-\sigma}-D)g(z)d(z)\\+\Psi\frac{Bz_x^*\omega^{-\sigma}-D}{1+z_x^*\omega^{1-\sigma}}-\Psi\frac{Bz^*\omega^{-\sigma}-D}{1+z^*\omega^{1-\sigma}}\end{aligned} \tag{A.30}$$

where

$$\Theta = -\frac{(\varepsilon-1)^2}{\sigma-1}\frac{\omega^{1-\sigma}}{1+z^*\omega^{1-\sigma}}\left(\frac{(1+z_x^*\omega^{1-\sigma})}{(1+z^*\omega^{1-\sigma})}\right)^{\frac{\varepsilon-1}{\sigma-1}}\left[1+\frac{(1+z^*\omega^{1-\sigma})g(z^*)f_d}{(1+z_x^*\omega^{1-\sigma})g(z_x^*)f_x}\right]\frac{\tau^{-\varepsilon}}{D^2} < 0$$

$$\Psi = (1-\varepsilon)\frac{f_x}{f_d}\tau^{\varepsilon-2}g(z^*)(1+z^*\omega^{1-\sigma})^{\frac{\varepsilon-1}{\sigma-1}} < 0$$

Because $\frac{Bz_x^*\omega^{-\sigma}-D}{1+z_x^*\omega^{1-\sigma}} > \frac{Bz^*\omega^{-\sigma}-D}{1+z^*\omega^{1-\sigma}}$, the last two terms of (A.30) yields a negative result.

Since Θ is negative, Δ and thus $\frac{d\omega}{d\tau}$ are negative.

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