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DYNAMICS TRADE, EDUCATION AND INTERGENERATIONAL INEQUALITY

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Abstract

To what extent does education alleviate income inequality between skilled and unskilled workers induced by globalization? What are the corresponding intergenerational welfare implications? This paper presents a multi-country dynamic general equilibrium framework to investigate these questions. In this model, interactions between comparative advantage, capital accumulation, and endogenous education are the main driving forces of the transitional path. The flexibility to adjust supply in different factors determines the inequality in different stages of economic transition. I use the World Input-Output Database to quantify the key features of the model for 40 countries and 6 industries.For trade liberalization counterfactual, I find that (1) the skill premium and educational attainment increase for all countries in a steady state; (2) income inequality between education categories is more severe in the short run than in the long run; (3) education reduces 65% of trade-induced inequality; and (4) the gains from trade are unevenly distributed across generations and educational categories — as older and educated workers gain the most, and old and uneducated workers gain the least.

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1.1 Introduction

To what extent does education alleviate income inequality between skilled and unskilled workers induced by globalization? How does educational attainment respond to trade shocks? How are gains from trade distributed across generations and education attainment in the short run and long run? The main objective of this paper is to address these important questions. Existing work mainly focuses on two-country or small open economy examples. This paper aims to provide the transitional paths of educational outcome, inequality, and other economic variables in a multi-country global equilibrium setting. I present a dynamic general equilibrium model of trade with endogenous educational choice to quantify the interactions among comparative advantage, skill-biased technical change, and education.

Recent empirical studies offer compelling evidence that an individual's educational decision is influenced by comparative advantage in international trade. Hickman and Olney (2011) study the U.S. economy, finding that globalization increases the educational attainment of workers in the United States.Atkin (2016) studies Mexico in the period between 1986 and 2000, finding that export expansion in the manufacturing sector is associated with an increased high school dropout rate. Blanchard and Olney (2017) use a panel of 102 countries over 45 years to investigate the relationship between export composition and educational attainment. By implementing a gravity regression to eliminate endogeneity, Blanchard andBlanchard and Olney (2017) find that increases in the export of high-skill intensive goods are associated with higher educational attainment, while increases in the export of low-skill intensive goods are associated with lower educational attainment.

Although conventional trade models suggest that globalization can reduce the skill premium in developing countries and raise the skill premium in developed countries through the reallocation of labor across sectors (i.e., the Stolper-Samuelson theorem), empirical evidence shows that globalization can increase the skill premium for both developing and developed countries (see Goldberg and Pavcnik 2007). Rising income inequality in many countries over the last two decades has become a growing concern for policy makers around the world OECD. (2008) and Dabla-Norris et al. (2015)). Education is often regarded as an instrument to combat inequality (see Corak 2013 and Gregorio and Lee 2002). Therefore, quantifying the effectiveness of education in reducing trade-induced inequality is an important objective of this paper and has substantial policy relevance.

Empirical studies offer evidence that educational attainment and the skill premium are influenced by globalization, but are not capable of evaluating the quantitative effects of trade shocks and relevant policies on educational outcomes. This paper aims to provide a framework for analysis by constructing and calibrating a quantitative model built upon the following insights offered by Atkin (2016): (1) the opportunity cost of education is the time an individual could have spent working as an unskilled worker, and (2) globalization may create jobs of different skill intensities. My model provides a tractable framework to quantify the dynamic impacts of trade shocks on educational attainment, the skill premium, intergenerational welfare, and other important economic variables in a globalized economy.

The main driving forces of this model are cross-industry differences in skill intensity, and cross-country differences in productivity and educational institutions, capital-skill complementarity, and educational choice. Following Eaton and Kortum (2002) (henceforth EK), there are continuums of heterogeneous sector-specific intermediate goods in which each uses capital and skilled and unskilled workers as inputs, combined according to a constant returns to scale production function. Moreover, sectoral good producers pool intermediates from all over the world for production, while final good producers purchase sectoral goods from the domestic market and combine them to produce the composite final good.

Without loss of generality, I assume the representative household in each country dictates capital investment and total consumption. The representative household has perfect foresight and maximizes its welfare as a function of a stream of discounted instantaneous utility from total real consumption.

The economy is populated by infinitely-lived individuals who face a constant probability of death in each period (as in Blanchard (1985)). I assume there is no population growth, so the perished population is replenished by newly born individuals each period. Forward-looking individuals face a one-time idiosyncratic innate ability shock. Heterogeneous innate ability is directly linked to the time cost of education. Education is a binary decision. An individual chooses whether to pursue education in his first period of life. If he chooses to pursue higher education, he must spend some proportion of his time each period to maintain his status as a skilled worker, using his remaining time to earn wages through skilled labor. The higher the innate ability of an individual and quality of country-specific educational institutions, the lower the time cost associated with education. If an individual chooses not to pursue higher education, he spends his time earning wages as an unskilled worker. Forward-looking individuals make decisions regarding education based on future states of the economy, which in turn determine the dynamic of aggregate skill supply in each country.

My multi-country model captures short-, medium- and long-run effects on the economy due to trade shocks or structural change. In the short run, since all factors for production are unable to adjust supply promptly, comparative advantage represents the sole driver of prices and trade. The skill premium rises in countries with a comparative advantage in skill-intensive sectors, and falls in countries with a comparative advantage in skill-unintensive sectors. In the medium run, physical capital adjusts faster than human capital, meaning that the skill premium is mainly driven by capital accumulation. Supposing capital becomes cheaper, a country invests more in capital formation. Since my model features complementarity between capital and skilled labor, the relative productivity of skilled workers rises. As a result, the skill premium rises. In the long run, the skill supply adjusts freely in response to changes in the skill premium. The adjustment in skill supply neutralizes the short- and medium-run effects from comparative advantage and physical capital investment, shaping the long-run outcome.

I apply a parameterized model to investigate the effect of trade liberalization (a 25% bilateral trade cost reduction) on labor markets in 40 countries in my sample. The principal interest considers the skill premium and the relative skill supply. Following the definition in my data, a skilled worker is a worker who has at least a college degree. Designed to capture between-educational-category inequality, the skill premium is defined as the ratio of wages of skilled to unskilled workers. Relative skill supply is defined as the ratio of the supply of skilled to unskilled workers. The counterfactual shows that a decline in bilateral trade costs raises the long-run skill premium for all countries in my sample. This result indicates that capital-skill complementarity is the dominant force shaping income distribution. The transitional path also shows that inequality is more severe in the short run than in the long run. In addition, educational attainment increases for all countries. By comparing the transitional paths both allowing and forbidding workers to pursue an education, my model suggests that education can eliminate nearly 65% of between-educational-category inequality induced by globalization.

Furthermore, I study the distribution of gains from trade across generations and education categories. By comparing the percentage gain in discounted lifetime wealth for each group, I find that the older and educated group gains the most from globalization, while the oldest and uneducated group gains the least. This finding shows that globalization can be a source of increasing intergenerational inequality, leading to an expanding understanding of the recent heated discussion about intergenerational inequality[1].

The existing literature examines the interaction between skill premium and international trade from a wide range of perspectives, which include skill-biased technology (Burstein and Vogel 2016, Parro 2013 and Yeaple 2005), structural change (Cravino and Sotelo 2016 and Xu 2016), and global value chain (Costinot

[1]See Erikson and Goldthorpe (2002) and Bowles and Gintis (2002)

et al. 2012). One common assumption throughout this research is that the supply of skilled workers is exogenously determined. However, such an assumption excludes the potential impact of endogenous skill supply on the skill premium. As a result, trade patterns are mainly determined by cross-country differences in the abundance of skill and productivity, and cross-sector differences in skill intensities. Because exogenous shocks in these models only affect relative skill demand, the quantitative results depict movement along a vertical skill supply curve. Thus, the ensuing analysis can potentially exaggerate changes in skill premium. My model suggests that this research only captures short- and medium-run outcomes.

This paper is not the first to study the interaction between international trade and educational choice. Findlay and Kierzkowski (1983) build a two-country, two-sector Heckscher-Ohlin model with endogenous educational choice. In their model, the Stolper-Samuelson effect drives the relative return between skilled and unskilled labor. When a country with a comparative advantage in skill-intensive sector is more opens to trade, the relative reward to skill rises and the country becomes more skill abundant. Danziger (2017) studies a dynamic model of educational choice and trade that is restricted to small open economies. In contrast, my model considers a multi-country setting in which the skill premium and educational choice are driven by both comparative advantage and the quality of educational institutions, and addresses effects for developed and developing countries simultaneously under a single framework..[2] Blanchard and Willmann (2016) utilize a two-country general equilibrium model to show that the curvature of the education cost function can determine trade patterns, demonstrating how globalization induces the polarization of skills and wages.

My model offers quantitative and theoretical foundations of educational choice and international trade studied by Atkin (2016),Blanchard and Olney (2017), as well asHickman and Olney (2011). By adapting the procedure of Alvarez and Lucas (2007)to a dynamic framework, this paper also aligns with recent growing literature on dynamic trade.[3]

[2]Furthermore, my framework studies how small changes of economic fundamentals can have aggregate impacts for different countries and labor markets. The framework of Danziger (2017) only offers an analysis of aggregate impacts on a single country.

[3]Artuç et al. (2010), Dix-Carneiro (2014) and Caliendo et al. (2015) study trade shocks on the

The rest of the paper is organized as follows. In Section 2, I present the dynamic model of international trade and educational choice. In Section 3, I demonstrate the intuition and mechanisms of the model by using a simplified two-country two-sector economy. In Section 4, I explain how the model is parameterized and calibrated. In Section 5, I present counterfactual results about the effect of trade liberalization on dynamic educational outcomes and on the distribution of gains from trade across generations and educational categories. Lastly, Section 6 concludes this paper.

1.2 Model

I consider an economy of N countries and J sectors, where countries are indexed by i and n, and sectors are indexed by j. Within each sector j, there is a continuum of intermediates $\omega \in [0, 1]$. The international trade setting for each industry follows Eaton and Kortum (2002). A final goods producer in each country buys sector-j goods domestically, and combines them to produce a final good. All markets are competitive, including factor markets and goods markets.

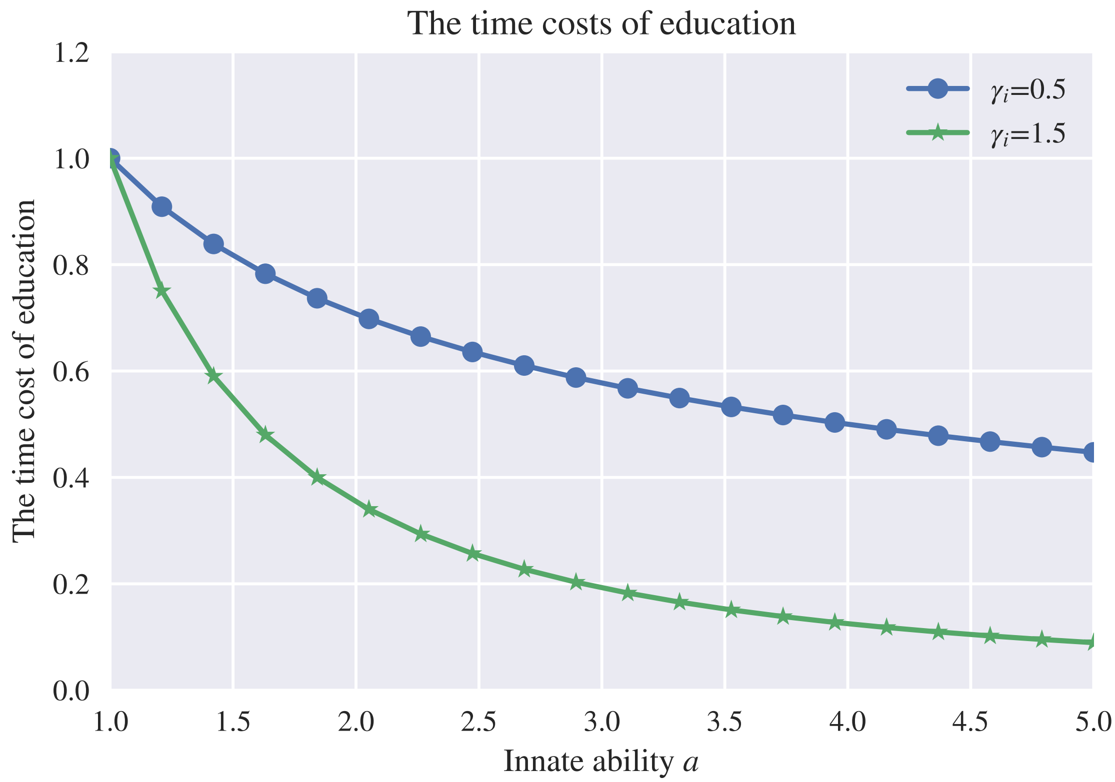
1.2.1 Workers

The economy is populated by infinitely-lived individuals who face constant probability of death ζ in each period (as in Blanchard 1985). At each time t, there is a population of mass L_i born in country i. I assume there is no population growth; hence, newly born individuals exactly replenish the perished population in each period.

Upon birth, each worker draws idiosyncratic innate ability a from a Pareto distribution $G(x) = 1 - x^{-1}$, $x \in [1, \infty)$. The realization of innate ability is directly linked to the cost of education. Each worker decides about obtaining an education in his first period; if he chooses to become educated, he will stay educated for the rest of his lifetime. Similarly, if he chooses not to pursue an education, he would

reallocation of workers. Alvarez (2017), Caliendo et al. (2015), Eaton et al. (2016), and Ravikumar et al. (2017) study dynamic multi-country trade model.

Figure 1.1: Time cost of education and different value of education efficiency γ_i.



not be able to do so in the future. Each worker is endowed with one unit of time in each period. If an individual chooses to pursue an education, he must spend $a^{-\gamma_i}$ of his time in each period to maintain his education status, spending his remaining time to earn wages as a skilled worker. If an individual chooses not to pursue education, he uses the entirety of his time to earn wages as an unskilled worker.

The time cost of education is determined by the innate ability of each individual and a country-specific parameter γ_i. The cost is inversely related to innate ability a (i.e., the smarter an individual is, the lower the time cost to maintain his status as a skilled worker). Parameter γ_i captures the quality of educational institutions in country i. Figure (1.1) shows that, given the same level of innate ability, the larger γ_i is, the less time required in each period to maintain educational status. Countries with larger γ_i provide better environments for workers to pursue an education.

