Trade and Inequality: Educational and Occupational Choices Matter

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Abstract

How does trade affect inequality? Using recent cross country data, I document a positive association between trade and skill intensity, but I find no association between trade and the skill premium. To explain these findings, I develop a tractable model of trade featuring heterogeneous firms, skill-biased productivity, and agents' educational and occupational choices. These choices endogenize changes in the supply of high-skilled labor, rationalizing observed changes in the quantity of skilled labor rather than its price. The model also has testable implications about the occupational responses to trade, for which I find evidence in the data. I quantify the model and simulate the effects of China's entry into the WTO on the skill premium. I find that the effect of trade on the skill premium is less severe than previous literature suggests. Nevertheless, my counterfactual analysis implies that reducing the cost of education redistributes the gains from trade from firm profits to worker wages.

Keywords: exports, welfare, human capital.

JEL Classification: F12, F14, F16, J24

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1 Introduction

What are the distributional consequences of trade? The rise of globalization has increased concern about the winners and losers of trade policy, and in particular about the potential for trade to amplify inequality. Classic trade theory predicts that trade liberalizations will increase the wage gap between high- and low-skilled workers (the skill premium) in skill-abundant countries, and decrease the skill premium in skill-scarce countries. More recent literature suggests that trade increases demand for skilled labor in all countries. However, fully evaluating the differential effects of trade requires a general equilibrium analysis of its impact on both the demand and the supply of skilled labor.

In this paper, I start by documenting a puzzling fact about recent cross country data: changes in trade are positively associated with increases in the share of high-skilled hours worked (skill intensity), but not with the skill premium. Although descriptive, these correlations suggest that trade indeed increases demand for skilled labor, but the adjustment takes place through an expansion in skill intensity rather than the skill premium. To explain this puzzle, I develop a tractable, general equilibrium model of trade wherein heterogeneous firms and skill-biased productivity increase demand for skilled labor following a liberalization, while agents' educational and occupational choices increase the supply of skilled labor, both in the long run and in the short run. I calibrate this model, and simulate a reduction in trade barriers that results in an increase in trade flows similar to the one following China's accession into the WTO. Endogenizing the skill supply response to trade mitigates the impact of trade on the skill premium absent supply channels. While adjustments to skill supply increases the gains from trade, these gains disproportionately accrue to surviving firms who gain relative to workers. Counterfactual exercises on a reduction in the cost of education show the role of policy in reducing inequality between educated and uneducated agents, as this influences not only the skill premium but the relative gains of workers and entrepreneurs.

Empirically, I examine the relationship between trade, skill intensity and the skill premium using data from 37 countries from 1995 to 2009. Exploiting variation in the log changes in export share, there is an economically meaningful association between exports and skill intensity. However, there is no relationship between exports and the skill premium. These findings are true in the short run, using a stacked differences approach, and in the long run, examining long differences over the period of the sample. Moreover, these findings hold for both skill-abundant and skill-scarce countries. This is consistent with recent trade theories that predict an association between trade and skill demand regardless of factor abundance, but puzzling in that the adjustment occurs in quantities rather than prices.

To explain the observed facts, I develop a general equilibrium model of trade with heterogeneous firms featuring standard and novel ingredients. Consistent with the literature on skill-bias in trade, the model features skill-biased productivity. This feature produces the correlation between trade shares and relative demand for skilled labor in the model, which maps to skill intensity in the data. The model has two novel features. First, to match the long run stability of the skill premium, I endogenize skill supply through schooling. Second, to match the short run stability of the skill premium, I add occupational switching. I consider how each component affects the labor market equilibrium in response to trade using comparative statics.

I introduce a skill-biased production technology as in Burstein and Vogel (2016), to account for trade's association with increased skill intensity in both skill-abundant and skill-scarce countries. The skill-biased production technology implies that the largest, most productive firms rely more heavily on high-skilled labor. As the largest, most productive firms are also most likely to engage in trade, trade liberalizations increase demand for skilled labor. If factor shares were constant, the skill premium would increase.

I introduce educational choice to explain the long run association in the data between trade and skill intensity rather than the skill premium. I model agents with heterogeneous education costs, who decide between attending school and becoming either entrepreneurs or high-skilled workers, or not attending school and remaining low-skilled workers. As the benefit of being an educated agent increases with trade, more agents choose to attend school. This mechanism alone predicts a long run attenuation in the skill premium.