At time $t+s$, a skilled worker in country i receives a wage of $w^H_{i,t+s}$, while an unskilled worker receives $w^L_{i,t+s}$. Workers' instantaneous utility function is logarithmic, with future consumption discounted at a rate of $\beta \in [0,1]$. Since individuals face a constant chance of death ζ, the effective discount factor is $\nu = (1-\zeta)\beta$. Each worker has perfect foresight about the aggregate economy and evaluates the benefits of being a skilled versus an unskilled worker in deciding whether to pursue an education. Assume individuals cannot save their income, the optimization problem for a worker with innate ability a born in country i at time t is given by:

$$\max\left\{\sum_{s=0}^{\infty}\nu^s \log\big[(1-\frac{1}{a^{\gamma_i}})\frac{w^H_{i,t+s}}{P_{i,t+s}}\big], \sum_{s=0}^{\infty}\nu^s \log\big[\frac{w^L_{i,t+s}}{P_{i,t+s}}\big]\right\}. \tag{1.1}$$

By equating the benefit of being a skilled worker versus an unskilled worker, we derive the threshold innate ability $\bar{a}_{i,t}$. A worker with innate ability$\bar{a}_{i,t}$ in country i born at time t is indifferent between being a skilled or an unskilled worker. This threshold ability is denoted by:

$$\bar{a}_{i,t} = \left[1-\Big(\prod_{s=0}^{\infty}\big(\frac{w^L_{i,t+s}}{w^H_{i,t+s}}\big)^{\nu^s}\Big)^{\frac{1}{\sum_{s=0}^{\infty}\nu^s}}\right]^{-\frac{1}{\gamma_i}} \tag{1.2}$$

For a worker born at time t in country i, if his innate ability is larger than $\bar{a}_{i,t}$, the benefit of being a skilled worker outweighs that of being an unskilled worker; hence, he pursues an education. In all other instances, he does not pursue education otherwise. Equation (1.2) denotes a key equilibrium condition which implies that a more efficient educational institution and higher skill premium in the subsequent periods are associated with higher educational attainment.

1.2.2 Labor Supply Dynamic

Computing skilled and unskilled labor supply of country i at time t requires information about the skill supply from the last period as well as the ability threshold of the current generation. Given$\bar{a}_{i,t}$, the average skilled labor hour of country i and generation t is given by:

$$\int_{\bar{a}_{i,t}}^{\infty}(1-\frac{1}{x^{\gamma_i}})dG(x) = \bar{a}_{i,t}^{-1} - \frac{1}{(1+\gamma_i)}\bar{a}_{i,t}^{-(\gamma_i+1)} = \mu_{i,t}. \tag{1.3}$$

Similarly, given $\bar{a}_{i,t}$, the average unskilled labor supply of country i and generation t is given by:

$$\int_{1}^{\bar{a}_{i,t}} dG(x) = G(\bar{a}_{i,t}). \tag{1.4}$$

Letting $L_{i,t}^{H}$ and $L_{i,t}^{L}$ be the total skilled and unskilled labor supply of country i at time t, the transitions of skilled and unskilled labor supply can be characterized by:

$$L_{i,t}^{H} = (1-\zeta)L_{i,t-1}^{H} + \mu_{i,t}L_i \tag{1.5}$$

$$L_{i,t}^{L} = (1-\zeta)L_{i,t-1}^{L} + G(\bar{a}_{i,t})L_i. \tag{1.6}$$

The first term on the right-hand side of equations (1.5) and (1.6) capture the remaining population from the existing labor force pool. Adding the supply of skilled and unskilled labor from newly born individuals, we arrive at the total labor supply at time t. The evolution of the skilled and unskilled labor supply can be fully characterized by their corresponding initial values and path of ability thresholds.

1.2.3 Production

I introduce capital-skill complementarity in the production function of sector-j intermediate ω. Capital, skilled workers, and unskilled workers are used to produce intermediates. Production of sector-j intermediate ω follows a technology:

$$M_{i,t}^{j}(\omega) = \left([\delta_i^j]^{1/\rho}[L_{i,t}^{H,j}(\omega)]^{\frac{\rho-1}{\rho}} + [1-\delta_i^j]^{1/\rho}[K_{i,t}^{j}(\omega)]^{\frac{\rho-1}{\rho}}\right)^{\frac{\rho}{\rho-1}} \tag{1.7}$$

$$y^j_{i,t}(\omega) = A^j_{i,t}(\omega) B^j_i [L^L_{i,t}(\omega)]^{\alpha^j_i} [M^j_{i,t}(\omega)]^{1-\alpha^j_i} \tag{1.8}$$

where $K^j_{i,t}(\omega)$, $L^H_{i,t}(\omega)$ and $L^H_{i,t}(\omega)$ are the amounts of capital, skilled, and unskilled workers respectively used by producer of intermediate ω. Specifically, capital and skilled workers are combined in a CES function with an elasticity of substitution ρ to produce $M^j_{i,t}(\omega)$. The intermediate production follows a Cobb-Douglas technology combining unskilled labor and $M^j_{i,t}(\omega)$. The input share of unskilled labor is represented by α^j_i, with lower values of α^j_i resulting in a more skill-intensive sector j. Skill intensities are heterogeneous across both sectors. Additionally, is the productivity of intermediate ω of sector j in country i at time t, and is drawn from a Fréchet distribution $F^j_{i,t}(z) = e^{-T^j_{i,t} z^{-\theta}}$. Lastly, $B^j_i = (\alpha^j_i)^{-\alpha^j_i}(1-\alpha^j_i)^{-(1-\alpha^j_i)}$ is a normalizing parameter. Letting $r_{i,t}$, $w^H_{i,t}$ and $w^L_{i,t}$ be the capital rent and wages of skilled and unskilled workers in country$i$ at time t, the unit cost to produce intermediate ω of sector j in country i at time t is given by:

$$c^j_{i,t}(\omega) = \frac{c^j_{i,t}}{A^j_{i,t}(\omega)} \tag{1.9}$$

with

$$c^j_{i,t} = (w^L_{i,t})^{\alpha^j_i} (P^{M,j}_{i,t})^{1-\alpha^j_i} \tag{1.10}$$

$$p^{M,j}_{i,t} = \left[\delta^j_i (w^H_{i,t})^{1-\rho} + (1-\delta^j_i)(r_{i,t})^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{1.11}$$

Sector-j goods in country i are produced by using intermediates $\omega \in [0,1]$ priced at $p^j_{i,t}(\omega)$. Intermediates ω are either from a domestic market or foreign countries. Letting $Y^j_{i,t}$ be the total quantity of sector-j goods in country i produced at time t, and $q^j_{i,t}(\omega)$ be the total quantity of intermediate ω used by sector j in country i at time t, the production of sector-j good follows a CES technology:

$$Y^j_{i,t} = \Big(\int_0^1 [q^j_{i,t}(\omega)]^{\frac{\eta-1}{\eta}} d\omega \Big)^{\frac{\eta}{\eta-1}}, \tag{1.12}$$

where η is the elasticity of substitution within a sector. Sector-j price index in country i at time t is given by:

$$P_{i,t}^{j} = \left(\int_{0}^{1} [p_{i,t}^{j}(\omega)]^{1-\eta} d\omega \right)^{\frac{1}{1-\eta}} \tag{1.13}$$

The final goods producer in country i combines sectoral goods from the domestic market priced at $P_{i,t}^{j}$. Letting $Y_{i,t}$ be the total output of final goods in country i at time t, and $q_{i,t}^{j}$ be the amount of sectoral goods used by the final good production, the production of final good follows a CES technology:

$$Y_{i,t} = \left(\sum_{j=1}^{J} [q_{i,t}^{j}]^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{1-\sigma}}, \tag{1.14}$$

where ρ is the elasticity of substitution across sectors. The price index in country i at time t is given by:

$$P_{i,t} = \left[\sum_{j=1}^{J} (P_{i,t}^{j})^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{1.15}$$

The total expenditure on sector-j good in the production of final good in country i at time t is given by:

$$E_{i,t}^{j} = \left(\frac{P_{i,t}^{j}}{P_{i,t}} \right)^{\frac{1}{1-\sigma}} \times P_{i,t} Y_{i,t} \tag{1.16}$$

1.2.4 Capital Supply

For simplicity, assume representative household in each country dictates the decision of capital investment. Individuals do not make decision regarding investment. Instead, the social planner in country i maximizes the following lifetime welfare function:

$$U_i = \sum_{t=0}^{\infty} \nu^t \log(C_{i,t}), \tag{1.17}$$

with resource constraints:

$$W_{i,t} = w_{i,t}^H L_{i,t}^H + w_{i,t}^L L_{i,t}^L + r_{i,t} K_{i,t} \tag{1.18}$$

$$\frac{W_{i,t}}{P_{i,t}} = C_{i,t} + I_{i,t} \tag{1.19}$$

$$K_{i,t+1} = (1-\delta) K_{i,t} + I_{i,t}, \tag{1.20}$$

where $C_{i,t}$, $I_{i,t}$ is the real consumption and investment, respectively, of country i at time t, and δ is the depreciation rate of capital. The representative household in each country collects all nominal income from workers and capital, and then allocates resources between real consumption $C_{i,t}$ and capital investment $I_{i,t}$ by solving the optimization problem. Equation (1.20) captures capital stock dynamic in country i.

As stated previously, the representative household has perfect foresight. Solving the maximization problem, the following Euler's equations are given by:

$$\lambda_{i,t} = \frac{1}{C_{i,t}} \tag{1.21}$$

$$-\lambda_{i,t} + \nu \lambda_{i,t+1} \left[\frac{r_{i,t+1}}{P_{i,t+1}} + (1-\delta) \right] = 0 \tag{1.22}$$

$$\frac{W_{i,t}}{P_{i,t}} = C_{i,t} + K_{i,t+1} - (1-\delta) K_{i,t}. \tag{1.23}$$

The dynamics of capital are governed by the Euler's equations. These conditions pin down the transition of capital supply for each country. Combining this with the transition of skill supply, we derive the factor supply for every country at each time period.

1.2.5 International Trade

The iceberg trade cost of delivering one unit of a sector-j intermediate from country i to n is denoted by $d^j_{i,n} \geq 1$. Hence, the unit cost of producing sector-j intermediate ω in country i after delivering to country n is given by $c^j_{i,n,t}(\omega) = c^j_{i,t}(\omega) d^j_{i,n}$. Since the market is competitive, the sector-j good producer in country n buys each intermediate ω from the cheapest source, the price of intermediate ω is given by:

$$p^j_{i,n,t}(\omega) = \min_i \left\{ c^j_{i,n,t}(\omega) \right\}. \tag{1.24}$$

Following (Eaton and Kortum, 2002), to solve trade share and sectoral price indices, the probability of country n buying sector-j intermediates from country i at time t is

$$\pi^j_{i,n,t} = \frac{T^j_{i,t}[d^j_{i,n} c^j_{i,t}]^{-\theta}}{\sum_{i'=1}^N T^j_{k,t}[d^j_{i',n} c^j_{i',t} c^j_{i',t}]^{-\theta}} = \frac{T^j_{i,t}[d^j_{i,n} c^j_{i,t}]^{-\theta}}{\Phi^j_{n,t}}. \tag{1.25}$$

$\pi^j_{i,n,t}$ is also n's expenditure share on i in sector j. Let $E^j_{i,n,t}$ be the total sector-j intermediate export from country i to country n at time t, and is given by

$$E^j_{i,n,t} = \pi^j_{i,n,t} E^j_{n,t} = \frac{T^j_{i,t}[d^j_{i,n} c^j_{i,t}]^{-\theta}}{\Phi^j_{n,t}} E^j_{n,t}. \tag{1.26}$$

Equation (1.26) is the gravity equation, where θ is the trade elasticity, i.e., the elasticity of export with respect to trade cost. A smaller dispersion of productivity across countries corresponds to higher trade elasticity, since trade flows are more responsive to trade cost when countries are more similar in the distribution of productivity.

The price index for sector j in country n at time t is given by:

$$\begin{aligned} P^j_{n,t} =& \Big[\int_0^1 p^j_{n,t}(\omega)^{1-\eta} d\omega \Big]^{\frac{1}{1-\eta}} \\ =& \Gamma(\frac{\theta - 1 + \eta}{\theta}) \times [\Phi^j_{n,t}]^{-\frac{1}{\theta}}, \end{aligned} \tag{1.27}$$

where $\Gamma(\cdot)$ is a gamma function.

1.2.6 General Equilibrium

Assuming trade is balanced, the goods markets and all factor markets clear for every country and all time periods in the general equilibrium. The sectoral goods are cleared if the following condition holds for each i, j, and t:

$$E_{i,t}^{j} = P_{i,t}^{j} Y_{i,t}^{j} = \sum_{n=1}^{N} \pi_{i,n,t}^{j} E_{n,t}^{j} \tag{1.28}$$

Where $E_{i,t}^{j}$ is the value of gross output of sector j in country i at time t. Equilibrium also requires total spending equals total income for each country and each time period,

$$P_{i,t} Y_{i,t} = w_{i,t}^{H} L_{i,t}^{H} + w_{i,t}^{L} L_{i,t}^{L} + r_{i,t} K_{i,t} \tag{1.29}$$

Since factors can freely move across sectors but are unable to move across countries, factor prices are equalized across sectors within each country. The market clearing conditions for capital, skilled, and unskilled labor in country i at time t is

$$r_{i,t} K_{i,t} = \sum_{j=1}^{J} \left[(1-\alpha_i^j)(1-\delta_i^j) \left(\frac{r_{i,t}}{P_{i,t}^{M,j}} \right)^{1-\rho} \sum_{n=1}^{N} \pi_{i,n,t}^{j} X_{n,t}^{j} \right] \tag{1.30}$$

$$w_{i,t}^{H} L_{i,t}^{H} = \sum_{j=1}^{J} \left[(1-\alpha_i^j)\delta_i^j \left(\frac{w_{i,t}^{H}}{P_{i,t}^{M,j}} \right)^{1-\rho} \sum_{n=1}^{N} \pi_{i,n,t}^{j} X_{n,t}^{j} \right] \tag{1.31}$$

$$w_{i,t}^{L} L_{i,t}^{L} = \sum_{j=1}^{J} \left[\alpha_i^j \sum_{n=1}^{N} \pi_{i,n,t}^{j} X_{n,t}^{j} \right]. \tag{1.32}$$

The left-hand side of equations (1.30) to (1.32) is the total income of each factor in country i at time t, and the right-hand side is the total payment to each factor. In equilibrium, these market conditions hold across all$i$ and all t.

Given all equilibrium conditions, including the solutions to maximization problems, trade share, and price indices, the equilibrium is defined in the following manner. Denoting economic fundamental at time t as Ψ_t, which include bilateral trade cost $d^j_{i,n,t}, \forall i, n \in N, j \in J$, and productivity $T^j_{i,t}, \forall i, \in N, j \in J$, these variables can potentially be time-varying but are deterministic and converge at some constants. Denoting the initial condition as Θ_0, it includes initial factor supply $K_{i,0}$, $L^H_{i,0}$ and $L^L_{i,0}$ $\forall i$. Given Θ_0 and $\{\Psi_t\}^{\infty}_{t=0}$, an equilibrium is comprised of sequences of factor prices, ability threshold, and factor supply $\{r_{i,t}, w^H_{i,t}, w^L_{i,t}, \bar{a}_{i,t}, K_{i,t}, L^H_{i,t}, L^L_{i,t}\}^{\infty}_{t=0}, \forall i \in N$ such that all equilibrium conditions and market clearing conditions are satisfied.

Steady state equilibrium can be defined similarly. Given steady-state fundamental Ψ^*, which includes trade cost $d^j_{i,n}, \forall i, n \in N, j \in J$ and $T^j_i, \forall i \in N, j \in J$, a steady-state equilibrium is $\{r_i, w^H_i, w^L_i, \bar{a}_i, K_i, L^H_i, L^L_i\}, \forall i \in N$ such that all equilibrium conditions and market clearing conditions are satisfied.[4]

[4]See the Appendix (3.2) for the equilibrium conditions of steady state and the algorithm to compute both steady state and transitional path.

Chapter 2 Quantitative Model

2.1 Special Cases

In this section, I explore a simplified version of my model to demonstrate the underlying mechanisms. These mechanisms consist of the comparative advantage channel and the educational institution channel. The following questions are studied: (1) How comparative advantage shapes the skill premium and skill supply? and (2) What role does educational institutions play in determining the trade pattern and educational outcomes? The model is simplified based on the following assumptions. There are two countries (North and South), two sectors (service and manufacturing), and the manufacturing sector is more unskilled labor intensive. I also assume that there is no capital-skill complementarity (setting $\rho = 1$) to emphasize other mechanisms.

In what follows, I study each of these mechanisms quantitatively. Values of the baseline parameters used are listed in Table (2.1).

2.1.1 The Comparative Advantage Mechanism

In this subsection, I assume the following: (1) $T_i^j = 1$ for all i and j except for $T_{North}^{service} = 2$; (2) educational efficiencies are all set to $\gamma_i = 1$ for all i; and (3) initial bilateral trade cost is set to $d_{i,n}^j = 3$. As a result, North has a comparative advantage in the high-skill sector, while South has a comparative advantage in the low-skill sector. The quantitative experiment is to gradually reduce the trade cost until all

Table 2.1: Baseline Parameters for the Simplified Cases

Parameters		Value
Elasticity of substitution across sector:	σ	2.2
Elasticity of substitution within sector:	η	2.7
Elasticity of substitution between skilled labor and capital:	ρ	1
Productivity dispersion:	θ	4
Unskilled labor intensity in manufacturing:	α^M	0.7
Unskilled labor intensity in service:	α^S	0.3
Skill share relative to capita:	δ^j	0.7
Population:	L_i	1

trade barriers are removed, and record the changes in skill premium and skill supply relative to the baseline equilibrium.

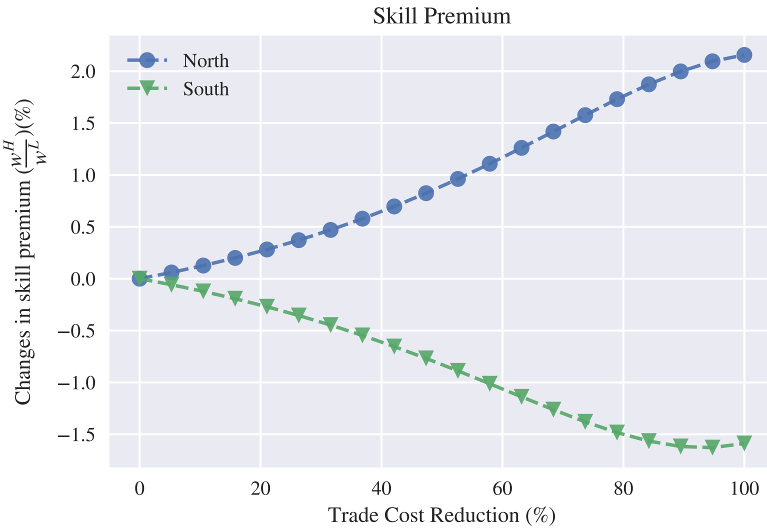
Figure (2.1) presents the changes in the skill premium and the relative skill supply for this quantitative experiment. As in the prediction of the Stolper-Samuelson theorem, the reduction in trade costs causes the factors to be allocated toward the sectors that have a comparative advantage in each country. Since North has a comparative advantage in the high-skill sector, the between-sector reallocation induced by the trade cost reduction raises the skill premium in the North. In response to the higher skill premium, workers in the North seek more education, meaning that educational attainment also rises. These changes in educational outcome reflect the outward shift of relative skill demand along a positively sloped skill supply. As a result, the relative price rises and relative quantity falls. The opposite occurs in the South since it has a comparative advantage in the low-skill sector.

The results of this quantitative experiment echo the theoretical prediction of Findlay and Kierzkowski (1983) that trade liberalization induces skill-upgrading or skill-downgrading in accordance with a country's comparative advantage. In addition, the results are consistent with the empirical findings of Blanchard and Olney (2017).

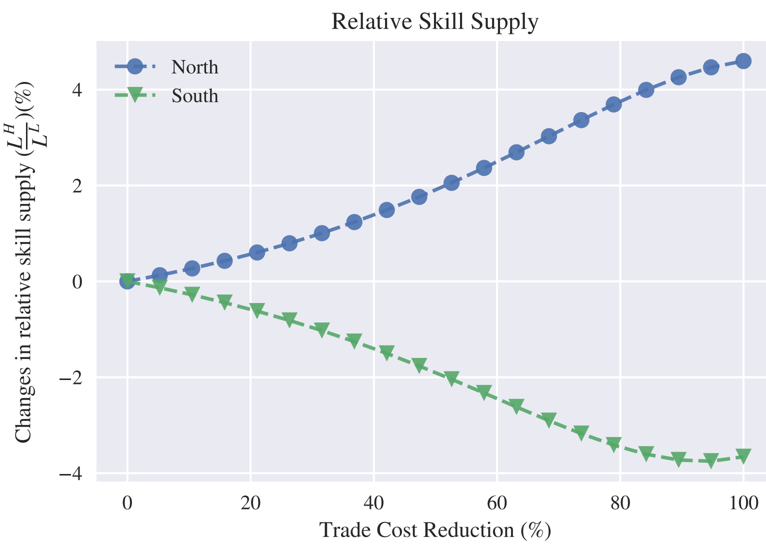
2.1.2 The Educational Institution Mechanism

In this subsection, I study the educational institution mechanism, assuming productivity across countries and sectors are the same, $T_i^j = 1$ for all i, j, and zero

Figure 2.1: An Illustration of Stolper-Samuelson Mechanism



(a) Evolution of skill premium.



(b) Evolution of relative skill supply.

trade costs for any j, i, n. The goal of these assumptions is to isolate the effect that educational institutions have on the economy. The initial values for educational efficiency γ_i are set to 1 for all countries in the baseline. The quantitative experiment entails gradually increasing North's educational efficiency until it reaches 1.5, while holding everything else unchanged, and record the changes in the skill premium, the relative skill supply, and the patterns of specialization.

Figure (2.2)presents the changes in the skill premium, the relative skill supply, and the pattern of specialization for the economy. Panel (2.2) and (2.2) in Figure (2.2) show that as North's educational institutions become more robust, the skill premium falls and educational attainment rises. An improvement in North's educational institutions does not have a significant impact on South's labor market, as it slightly reduces the skill premium and relative skill supply of the latter.

Even though North's institutional improvement has no meaningful impact on South's labor market, it has a significant impact on the pattern of specialization. Panel(2.2) in Figure (2.2) shows that, as North's educational institutions improve, it exports relatively more high-skill goods, while South exports relatively more low-skill goods. Stated differently, North specializes in high-skill sectors, and South specializes in the low-skill sectors.

This example demonstrates that differences in educational institutions across countries can be a source of comparative advantage. Countries with more robust educational institutions are more capable of providing skilled labor and more likely to specialize in high-skill sectors. Educational policies not only serve as vehicles to combat inequality, but can also be used as instruments in trade policies.

2.2 Parameterization

Model parameters are either taken from the literature, estimated, or calibrated to the base year. Using data from the World Input-Output Database (WIOD), as discussed in Timmer et al. (2015), I calibrate the parameters of my model to match observations in the year 2000. I assume the world is in a steady state at year 2000. The model is calibrated based on 40 countries and 6 sectors aggregated from 33 industries[1] using bilateral trade data from World Input-Output Table (WIOT) and production data from Socio-economic Accounts (SEA). Table (A.1) and (A.2) in Appendix (A.1) provide the lists of countries and industries.

[1] See Table (A.3) for the details of aggregation.

Table 2.2: Common Parameters

Parameters		Value
Elasticity of substitution across sector:	σ	2.2
Elasticity of substitution within sector:	η	2.7
Elasticity of substitution between skilled labor and capital:	ρ	0.67
Trade Elasticity:	θ	4
Rate of capital depreciation:	δ	0.05
Probability of death:	ζ	0.025
Discount factor:	β	0.98
Factor shares:	α^j and δ^j	the U.S. data

2.2.1 Common Parameters

In this section, I assume the following parameters are common across countries, elasticities, factor shares for each industry, constant probability of death, discount factor, and the rate of capital depreciation.

Following the estimation of Simonovska and Waugh (2014) trade elasticity is set to $\theta = 4$. I set elasticity of substitution within sector $\eta = 2.7$, and across sector$\sigma = 2.2$ to match the median 5-digit SITC and 3-digit elasticity of substitution between 1990 and 2001 estimated by Broda and Weinstein (2006). The elasticity of substitution between skilled labor and capital is set to $\rho = 0.67$ following the estimation of Krusell et al. (2000). I set the constant probability of death $\zeta = 0.025$, such that workers stay in labor force for 40 years on average. Lastly, the capital depreciation rate is set to $\delta = 0.05$ and the discount factor is set to $\beta = 0.98$.

For the factor shares, I assume α_i^j and δ_i^j are the same across all countries, but are different across industries. Using U.S. data in year 2000 from SEA as the baseline, I compute the expenditure shares of capital, skilled, and unskilled labor for each industry. I set α_i^j to match the expenditure share on unskilled labor and δ_i^j to match the expenditure share on skilled labor relative to capital for each industry. See Table (A.4) in Appendix (A.1) for the values of factor shares for each industry.

2.2.2 Country-specific Parameters and Iceberg Trade Costs

SEA records the number of employees in the production process for each country, and I use this variable as the total labor force L_i. The SEA dataset also enables me to compute relative skill supply, skill premium, and nominal wages for skilled and unskilled labor. See Appendix (3.1) for further details.

I use the gravity structure from my model to estimate productivity and iceberg trade costs. First taking log to gravity equation (1.26), I get

$$\log E_{i,n,t}^j = \log T_{i,t}^j - \theta d_{i,n,t}^j - \theta c_{i,t}^j + \log \left(E_{n,t}^j / \Phi_{n,t}^j \right). \tag{2.1}$$

I assume that trade costs take the form

$$d_{i,n}^j = (Dist_{i,n})^{b_1^j} \times \exp(b_2^j \times border_{i,n} + b_3^j \times language_{i,n} + b_4^j \times colony_{i,n}) \tag{2.2}$$

for all i, n. This specification proxies the geographical barriers. $Dist_{i,n}$ is the distance between i and n, and I set $D_{i,i} = 1$. $border_{i,n} = 1$ if i and n do not share border. Similarly, $language_{i,n}$ and $colony_{i,n}$ refer, respectively to whether i and n share a language, and whether they share colonial history. The data on the geography and trade barriers for each country pair are from Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). Combine the specification of trade costs with the gravity equation, the empirical specification is given by:

$$\begin{aligned} \log E_{i,n}^j =& b_1'^j \log D_{i,n} + b_2'^j \times border_{i,n} + b_3'^j \times language_{i,n} + b_4'^j \times colony_{i,n} \\ &+ Exporter_i^j + Importer_n^j + \varepsilon_{i,n}^j, \end{aligned} \tag{2.3}$$