Finally, the occupational choice of educated agents explains the positive association between trade and skill intensity in the short run. An educated agent may either become an entrepreneur or provide high-skilled labor. Following a trade liberalization, the least productive firms exit, with their entrepreneurs switching occupations to become high-skilled workers. This increases skill intensity and mitigates the skill premium increases caused by skill-biased productivity, mapping to the short run associations in the data. Meanwhile, surviving entrepreneurs face less competition and increased profits. This drives agents' incentives to increase their educational attainment.

Skill-biased productivity, educational choice and occupational choice are sufficient ingredients to explain the observed facts in the data. Moreover, my model makes additional predictions about firm responses to increased trade: namely, that profitability increases and that the share of entrepreneurs declines in the short run. I find evidence of increased firm profitability by documenting a short run decline in labor share associated with short run increases in trade using the cross country data. I interpret this as suggesting an increase in firm profits. To examine entrepreneurial exit, I use US state-level data. I document that similar associations between trade, the skill premium and skill intensity occur across US states as across countries. Following increases in trade, I observe a decline in the share of entrepreneurs.

To examine quantitative relevance of these mechanisms, I calibrate a three country version of the model and simulate a trade liberalization similar to China's entry into the WTO. Shutting down the educational and occupational choice channels, my model predicts an increase in the skill premium consistent with the literature. Adding agent occupational choice, skill intensity increases and a the skill premium is stable, in line with the short run associations in the data. Incorporating educational choice is important to quantitatively match the long run increases in skill intensity. I also demonstrate the importance of the changes in competition resulting from reductions in trade barriers in generating the skill intensity effect relative to the counterfactual effect of a uniform increase in the demand for skilled labor in the production technology.

Though my model generates skill premium stability in the short run, surviving firms gain relative to workers, increasing the benefit of education. Increased education, on the other hand, also increases competition between firms, transferring gains from firms to workers of both types. I conduct counterfactual exercises on a reduction in education costs, and find it increases labor share, reduces firm profits and reduces inequality between educated and uneducated agents.

Understanding the relationship between trade and inequality is a first-order issue in international economics. According to the Stolper-Samuelson theorem, upon a trade liberalization, the skill premium should increase in skill-abundant countries and decrease in skill-scarce countries. Goldberg and Pavcnik (2007), however, find that early trade liberalizations in developing (skill-scarce) economies are associated with increased inequality. Explanations for this include trade-induced skill-biased technological change, e.g. Acemoglu (2003), capital-skill complementarity, e.g. Parro (2013), factor intensity across traded and non-traded sectors, e.g. Cravino and Sotelo (2017), and skill-bias in productivity, e.g. Burstein and Vogel (2016). The skill-bias mechanism aligns with evidence that the largest, most productive firms engage most heavily in trade and rely more heavily high-skilled labor, e.g. Bernard, Jensen, Redding, and Schott (2007). While my empirical finding is consistent with this mechanism for skill demand, my findings suggest skill supply also responds in equilibrium.

The literature considers both macro and microeconomic responses of skill supply to trade. Blanchard and Willmann (2016) and Blanchard and Olney (2017) provide theoretical rationale and empirical evidence respectively, for increases in educational attainment in response to trade at a macro level. Edmunds, Pavcnik, and Topalova (2008) find microeconomic evidence of trade increasing schooling in India, while Atkin (2016) find schooling responds to changes in rewards to education following liberalizations in Mexico. Danziger (2017) incorporates changes in the supply of skilled labor though schooling in a general equilibrium context, finding long-run skill premium stabilization through the educational channel. However, as I document an increase in skill intensity and not the skill premium in the short run, my model adds an occupational choice channel which both explains the short run finding, and motivates increased educational attainment in the long run.

Direct empirical estimation of the distributional consequences of trade is often difficult to implement at the country level. Autor, Dorn and Hanson (2013, 2016) use the China shock to estimate the effect of import competition on workers, offering invaluable insights to the effects of trade on local markets. Galle, Rodríguez-Clare, and Yi (2017) and Lee and Yi (2017) provide structural estimates of the general equilibrium effect of trade on the skill premium through the impact of trade on cross-sector mobility by skill group. My model, in contrast focuses on effects of trade when agents can move across skill categories rather than across sectors. I find a one sector model with educational and occupational choice is sufficient to explain the observed facts in the data.