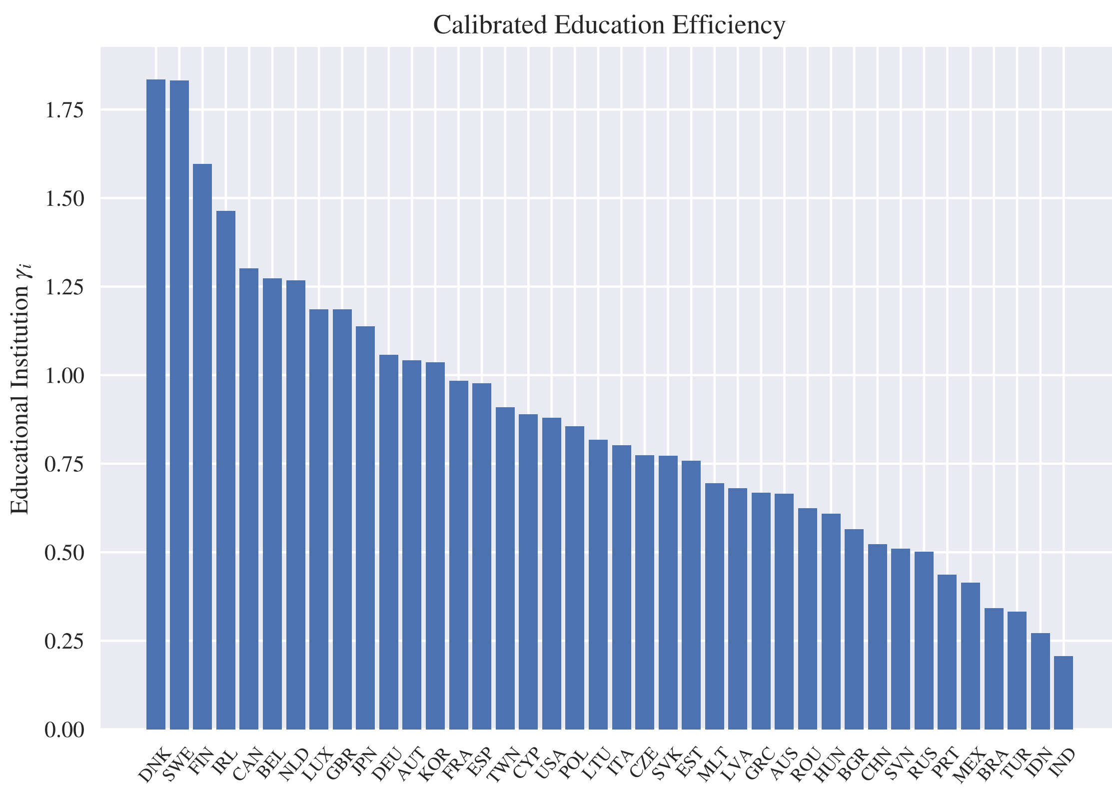
where $Exporter_i^j$ and $Importer_n^j$ are the exporter and importer dummies, respectively. I estimate equation (2.3) industry-by-industry using fixed effects model. Given the value of trade elasticity θ, the parameters about iceberg trade costs for each industry can be calculated by $b^j = -\theta \hat{b}'^j$. See Table (A.5) in the Appendix (3.1) for the estimated parameters for trade costs. The productivity can be recovered by the estimated exporter fixed effect

$$\hat{T}_i^j = \exp(Exp\hat{orter}_i^j)(c_{i,t}^j)^\theta. \tag{2.4}$$

Following equations (1.11) and (1.10), the unit bundle cost $c_{i,t}^j$ is a function of factor prices, factor shares, and elasticity ρ and θ. Imposing an interest rate of $r = 0.06$, and combing it with wages from SEA and calibrated parameters, the unit cost $c_{i,t}^j$ of each j and each i can be calculated. The parameters for productivity for each country and each sector are computed.

2.2.3 Educational Institution

Figure 2.3: Educational institution γ_i



The only remaining unspecified parameter is the educational institution γ_i for each country. The educational institution γ_i is calibrated such that the steady-state skill premium in the model matches the skill premium in the data for each country. Details of the calibration procedure can be found in Appendix (3.3).

Figure (2.3) illustrates the calibrated value of educational institutions for each country. In general, more developed countries have more efficient educational institutions, while less developed countries have less efficient education institutions. Countries with the most efficient educational institutions are European welfare states such as Denmark, Sweden, and Finland. Large developing countries such as Indonesia and India have the least efficient education institutions.

To compare with other measurements on the quality of educational institutions across countries, Figure (2.4) shows calibrated educational institution and Program for International Student Assessment (PISA) scores in math and reading in 2003. The PISA score is the most commonly used measure for global educational rankings, although this measure is not without criticism[2]. The calibrated educational institution score is positively correlated with PISA score in both mathematics and reading (see Table (2.3)). Similar to Yeaple and Xiang (2017), this paper uses a general equilibrium framework to quantify the quality of educational institutions across countries. The aspect of the educational institution featured in this model is the opportunity to access education.

[2] See Hanushek and Woessmann (2011) and Yeaple and Xiang (2017)

Figure 2.4: Calibrated Educational Institution γ_i and PISA scores

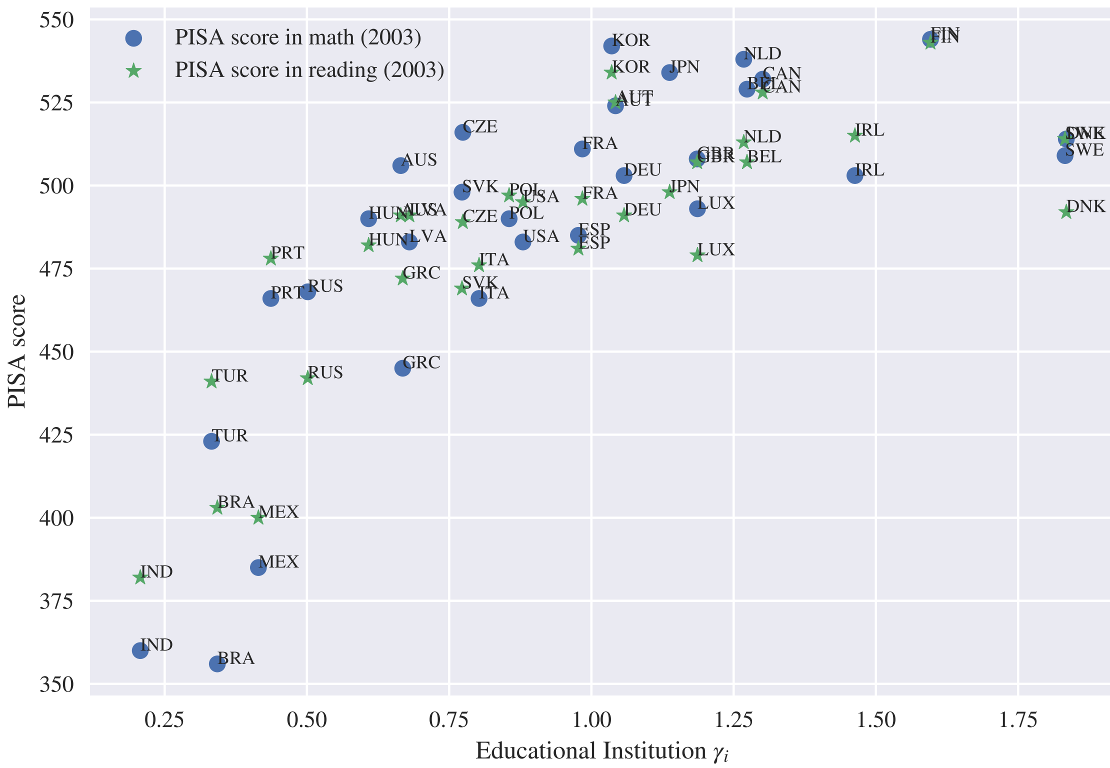


Table 2.3: Correlations between calibrated educational institution and PISA scores.

	PISA score in math (2003)		PISA scroe in reading(2003)	
	Correlation Coef.	Rank Corr.	Correlation Coef.	Rank Corr.
Calibrated γ_i	0.74	0.78	0.75	0.81

Note: The correlation coef. is Pearson correlation coefficient. The rank corr. is Spearman's rank correlation coefficient.

2.2.4 Model Fit

Figure 2.5: Model fit: Skill premium and relative skill supply

I use the calibrated parameters to compute the steady state of the model. The model matches target data well. Figure (2.5) plots the skill premium and relative skill supply in the data and the calibrated model. The skill premium is my targeted moment, and the model matches the data almost perfectly, with the correlation of 1. For the relative skill supply, the correlation between my model and the data is 0.6. Figure (2.5) shows that there is a negative relationship between the skill premium and the relative skill supply in the data, with a correlation coefficient of -0.59. The model preserves this negative relationship, with a correlation coefficient of -0.83. In summary, the model matches the skill premium perfectly, preserving the relationship between skill premium and relative skill supply shown in the data.

2.3 Counterfactual: Trade Liberalization

In this section, I study the effect of an unanticipated permanent trade liberalization. The trade liberalization corresponds to a uniform reduction in iceberg trade costs. At period $t = 0$, the economy begins in a calibrated steady state. At period$t = 1$, iceberg trade costs fall by 25% for each country pair and each sector. That is

$$d^j_{i,n,t} = (d^j_{i,n,0} - 1) \times (1 - 0.25) + 1, \;\; \forall i, n \in \mathbf{N}, j \in \mathbf{J} \text{ and } t = 1, 2, \ldots. \tag{2.5}$$

I compute the transitional path for all countries and quantify interactions between educational outcome, labor market, and international trade. Solving the transitional path for all 40 countries simultaneously is a daunting task since it involves finding solutions in a vast state space. I adapt the algorithm of Alvarez and Lucas (2007) to this dynamic framework by framing the problem as a finite horizon problem. The method I use is efficient, as the computation of the full transitional path takes around 2 minutes on my laptop. See Appendix (3.2) for details of the algorithm.

2.3.1 Educational Outcomes

Figure 2.6: Changes in skill premium and relative skill supply resulting from trade liberalization in the steady state.

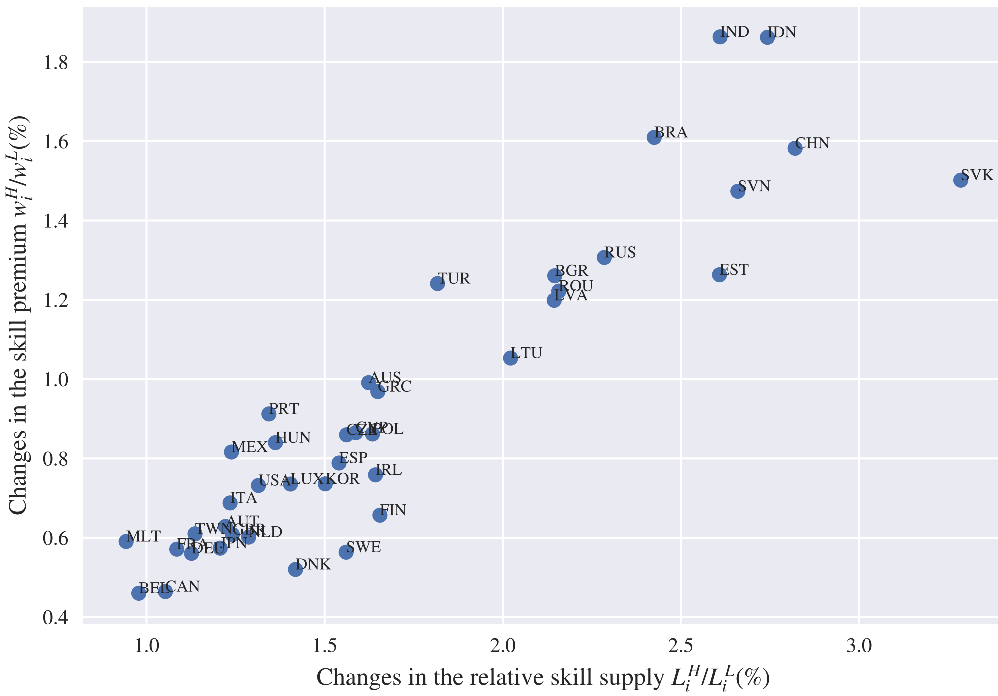


Figure (2.6) plots the percentage change in the relative skill supply and the skill premium relative to the baseline for each country. The skill premium and relative skill supply rise by 0.93% and 1.71% on average, respectively, but vary widely across countries. The skill premium rises by as much as 1.61% in Brazil, 1.86% in India and Indonesia, and by as little as 0.46% in Canada and Belgium. The relative skill supply rises by as much as 3.29% in Slovakia, 2.74% in Indonesia, 2.61% in India, and by as little as 0.94% in Malta and 0.98% in Belgium. Note that contrary to the prediction of the Stolper-Samuelson theorem, the skill premium rises in all countries. For both developed and developing countries, workers with higher education levels gain more from trade, resulting in growing inequality between education categories. This result suggests that capital-skill complementarity is the dominant force in shaping educational outcome and inequality. Relative skill supply changes in the same direction as skill premium, and changes in the educational outcome in a steady state reflect movement along a positively sloped relative skill supply curve.

Figure 2.7: Changes in skill premium and educational institution.

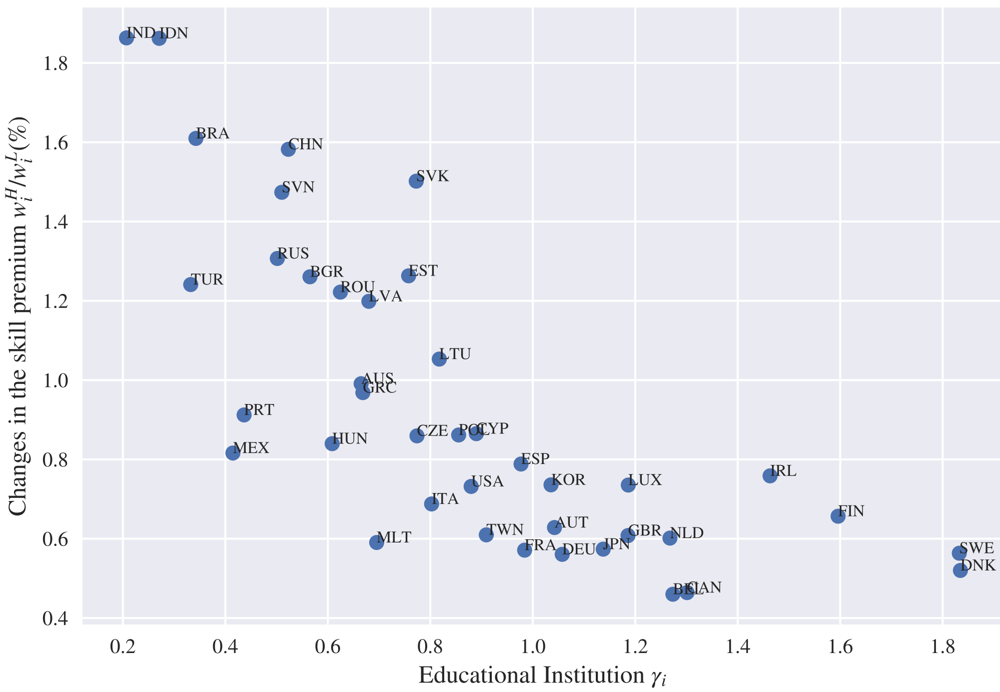


Figure (2.7) depicts a clear negative correlation between predicted change in skill premium in this counterfactual and educational institutions, with a correlation coefficient of -0.6. A more robust educational institution indicates that it is less frictional to accumulate human capital in the long run. Since individuals make education decisions by evaluating the relative reward between being a skilled or an unskilled worker, a more robust educational institution makes a country's economy less susceptible to intensifying inequality under trade shocks.

Figure 2.8: Transitional paths for skill premium and relative skill supply in the U.S.

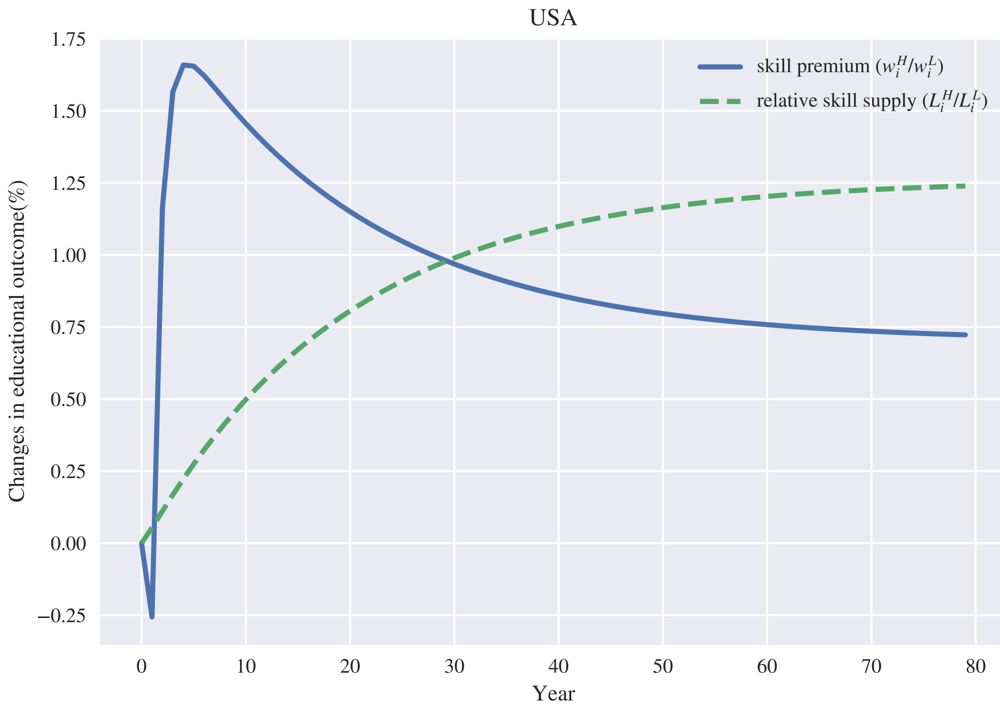


Figure (2.8) illustrates the transitional paths of skill premium and relative skill supply in the United States. The skill premium rises rapidly after trade liberalization, and peaks at $t = 5$. As shown in Figure (2.8), the skill premium increases by 1.75% at the peak. Older generations cannot adjust their education status, resulting in a slow adjustment of human capital is slow. Relative skill supply climbs slowly along the transitional path after trade liberalization. As demonstrated in Figure (2.8), this leads to an eventual 1.26% increase in relative skill supply. In the long run, the adjustment of human capital affects the skill premium; as more people become skilled workers, the skill premium falls and converges to the new steady state following the trade liberalization. At the new steady state, the skill premium rises by 0.75%; human capital accumulation eliminates 57% of the increased skill premium from the peak in the United States. The transitional paths of other countries are similar to that of the United States.

In summary, trade liberalization raises inequality between educational categories and educational attainment. In general, countries with more robust educational institutions are less affected by intensifying inequality. Inequality is most severe in the early stage of transition following trade liberalization, and decreases as future generations accumulate more human capital. The freedom to pursue an education removes more than half of the transitory inequality.

2.3.2 Channels on the Transition Path

There are two main components of the model: physical capital accumulation and human capital accumulation. The interaction between these two components drives the transitional behavior of the economy in each country. By turning each component on and off, I can isolate and investigate different channels at work.

First, I compute the baseline steady-state equilibrium using the calibrated parameters and collect the steady-state capital and skill supply. To turn off capital accumulation under trade shocks, I force capital supply to be at the baseline steady-state level while computing the full transitional path. Human capital accumulation is turned off in a similar manner.

In the short run, all factors are not able to adjust. Turning off both capital and human capital accumulation illustrate the economic consequence in the short run. At this stage, the outcome is driven by the comparative advantage channel (C-A). The skill premium rises in countries with a comparative advantage in high-skill sectors, and falls in countries with a comparative advantage in low-skill sectors. Since physical capital adjusts faster than human capital, allowing capital accumulation accentuates the economic impact in the medium run. In the medium run, active channels include comparative advantage and capital accumulation. In this stage, because capital becomes cheaper under trade liberalization, the representative

Table 2.4: Components in the model and the corresponding active channels

Cases	Factor Supply		Active Channel		
	Skill	Capital	C-A	SBTC	Education
(1) Short-run	✗	✗	✓	✗	✗
(2) Medium-run	✗	✓	✓	✓	✗
(3) Long-run	✓	✓	✓	✓	✓

household invests more intensively in capital, and the complementarity between capital and skilled labor raises the skill premium. Lastly, in the long run, all factors can freely adjust and all components are active. The long run features all channels, includes comparative advantage, capital accumulation, and education. At this stage, human capital accumulation catches up with the accumulation of physical capital, and it dampens trade-induced inequality. Active and inactive channels under different scenarios are briefly summarized in Table (2.4).

Figure 2.9: Decompostition of the change in skill premium

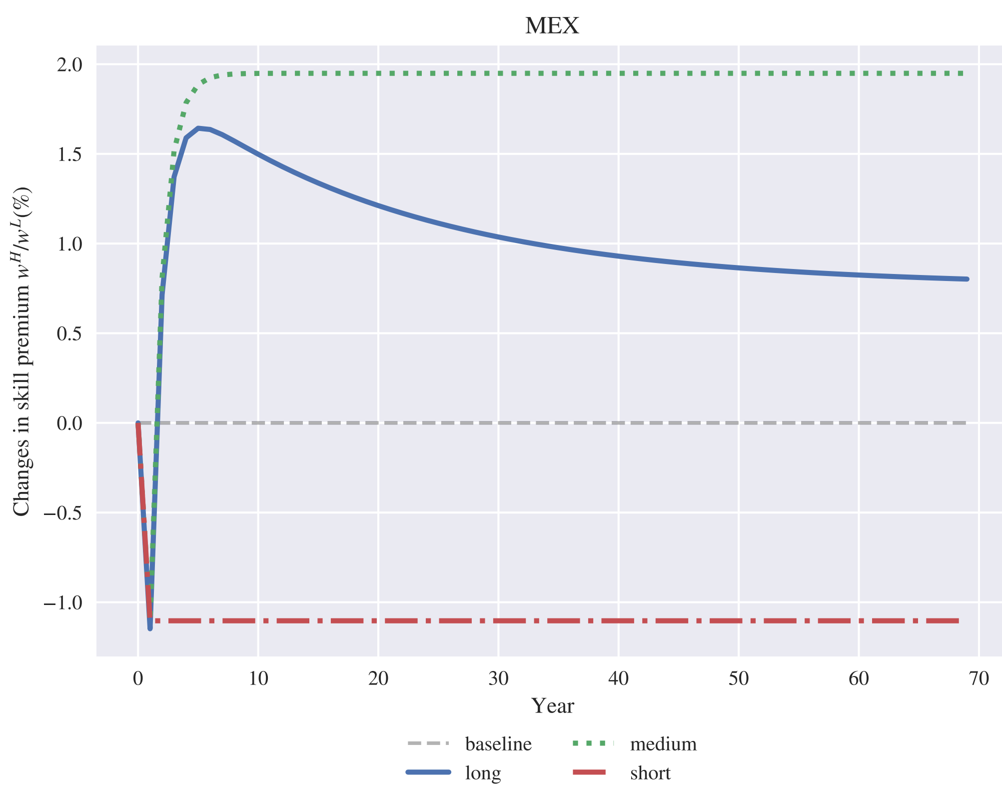


Figure (2.9) shows the decomposition of the transitional path of the skill premium in Mexico following trade liberalization. When all components are inactive, the skill premium drops, which is driven by the comparative advantage mechanism. This explains the initial drop in skill premium at $t = 1$ along the transitional path. When only capital accumulation is active, the initial drop in the skill premium is preserved. The dramatic rise in the skill premium reflects the rapid capital accumulation and the skill-capital complementarity. In this case, the lack of educational choice makes the steady-state skill premium higher than the peak on the transitional path. When all components are active, education channel neutralizes the effect of capital accumulation on skill premium. As a result, the skill premium falls along the transitional path, but the eventual skill premium is still higher than in the baseline.

A similar pattern in the transition of skill premium following trade liberalization has been documented in the data. For example, Mexico joined the General Agreement on Tariff and Trade (GATT) in 1986. As a result, trade barriers were substantially reduced in the country.Atolia and Kurokawa (2016) show that although the skill premium in Mexico rose rapidly between 1986 to 1994, it subsequently declined over a long period of time. This pattern has been observed in Korea after trade liberalization in 1970s , and in China after joining World Trade Organization (WTO) in 2002[3], and in China after joining World Trade Organization (WTO) in 2002[4]. These observations indicate that physical capital and human capital accumulation are crucial in shaping the transition of wage inequality between educational categories. Ignoring these channels exaggerates changes in inequality and does not offer an explanation for the rich dynamic following trade shocks.

[3]See Kim and Topel (2007).

[4]See Figure (A.1) in the Appendix (A.2).

2.3.3 Education and Trade-Induced Inequality

Figure 2.10: Changes in skill premium for all cases.

Figure (2.10) and Table (A.9) record percentage changes in the skill premium for all countries and all cases. When only the comparative advantage channel is active, the skill premium drops in 32 out of 40 countries. Capital-skill complementarity dominates in all countries, resulting in an eventual skill premium rise in all countries. The difference in skill premium between case (2) and case (3) is globalization-induced inequality eliminated by education. Education eliminates 58% to 73% of trade-induced inequality, with an average rate of 65%. This quantitative analysis suggests that education can be a very effective instrument in combating trade-induced inequality.

2.3.4 Gains from Trade and Intergenerational Inequality

Table (A.8) shows the percentage change in real wages for all educational categories and all countries in a steady state. We can see that both skilled and unskilled labor gain from trade liberalization in all countries. Mean real wages rise by as much as 35% in Indonesia, 34% in Brazil, and by as little as 13% in Canada and 14% in Belgium. The average mean real wage rise is 26%.

Contrary to the traditional static trade model, the dynamic structure of my framework allows me to further explore the distribution of gains from trade across different generations and educational categories. Let $W^e_{i,t}$ be the lifetime earnings for the group born at time t in country i with educational category e, where $e \in \{skilled, unskilled\}$ and

$$W^e_{i,t} = \sum_{s=0}^{\infty} \nu^s \left(\frac{w^e_{i,t+s}}{P_{i,t+s}} \right)^s . \tag{2.6}$$

I calculate the lifetime earnings for each group under the baseline steady state and the transitional path under trade liberalization. The percentage difference in $W^e_{i,t}$ relative to the baseline captures the welfare gains for each group

Figure 2.11: Changes in lifetime earnings(%) for each generation and each educational category.

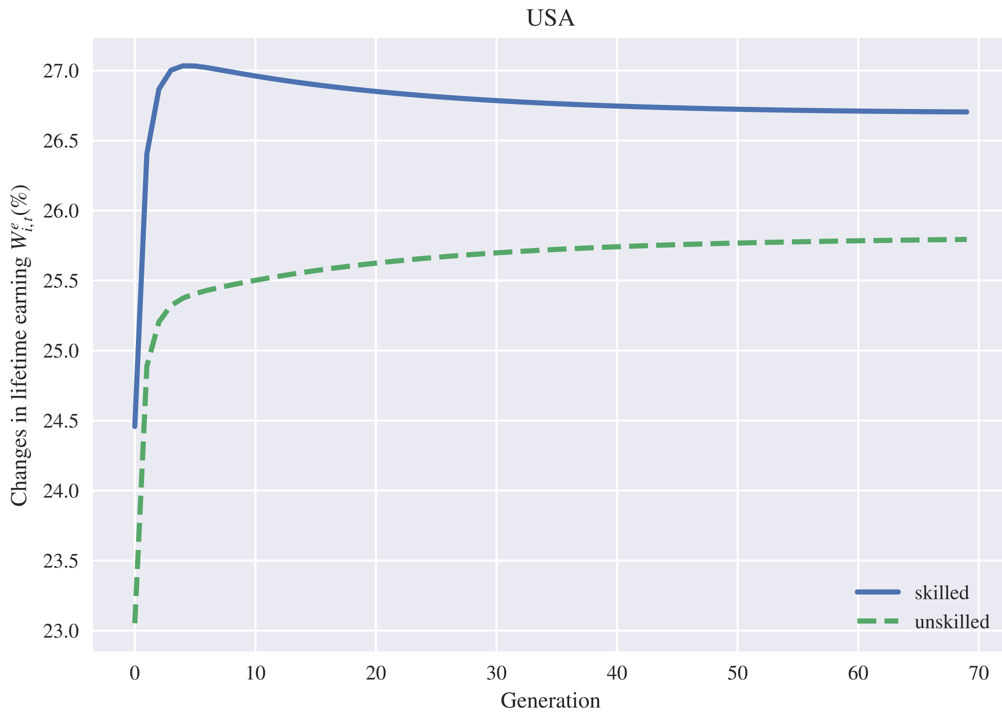


Figure (2.11) depicts the percentage change in lifetime earning relative to the baseline for each generation and educational category in the United States. For all generations, skilled workers gain more from trade relative to unskilled workers. For skilled workers, the educated group born at $t = 5$ gains the most from globalization. This group is able to enjoy the above new steady-state skill premium for the most of their lifetime. The educated groups born after $t = 5$ can still enjoy the above-steady-state skill premium; however, as skill premium approaches the new steady state, there is less room for future educated generations to take advantage of. The educated groups born before $t = 5$ gain relatively less from globalization, because for the first few periods after trade liberalization, the skill premium adjusts from the baseline steady state, which is below the new steady-state level. For uneducated workers, the oldest group gains the least. Subsequent generations gain relatively more, but never reach the gains of educated workers. Other countries show similar patterns in the distribution of welfare to that of the United States.

In summary, trade liberalization favors the older and educated group the most, and subsequent groups do not gain as much. The group which gains the least is the oldest and uneducated group. These results show that the distribution of gains from trade not only is unequal across education categories, but is also unequal across generations. In addition, the results suggest that globalization can be a potential cause of rising intergenerational inequality.

2.4 Conclusion

I find that the transitional dynamics of trade-induced inequality are closely related to adjustments in the factor supply. Upon an unanticipated trade liberalization, both capital and skill supply do not respond to the shock immediately. Comparative advantage is the main driving force that shifts relative demand to skilled labor, resulting in changes in inequality. Since the adjustment of physical capital is more flexible than education, the subsequent stage of the economic transition mostly reflects capital accumulation. Moreover, because trade liberalization reduces the cost of physical capital, investment takes place more intensively. The skill-capital complementarity and abundant supply of capital increase the productivity of skilled workers, resulting in a widening wage gap among skilled and unskilled labor. In the long run, newly-born generations make educational decisions based on prospects of the future economy, and they gradually replace old generations in the existing population. The gradual change in the skill supply shapes the eventual outcome of inequality. This quantitative result is consistent with observations of recent trade liberalization in Mexico, Korea, and China.

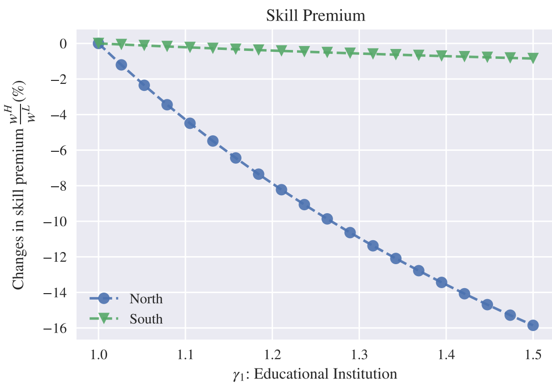
The analysis on the dynamic of the economy also indicates that education is an effective means of combating globalization-induced inequality. The slow adjustment in the supply of human capital ultimately reduces trade-induced inequality. Furthermore, the quality of educational institutions is also a potential source of comparative advantage. A country with more efficient educational institutions is more likely to specialize in skill-intensive goods. More robust educational institutions also make it easier for individuals to become skilled workers, and it offers more skilled labor for local industries, providing momentum for the expansion of skill-intensive industries.

Because of the static nature of conventional trade models, most research focuses on income inequality among educational categories or occupations. In contrast, my rich framework provides implications for intergenerational distribution of gains from trade. The quantitative analysis demonstrates that globalization leads to a drastic increase in the skill premium immediately upon trade liberalization; therefore, elderly educated generations benefit the most from globalization, as they can fully exploit the above-steady-state skill premium in earlier stage of their lives. Young educated generations still enjoy substantial gains from trade, but do not gain as much as their educated older counterparts as the economy becomes more stabilized. Old and uneducated groups gain the least from globalization because they experience the largest income gap between skilled and unskilled workers following trade liberalization. Recently, there has been much discussion in policy and press circles about rising intergenerational inequality. My analysis offers a different perspective to view this issue—it suggests that globalization can be a potential cause for intergenerational inequality.

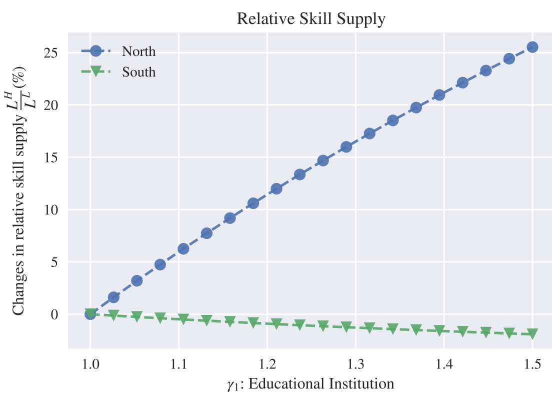
This tractable framework can be used to address broader questions about both trade and education policies. Many developing countries have implemented policies aiming to promote higher educational attainment and increased exports at the same time. As my model shows, improving the quality of educational institutions in countries with a comparative advantage in low-skill sectors can reduce exports, which could result in trade-offs between education and exports. My framework also offers a tool for policy makers to carefully design and examine possible interactions among trade and educational policies, and in turn make more informed decisions.

For future research, this framework can be extended and applied to different economic issues. For example, by applying my model to province- or state-level data, differences in educational institutions across various locations can be investigated. This type of comparison is vital for the educational administration in a country to allocate limited resources across different locations within the country more efficiently. Retraining programs such as Trade Adjustment Assistance (TAA) in the United States provides opportunities for workers to retrain and gain additional work-related skills. Introducing retraining to this model can help in analyzing economic benefits of the TAA program and its effects on trade patterns and transitory costs of inequality.

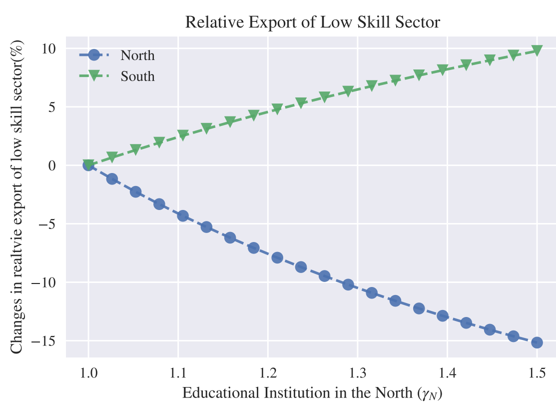
Figure 2.2: An Illustration of Education Institution Mechanism



(a) Evolution of relative skill premium.



(b) Evolution of relative skill supply.



(c) Evolution of relative skill supply.

Chapter 3 | Technical Detail

3.1 Data

The relative skill supply and skill premium in each country are computed using Social Economic Account(SEA) from WIOD.

Relative Skill Supply

SEA records the share of total hours worked by high skilled, medium skilled and low skilled workers over 15 years old (H_HS, H_MS and H_LS) to compute relative skill supply. Which is given by

$$\text{Relative Skill Supply}_i^{data} = \frac{H\_HS_i}{H\_MS_i + H\_LS_i}$$

Skill Premium

I combine additional data on the share of total labor compensation to high skilled, medium skilled and low skilled workers over 15 years old ($LABHS$, $LABMS$ and $LABLS$) to compute skill premium. Which is given by

$$\text{Skill Premium}_i^{data} = \frac{LABHS_i / H\_HS_i}{(LABMS_i + LABLS_i)/(H\_MS_i + H\_LS_i)}$$

Labor Force

I use number of persons engaged (EMP) as total labor force in each country.

Nominal Wages

SEA records total labor compensation (LAB) for each country. The nominal wage for each country is calculated by LAB/EMP (in national currency). I use exchange rate at June 30, 2000[1] to convert nominal income to US dollars.

Wages for skilled and unskilled workers are computed by combining information on nominal wage, skill premium and relative skill supply ion each country. Which are given by

$$w_i^{L,data} = \left[\frac{\text{skill premium}_i^{data}}{1 + (\text{relative skill supply}_i^{data})^{-1}} + (1 + \text{relative skill supply}_i^{data})^{-1} \right]^{-1} \times w_i^{data}$$
$$w_i^{H,data} = w_i^{L,data} \times \text{skill premium}_i^{data}.$$

3.2 Solution Algorithms

In this section, I describe the algorithm for computing both steady state and transitional path. The technique to solve the model is built upon Alvarez and Lucas (2007). The goal is to find sequence of factor prices such that the resulting educational choice is optimal, Euler equations are satisfied and factor markets are cleared.

3.2.1 Computing the Steady State

Let $x(\tau)$ be the τ^{th} round of iteration of variable x. First, start with initial guess of steady state wages such that $w_i^H(0) > w_i^L(0)$ for all i and guess of capital rent $r_i(0) > 0$, capital stock $K_i(0) > 0$. Then follow the below procedure:

1. **Update Skill Supply**

[1] Source: https://openexchangerates.org

Use $w_i^H(\tau)$ and $w_i^L(\tau)$ to find ability threshold[2]:

$$\bar{a}_i(\tau) = \Big[1 - \Big(\frac{w_i^L(\tau)}{w_i^H(\tau)}\Big)\Big]^{-1/\gamma_i}, \quad \forall i$$

Use $\bar{a}_i(\tau)$ to get skilled and unskilled labor supply[3]

$$\begin{aligned} L_i^H(\tau) =& \frac{\mu(\bar{a}_i(\tau), \gamma_i)}{\zeta} \times L_i, \quad \forall i \\ L_i^L(\tau) =& \frac{G(\bar{a}_i(\tau)}{\zeta} \times L_i, \quad \forall i. \end{aligned}$$

2. **Update Trade Share and the Price Indices**

   Scale factor prices such that:

$$\sum_{i=1}^{N} \big[w_i^H(\tau)L_i^H(\tau) + w_i^L(\tau)L_i^L(\tau) + r_i(\tau)K_i(\tau)\big] = 1$$

   Compute unit cost for each i and each j:

$$\begin{aligned} & p_i^{j,M}(\tau) = \big[\delta_i^j(w_i^H(\tau))^{1-\rho} + (1-\delta_i^j)(r_i(\tau))^{1-\rho}\big]^{\frac{1}{1-\rho}} \\ & c_i^j(\tau) = [w_i^L(\tau)]^{\alpha_i^j}[p_i^{M,j}(\tau)]^{1-\alpha_i^j} \end{aligned}$$

   Compute bilateral trade share:

$$\begin{aligned} \pi_{i,n}^j(\tau) =& \frac{T_i^j[d_{n,i}^j c_i^j(\tau)]^{-\theta}}{\sum_{k=1}^{N} T_k^j[d_{n,k}^j c_k^j(\tau)]^{-\theta}} \\ =& \frac{T_i^j[d_{n,i}^j c_i^j(\tau)]^{-\theta}}{\Phi_n^j(\tau)} \end{aligned}$$

[2] The ability threshold in steady state is derived by dropping all time subscript t in equation (1.2).

[3] $\mu(\bar{a},\gamma) = \int_{\bar{a}}^{\infty}[1-1/x^{\gamma}]dG(x)$ is used to simplify notation.

Compute sectoral price indices:

$$p_n^j(\tau) = C[\Phi_n^j(\tau)]^{-\frac{1}{\theta}}$$

where $C = \Gamma\left(\frac{\theta+1-\eta}{\theta}\right)^{\frac{1}{1-\eta}}$.

Compute CPI:

$$P_n(\tau) = \Big[\sum_{j=1}^{J} \left(p_n^j(\tau)\right)^{1-\sigma}\Big]^{\frac{1}{1-\sigma}}$$

3. **Update Capital Supply**

Update the steady state capital rent

$$r_i'(\tau) = \nu^{-1} - (1-\delta) \times P_i(\tau).$$

Use the updated rent to compute total nominal income for each country

$$W_n'(\tau) = w_n^H(\tau)L_n^H(\tau) + w_n^L(\tau)L_n^L(\tau) + r_n'(\tau)K_n(\tau)$$

Compute total expenditure on sector j for each country:

$$X_n^{j'}(\tau) = \left(\frac{p_n^j(\tau)}{P_n(\tau)}\right)^{1-\sigma} \times W_n'(\tau).$$

Utilize this to compute the average expenditure share on capital in for each country:

$$\text{average capital share}_i'(\tau) = \frac{\sum_{j=1}^{J}\left[(1-\alpha_i^j)(1-\delta_i^j)\left(\frac{r_i'(\tau)}{p_i^{j,M}(\tau)}\right)^{1-\rho}\sum_{n=1}^{N}\pi_{i,n}^j(\tau)X_n^{j'}(\tau)\right]}{\sum_{j=1}^{J}\sum_{n=1}^{N}\pi_{i,n}^j(\tau)X_n^{j'}(\tau)}$$

Use average capital share and implied steady state rent to update capital stock:

$$K_i(\tau+1) = \frac{\text{average capital share}'_i(\tau) \times W'_i(\tau)}{r'_i(\tau)}$$

4. **Compute Excess Demand for Factors**

   Scale factor prices again, such that

$$\sum_{i=1}^{N} \left[w_i^H(\tau) L_i^H(\tau) + w_i^L(\tau) L_i^L(\tau) + r'_i(\tau) K_i(\tau+1) \right] = 1$$

   Compute total expenditure on sector j for each country:

$$X_n^j(\tau) = \left(\frac{p_n^j(\tau)}{P_n(\tau)} \right)^{1-\sigma} \times [w_i^H(\tau) L_i^H(\tau) + w_i^L(\tau) L_i^L(\tau) + r'_i(\tau) K_i(\tau+1)].$$

   Then compute excess demand function:

$$Z_i^L(\tau) = \frac{1}{w_i^L(\tau)} \sum_{j=1}^{J} \left[\alpha_i^j \sum_{n=1}^{N} \pi_{i,n}^j(\tau) X_n^j(\tau) - w_i^L(\tau) L_i^L(\tau) \right]$$

$$Z_i^H(\tau) = \frac{1}{w_i^H(\tau)} \sum_{j=1}^{J} \left[(1-\alpha_i^j)\delta_i^j \left(\frac{w_i^H(\tau)}{P_i^{M,j}(\tau)} \right)^{1-\rho} \sum_{n=1}^{N} \pi_{i,n}^j(\tau) X_n^j(\tau) - w_i^H(\tau) L_i^H(\tau) \right]$$

$$Z_i^K(\tau) = \frac{1}{r'_i(\tau)} \sum_{j=1}^{J} \left[(1-\alpha_i^j)(1-\delta_i^j) \left(\frac{r'_i(\tau)}{P_i^{M,j}(\tau)} \right)^{1-\rho} \sum_{n=1}^{N} \pi_{i,n}^j(\tau) X_n^j(\tau) - r'_i(\tau) K_i(\tau+1) \right]$$

5. **Update Factor Prices**

   Update factor prices by:

$$w_i^H(\tau+1) = w_i^H(\tau) \Big[1 + \psi \frac{Z_i^H(\tau)}{L_i^H(\tau)} \Big], \quad \forall i$$

$$w_i^L(\tau+1) = w_i^L(\tau) \Big[1 + \psi \frac{Z_i^L(\tau)}{L_i^L(\tau)} \Big], \quad \forall i,$$

$$r_i(\tau+1) = r_i(\tau) \Big[1 + \psi \frac{Z_i^K(\tau)}{K_i(\tau+1)} \Big], \quad \forall i,$$

where $\psi \in (0, 1]$.

6. **Check Convergence** Stop iteration if:

$$\max_i \left\{ \max \left\{ ||Z_i^H(\tau)||, ||Z_i^L(\tau)||, ||Z_i^K(\tau)|| \right\} \right\} < \text{tolerence}$$

   Go back to step 1 otherwise.

3.2.2 Computing Transitional Path

Consider the transitional path from $t = 0, 1, \ldots, T + T^*$. The path is split into three phases: (1) $t = 0$, the economy is at initial state; (2) the shock takes place at $t = 1$, and let $t = 1, 2, \ldots, T$ be the transitional phase; (3) $t = T + 1, \ldots, T + T^*$, is the terminal phase, such that economy reaches new steady state.

Equilibrium is a path of $\{w_{i,t}^H, w_{i,t}^L, r_{i,t}, L_{i,t}^H, L_{i,t}^L, K_{i,t}\}$ such that all equilibrium conditions are satisfied. Let x^{New} be the steady state of the variable x under the new economic environment. To solve the full transitional path, start with an initial guess of path on $\{w_{i,t}^H(0), w_{i,t}^L(0), r_{i,t}(0), L_{i,t}^H(0), L_{i,t}^L(0), K_{i,t}(0)\}$ such that:

$t = 0$: paths are set to initial condition.

$t = 1, \ldots, T$: arbitrary guess factor supply and factor prices such that $w_{i,t}^H(0) > w_{i,t}^L(0)$.

$t = T, \ldots, T + T^*$: paths are set to the new steady state x^{New}.

Furthermore, assume the economy reaches new steady state for any $t > T + T^*$.

Given the initial state, terminal state, and initial guess of prices, the procedure to solve the transitional path is the following:

1. **Update Labor Supply**

   Use the current guess of factor prices to solve ability thresholds $\bar{a}_{i,t}(\tau)$ for $t = 1, \ldots, T + T^*$:

$$\bar{a}_{i,t}(\tau) = \left[1 - \left(\frac{\prod_{s=1}^{\infty} (w_{i,t+s}^L(\tau))^{\beta^s}}{\prod_{s=1}^{\infty} (w_{i,t+s}^H(\tau))^{\beta^s}} \right)^{\frac{1}{\sum_{s=0}^{\infty} \beta^s}} \right]^{-1/\gamma_i}$$

$$=\left\{1-\left[\prod_{s=0}^{T+T^{*}-t}\left(\frac{w_{i,t+s}^{L}(\tau)}{w_{i,t+s}^{H}(\tau)}\right)^{\beta^{s}}\prod_{s=T+T^{*}-t+1}^{\infty}\left(\frac{w_{i}^{L,New}}{w_{i}^{H,New}}\right)^{\beta^{s}}\right]^{1-\beta}\right\}^{-1/\gamma_{i}}$$

$$=\left\{1-\left[\prod_{s=0}^{T+T^{*}-t}\left(\frac{w_{i,t+s}^{L}(\tau)}{w_{i,t+s}^{H}(\tau)}\right)^{\beta^{s}}\left(\frac{w_{i}^{L,New}}{w_{i}^{H,New}}\right)^{\frac{\beta^{T+T^{*}-1+1}}{1-\beta}}\right]^{1-\beta}\right\}^{-1/\gamma_{i}}$$

Compute skill supply sequentially for $t = 1, \ldots, T + T^{*}$:

$$L_{i,t}^{H}(\tau+1) =(1-\zeta)L_{i,t-1}^{H}(\tau+1)+\nu(\bar{a}_{i,t}(\tau),\gamma_{i})L_{i}$$
$$L_{i,t}^{L}(\tau+1) =(1-\zeta)L_{i,t-1}^{L}(\tau+1)+G(\bar{a}_{i,t}(\tau))L_{i}$$

2. **Update Trade Share and the Price Indices**

Scale factor prices such that:

$$\sum_{i=1}^{N}\left[w_{i,t}^{H}(\tau)L_{i,t}^{H}(\tau+1)+w_{i,t}^{L}(\tau)L_{i,t}^{L}(\tau+1)+r_{i,t}(\tau)K_{i,t}(\tau)\right]=1,\quad\forall t$$

Compute unit cost for all i, j, t:

$$p_{i,t}^{j,M}(\tau)=\left[\delta_{i}^{j}(w_{i,t}^{H}(\tau))^{1-\rho}+(1-\delta_{i}^{j})(r_{i,t}(\tau))^{1-\rho}\right]^{\frac{1}{1-\rho}}$$
$$c_{i,t}^{j}(\tau)=[w_{i,t}^{L}(\tau)]^{\alpha_{i}^{j}}[p_{i,t}^{M,j}(\tau)]^{1-\alpha_{i}^{j}}$$

Compute bilateral trade share:

$$\pi_{i,n,t}^{j}(\tau) =\frac{T_{i,t}^{j}[d_{n,i,t}^{j}c_{i,t}^{j}(\tau)]^{-\theta}}{\sum_{k=1}^{N}T_{k,t}^{j}[d_{n,k,t}^{j}c_{k,t}^{j}(\tau)]^{-\theta}}$$
$$=\frac{T_{i,t}^{j}[d_{n,i,t}^{j}c_{i,t}^{j}(\tau)]^{-\theta}}{\Phi_{n,t}^{j}(\tau)}$$

Compute sectoral price indices:

$$p_{n,t}^{j}(\tau)=C[\Phi_{n,t}^{j}(\tau)]^{-\frac{1}{\theta}}$$

where $C = \Gamma\left(\frac{\theta+1-\eta}{\theta}\right)^{\frac{1}{1-\eta}}$.

Compute CPI:

$$P_{n,t}(\tau) = \Big[\sum_{j=1}^{J}\big(p^{j}_{n,t}(\tau)\big)^{1-\sigma}\Big]^{\frac{1}{1-\sigma}}$$

3. **Update Capital Supply**

Compute real investment for all i, t using the current guess on the capital path

$$I_{i,t}(\tau) = K_{i,t+1}(\tau) - (1-\delta)K_{i,t}(\tau)$$

Use it to construct path of real consumption for representative household

$$C_{i,t}(\tau) = \frac{w^{H}_{i,t}(\tau)L^{H}_{i,t}(\tau+1) + w^{L}_{i,t}(\tau)L^{L}_{i,t}(\tau+1) + r_{i,t}(\tau)K_{i,t}(\tau)}{P_{i,t}(\tau)} - I_{i,t}(\tau)$$

The shadow price of real consumption for representative household is

$$\lambda_{i,t}(\tau) = \frac{1}{C^{i,t}(\tau)}$$

Compute average skill share$_{i,t}(\tau)$ similarly as in computing steady state. Let $W_{i,t}(\tau) = w^{H}_{i,t}(\tau)L^{H}_{i,t}(\tau+1) + w^{L}_{i,t}(\tau)L^{L}_{i,t}(\tau+1) + r_{i,t}(\tau)K_{i,t}(\tau)$. Equation (1.22) can be rewritten as

$$-\lambda_{i,t-1}(\tau) + \nu\lambda_{i,t}(\tau)\Big[\frac{\text{average skill share}_{i,t}(\tau)W_{i,t}(\tau)/K_{i,t}(\tau+1)}{P_{i,t}(\tau)} + (1-\delta)\Big] = 0$$

Rearrange this equation. Update capital supply by:

$$K_{i,t}(\tau+1) = \left[\frac{\text{average skill share}_{i,t}(\tau)W_{i,t}(\tau)}{P_{i,t}(\tau)}\right]\left[\frac{\lambda_{i,t-1}(\tau)}{\nu\lambda_{i,t}(\tau)} - (1-\delta)\right]^{-1}, \quad t = 2, \ldots, T+T^{*}$$

4. **Compute Excess Demand for Factors**

Scale factor prices again such that:

$$\sum_{i=1}^{N}\Big[w^H_{i,t}(\tau)L^H_{i,t}(\tau+1)+w^L_{i,t}(\tau)L^L_{i,t}(\tau+1)+r_{i,t}(\tau)K_{i,t}(\tau+1)\Big]=1,\quad \forall t$$

Then compute sectoral total expenditure:

$$X^j_{n,t}(\tau)=\Big[\frac{p^j_{n,t}(\tau)}{P_{n,t}(\tau)}\Big)^{1-\sigma}\times\big(w^H_{i,t}(\tau)L^H_{i,t}(\tau+1)+w^L_{i,t}(\tau)L^L_{i,t}(\tau+1)+r_{i,t}(\tau)K_{i,t}(\tau+1)\Big]$$

Then compute excess demand function:

$$Z^L_{i,t}(\tau)=\frac{1}{w^L_{i,t}(\tau)}\sum_{j=1}^{J}\left[\alpha^j_{i,t}\sum_{n=1}^{N}\pi^j_{i,n,t}(\tau)X^j_{n,t}(\tau)-w^L_{i,t}(\tau)L^L_{i,t}(\tau)\right]$$

$$Z^H_{i,t}(\tau)=\frac{1}{w^H_{i,t}(\tau)}\sum_{j=1}^{J}\left[(1-\alpha^j_i)\delta^j_i\left(\frac{w^H_{i,t}(\tau)}{P^{M,j}_{i,t}(\tau)}\right)^{1-\rho}\sum_{n=1}^{N}\pi^j_{i,n,t}(\tau)X^j_{n,t}(\tau)-w^H_{i,t}(\tau)L^H_{i,t}(\tau)\right]$$

$$Z^K_{i,t}(\tau)=\frac{1}{r_{i,t}(\tau)}\sum_{j=1}^{J}\left[(1-\alpha^j_i)(1-\delta^j_i)\left(\frac{r_{i,t}(\tau)}{P^{M,j}_{i,t}(\tau)}\right)^{1-\rho}\sum_{n=1}^{N}\pi^j_{i,n,t}(\tau)X^j_{n,t}(\tau)-r_{i,t}(\tau)K_{i,t}(\tau+1)\right]$$

5. **Update Factor Prices**

   Update factor prices for $t=1,\ldots,T+T^*$:

$$w^H_{i,t}(\tau+1)=w^H_{i,t}(\tau)\Big[1+\psi\frac{Z^H_{i,t}(\tau)}{L^H_{i,t}(\tau+1)}\Big]$$

$$w^L_{i,t}(\tau+1)=w^L_{i,t}(\tau)\Big[1+\psi\frac{Z^L_{i,t}(\tau)}{L^L_{i,t}(\tau+1)}\Big]$$

$$r_{i,t}(\tau+1)=r_{i,t}(\tau)\Big[1+\psi\frac{Z^K_{i,t}(\tau)}{K_{i,t}(\tau+1)}\Big]$$

   where $\psi\in(0,1]$.

6. **Check Convergence**

Stop iteration if:

$$\max_t \left\{ \max_i \left\{ \max \left\{ ||Z^H_{i,t}(\tau)||, ||Z^L_{i,t}(\tau)||, ||Z^K_{i,t}(\tau)|| \right\} \right\} \right\} < \text{tolerence.}$$

Go back to step 1 otherwise.

3.3 Calibration of Educational Institution γ_i

This section discusses the calibration procedure of educational institution γ_i for each country. The calibration procedure involves two nested loops. In the outer loop, I compute the steady state equilibrium given a guess of γ_i. The inner loop updates γ_i such that skill premium in the data is consistent to the ability threshold in the steady state equilibrium. Let $x(\tau)$ be the variable of x at τ^{th} iteration. Start with arbitrary initial guess of education institution $\{\gamma_i(0)\}_{i=1}^N$, $\gamma_i(0) > 0\ \forall i$. The calibration procedure is concluded in the following steps,

1. Compute steady state equilibrium using $\{\gamma_i(\tau)\}_{i=1}^N$. Record ability threshold in the steady state $\{\bar{a}_i(\tau)\}_{i=1}^N$.

2. Update education institution for each country by solving:

$$\gamma_i(\tau+1) : \bar{a}_i(\tau) - \left[1 - \left(\frac{w^{L,data}_{i,2000}}{w^{H,data}_{i,2000}} \right) \right]^{-\frac{1}{\gamma_i(\tau+1)}} = 0.$$

3. Stop iteration if

$$\max_i \left\{ ||\gamma_i(\tau+1) - \gamma_i(\tau)|| \right\} < \text{tolerence,}$$

go back to step 1 otherwise.

Appendix A
Figures and Tables

A.1 Tables

Table A.1: List of countries

ISO Code	Country Name	ISO Code	Country Name
AUS	Australia	JPN	Japan
AUT	Austria	KOR	Republic of Korea
BEL	Belgium	LVA	Latvia
BRA	Brazil	LTU	Lithuania
BGR	Bulgaria	LUX	Luxembourg
CAN	Canada	MLT	Malta
CHN	China	MEX	Mexico
CYP	Cyprus	NLD	Netherlands
CZE	Czech Republic	POL	Poland
DNK	Denmark	PRT	Portugal
EST	Estonia	ROU	Romania
FIN	Finland	RUS	Russia
FRA	France	SVK	Slovak Republic
DEU	Germany	SVN	Slovenia
GRC	Greece	ESP	Spain
HUN	Hungary	SWE	Sweden
IND	India	TWN	Taiwan
IDN	Indonesia	TUR	Turkey
IRL	Ireland	GBR	United Kingdom
ITA	Italy	USA	United States

Table A.2: Sector Codes in the World Input-Output Database

Industry code	Description
AtB	Agriculture, Hunting, Forestry and Fishing
C	Mining and Quarrying
15t16	Food, Beverages and Tobacco
17t18	Textiles and Textile Products
19	Leather, Leather and Footwear
20	Wood and Products of Wood and Cork
21t22	Pulp, Paper, Paper , Printing and Publishing
23	Coke, Refined Petroleum and Nuclear Fuel
24	Chemicals and Chemical Products
25	Rubber and Plastics
26	Other Non-Metallic Mineral
27t28	Basic Metals and Fabricated Metal
29	Machinery, Nec
30t33	Electrical and Optical Equipment
34t35	Transport equipment
36t37	Manufacturing, Nec; Recycling
E	Electricity, Gas and Water Supply
F	Construction
50	Sale, Maintenance and Repair of Motor Vehicles Retail Sale of Fuel
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles
52	Retail Trade, Except of Motor Vehicles ; Repair of Household Goods
H	Hotels and Restaurants
60	Inland Transport
61	Water Transport
62	Air Transport
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
64	Post and Telecommunications
J	Financial Intermediation
70	Real Estate Activities
71t74	Renting of M& Eq and Other Business Activities
L	Public Admin and Defence; Compulsory Social Security
M	Education
N	Health and Social Work

Table A.3: Industry Correspondence

Category	Industry Description
Agriculture, food and mining	AtB, 15t16, C
Machinery	29, 36t37, 34t35
High-skill manufacturing	24, 30t33
Low-skill manufacturing	21t22, 23, 25, 17t18, 19, 20, 26, 27t28
Low-skill service	50, 51, 52, 60, 61, 62, 63, 64, H, F
Professional service	J, 70, 71t74, L, M, N

Table A.4: Sector Characteristic

Sector	Share on L^L (α^j)	Share on L^H relative to K (δ^j)
Agriculture, food and mining	0.32	0.19
High-skill manufacturing	0.32	0.49
Low-skill manufacturing	0.43	0.33
Low-skill service	0.51	0.34
Machinery	0.47	0.39
Professional Service	0.27	0.44

Note: The U.S. data in year 2000 is used as baseline.

Table A.5: Estimation of Iceberg Trade Cost

Industry	log distance	border	common language	colonial
Agriculture,food and mining	-0.74	0.79	0.78	0.67
High-skill manufacturing	-0.51	0.82	0.58	0.45
Low-skill manufacturing	-0.65	1.00	0.83	0.52
Low-skill service	-0.79	-0.10	0.92	0.51
Machinery	-0.55	0.72	0.74	0.48
Professional	-0.77	-0.56	1.28	-0.19

Note: The parameters are estimated using data of year 2000 from WIOT.

Table A.6: Country Characteristics (year 2000)

Country	Skill Premium (w_i^H/w_i^L)	Relative Skill Supply (L_i^H/L_i^L)	Labor Force (thousands)
AUS	2.26	0.17	9130
AUT	1.75	0.19	3959
BEL	1.59	0.20	4165
BGR	2.30	0.08	3215
BRA	3.22	0.14	79544
CAN	1.53	0.26	15199
CHN	2.27	0.04	730250
CYP	1.89	0.40	322
CZE	1.97	0.14	4963
DEU	1.71	0.31	39316
DNK	1.34	0.37	2742.
ESP	1.77	0.39	16931
EST	1.81	0.46	578
FIN	1.41	0.47	2324
FRA	1.80	0.35	24765
GBR	1.65	0.42	29925
GRC	2.18	0.22	4261
HUN	2.35	0.19	4232
IDN	3.74	0.06	93437
IND	4.67	0.06	432376
IRL	1.54	0.33	1748
ITA	1.97	0.13	23393
JPN	1.63	0.31	64760
KOR	1.69	0.72	21557
LTU	1.87	0.35	1346
LUX	1.73	0.26	278
LVA	2.07	0.28	953
MEX	2.93	0.14	40103
MLT	2.29	0.11	149
NLD	1.59	0.29	8282
POL	1.86	0.16	14195
PRT	2.96	0.08	5121.
ROU	2.15	0.05	10657
RUS	2.35	0.14	74727
SVK	1.74	0.16	2037
SVN	2.27	0.18	909
SWE	1.34	0.33	4391
TUR	3.38	0.10	21524
TWN	1.86	0.32	9383
USA	1.93	0.43	146818

Note: See the Appendix (3.1) for the detail of the calculation.

Table A.7: The Baseline Equilibrium in the Steady State

	Educational	Skill	Relative	Real Wages Relative to real wage of USA		
	Institution	Premium	Skill Supply	Skilled	Unskilled	Avg
Country	γ_i	w_i^H/w_i^L	L_i^H/L_i^L	w_i^H/P_i	w_i^L/P_i	w_i/P_i
AUS	0.66	2.26	0.47	131.21	58.04	70.18
AUT	1.04	1.75	0.63	234.80	134.29	157.02
BEL	1.27	1.59	0.71	375.26	235.99	271.81
BGR	0.57	2.30	0.37	24.30	10.56	12.37
BRA	0.34	3.22	0.25	19.45	6.04	7.20
CAN	1.30	1.53	0.67	247.76	162.09	183.51
CHN	0.52	2.27	0.31	5.24	2.31	2.64
CYP	0.89	1.89	0.56	221.92	117.44	138.54
CZE	0.77	1.97	0.48	67.15	34.01	39.82
DEU	1.06	1.71	0.61	178.35	104.59	121.04
DNK	1.83	1.34	0.83	197.62	147.04	162.61
ESP	0.98	1.77	0.58	113.35	64.17	74.51
EST	0.76	1.81	0.39	9.03	4.99	5.59
FIN	1.60	1.41	0.76	187.73	133.10	148.60
FRA	0.98	1.80	0.61	190.83	106.03	124.48
GBR	1.19	1.65	0.69	182.02	110.26	128.02
GRC	0.67	2.18	0.45	98.85	45.41	53.94
HUN	0.61	2.35	0.43	68.76	29.25	35.26
IDN	0.27	3.74	0.20	8.54	2.29	2.71
IND	0.21	4.67	0.16	7.32	1.57	1.87
IRL	1.46	1.54	0.82	276.61	179.76	207.84
ITA	0.80	1.97	0.51	169.12	85.64	101.06
JPN	1.14	1.63	0.63	143.44	87.84	100.70
KOR	1.04	1.69	0.58	83.69	49.38	56.76
LTU	0.82	1.87	0.48	44.14	23.66	27.26
LUX	1.19	1.73	0.75	596.92	345.83	411.50
LVA	0.68	2.07	0.42	46.72	22.52	26.25
MEX	0.41	2.92	0.31	50.10	17.13	20.65
MLT	0.70	2.29	0.52	465.52	203.32	250.42
NLD	1.27	1.59	0.70	215.26	135.74	156.01
POL	0.86	1.86	0.51	63.92	34.34	39.88
PRT	0.44	2.96	0.34	141.14	47.64	58.71
ROU	0.62	2.15	0.39	22.87	10.62	12.35
RUS	0.50	2.35	0.30	14.95	6.37	7.32
SVK	0.77	1.74	0.37	4.16	2.40	2.65
SVN	0.51	2.27	0.30	3.95	1.74	1.98
SWE	1.83	1.34	0.81	162.43	121.54	134.00
TUR	0.33	3.38	0.25	36.03	10.65	12.86
TWN	0.91	1.86	0.57	121.28	65.24	76.66
USA	0.88	1.93	0.57	162.16	84.08	100.00
Average	0.87	2.11	0.51	134.85	76.12	88.66

Note: All real wages are relative to the U.S. average real wage. And the U.S. average real wage is normalized to 100.

Table A.8: Counterfactual Changes(%) Resulting from Trade Liberalization

Country	Skill Premium (w_i^H/w_i^L)	Relative Skill Supply (L_i^H/L_i^L)	Real Wage for Skilled (w_i^H/P_i)	Real Wage for Unskilled (w_i^L/P_i)	Average Wage (w_i/P_i)
AUS	0.99	1.62	32.33	31.03	31.70
AUT	0.63	1.22	21.90	21.14	21.54
BEL	0.46	0.98	13.80	13.28	13.56
BGR	1.26	2.15	31.21	29.58	30.33
BRA	1.61	2.43	37.11	34.94	35.91
CAN	0.46	1.05	14.10	13.57	13.84
CHN	1.58	2.82	36.03	33.91	34.79
CYP	0.86	1.59	28.46	27.36	27.93
CZE	0.86	1.56	26.01	24.94	25.46
DEU	0.56	1.13	22.11	21.43	21.78
DNK	0.52	1.42	25.96	25.31	25.65
ESP	0.79	1.54	27.67	26.67	27.18
EST	1.26	2.61	33.31	31.65	32.35
FIN	0.66	1.66	22.77	21.97	22.39
FRA	0.57	1.09	23.14	22.44	22.81
GBR	0.61	1.24	24.07	23.32	23.72
GRC	0.97	1.65	29.26	28.02	28.64
HUN	0.84	1.36	28.79	27.71	28.26
IDN	1.86	2.74	38.75	36.22	37.30
IND	1.86	2.61	35.68	33.20	34.26
IRL	0.76	1.64	19.42	18.53	19.03
ITA	0.69	1.23	26.28	25.42	25.86
JPN	0.57	1.21	24.82	24.11	24.47
KOR	0.74	1.50	26.45	25.53	25.99
LTU	1.05	2.02	29.94	28.59	29.23
LUX	0.74	1.40	15.50	14.65	15.13
LVA	1.20	2.14	30.64	29.10	29.82
MEX	0.82	1.24	29.32	28.28	28.77
MLT	0.59	0.94	25.56	24.82	25.23
NLD	0.60	1.29	21.31	20.58	20.97
POL	0.86	1.63	26.92	25.83	26.36
PRT	0.91	1.34	27.89	26.74	27.32
ROU	1.22	2.16	32.72	31.12	31.85
RUS	1.31	2.28	34.30	32.56	33.29
SVK	1.50	3.29	31.35	29.41	30.18
SVN	1.47	2.66	32.15	30.23	31.01
SWE	0.56	1.56	25.90	25.19	25.56
TUR	1.24	1.82	31.52	29.91	30.65
TWN	0.61	1.14	25.78	25.01	25.41
USA	0.73	1.31	26.85	25.93	26.42
Average	0.93	1.71	27.43	26.23	26.80

Note: Numbers are in %.

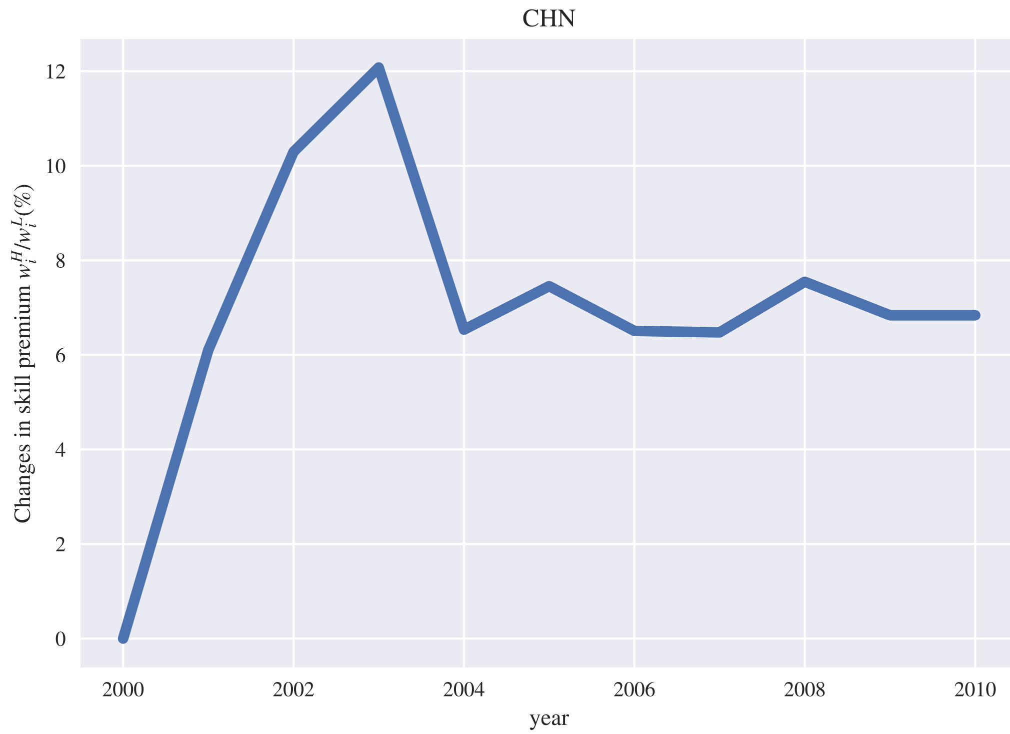
Table A.9: Decomposition of Changes in Skill Premium(%) resulting from Trade Liberalization

	Changes in Skill Premium (%)			
	(1)	(2)	(3)	(4)
Country	Short-run	Medium-run	Long-run	(1-(3)/(2))×100
AUS	-0.25	2.61	0.99	61.97
AUT	0.22	1.86	0.63	66.14
BEL	0.13	1.46	0.46	68.46
BGR	-0.14	3.44	1.26	63.31
BRA	-0.49	4.07	1.61	60.48
CAN	-0.37	1.55	0.46	70.09
CHN	-0.95	4.46	1.58	64.51
CYP	0.00	2.44	0.86	64.62
CZE	-0.19	2.44	0.86	64.74
DEU	-0.23	1.71	0.56	67.16
DNK	-0.35	1.94	0.52	73.20
ESP	-0.28	2.34	0.79	66.26
EST	-0.40	3.96	1.26	68.14
FIN	0.48	2.31	0.66	71.52
FRA	-0.36	1.68	0.57	65.96
GBR	-0.14	1.85	0.61	67.18
GRC	-0.12	2.62	0.97	63.03
HUN	-0.30	2.22	0.84	62.09
IDN	-0.57	4.66	1.86	60.02
IND	-0.58	4.52	1.86	58.82
IRL	0.75	2.37	0.76	68.03
ITA	-0.32	1.94	0.69	64.53
JPN	-0.44	1.79	0.57	67.96
KOR	-0.37	2.24	0.74	67.12
LTU	-0.19	3.10	1.05	66.05
LUX	0.87	2.10	0.74	65.05
LVA	-0.06	3.35	1.20	64.25
MEX	-1.10	2.09	0.82	60.89
MLT	-0.00	1.55	0.59	61.91
NLD	-0.15	1.90	0.60	68.31
POL	-0.29	2.52	0.86	65.74
PRT	-0.23	2.27	0.91	59.77
ROU	-0.42	3.39	1.22	63.98
RUS	-0.81	3.67	1.31	64.36
SVK	0.23	4.89	1.50	69.29
SVN	-0.41	4.23	1.47	65.18
SWE	0.10	2.11	0.56	73.32
TUR	-0.28	3.12	1.24	60.20
TWN	-0.47	1.77	0.61	65.52
USA	-0.20	2.04	0.73	64.11
Average	-0.22	2.66	0.93	65.33

Note: Column (4) records the proportion of trade induced inequality reduced by education.

A.2 Figures

Figure A.1: Percentage Change in Chinese Skill Premium since 2000



Note: The skill premium is computed using data from Social Economic Account in WIOD. See the Appendix (3.1) for the details.

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