The remainder of the paper is structured as follows: Section 2 presents novel stylized facts about trade, the skill premium and skill intensity. In Section 3 I describe the model, I then discuss its predictions for the impact of trade in Section 4 and its additional testable implications in Section 5. In Section 6, I quantify the model and conduct counterfactual analysis on the impact of a reduction in the cost of education. Section 7 concludes.

2 Facts about Exports, Skill Intensity and the Skill Premium

In this section, I examine empirically the relationship between exports, skill intensity and the skill premium.

2.1 Data

I obtain data on wages and hours worked by skill level in a sample of 37 countries covering the years 1995 to 2009 from the World Input Output Database (WIOD).[1] Skill level is defined by three categories: high-skilled workers are those with some tertiary degree (e.g. at least an associate's degree), middle-skilled workers have at least a high-school education and low-skilled workers are those without a high school degree. For my main analysis, I group the middle-skilled and low-skilled workers into one category (hereafter low-skilled workers), but my results are robust to a variety of alternative groupings. I merge these data with data on exports, imports and GDP for each country from the World Bank's World Development Indicators (WDI) dataset.

[1] For sample selection details, see Appendix A.

2.2 Skill Premium, Skilled Hours and Exports, Short Run

To fix ideas, I present two figures on the short run relationship between skill intensity, the skill premium and exports. The left panel of Figure 1 illustrates the relationship between the skill premium and exports. I plot two-year[2] changes in the log ratio of high- to low-skilled wages by two year changes in the log ratio of exports to GDP, controlling for year fixed effects. Surprisingly, I find no relationship between changes in exports and changes in the skill premium.

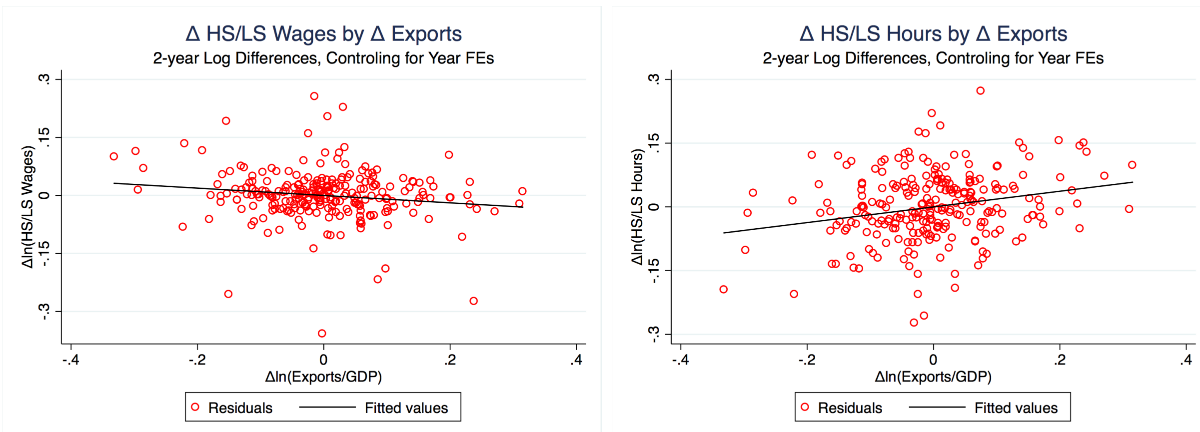

Figure 1: **Skill Premium and Skill Intensity by Export Percentage, Short Run.** The left panel shows the relationship between changes in export share and changes in the skill premium. The right panel shows the relationship between changes in export share and changes in the ratio of high- to low-skilled hours worked. Both control for year fixed effects. Data source: World Input-Output Database, Socio-Economic Accounts and World Bank World Development Indicators. All variables defined in two-year log differences for odd years, 1995-2009.

The right panel of Figure 1, illustrates the relationship between changes in the skill intensity and changes in exports. I plot two-year changes in the ratio of high- to low-skilled hours by two-year changes in the ratio of exports to GDP, finding a positive association between exports and the share of hours worked by high-skilled labor.

To further examine this finding, I specify a stacked differences regression:

[2] I consider two year differences as it smooths errors and accounts for the fact that some data in the sample are imputations while maximizing the use of the sample period. Considering one and three year differences produce similar results, as seen in Appendix B.

$$ln(Y_{i,t}) - ln(Y_{i,t-2}) = \beta_0 + \beta_1 \Big(ln\Big(\frac{Exp_{i,t}}{GDP_{i,t}}\Big) - ln\Big(\frac{Exp_{i,t-2}}{GDP_{i,t-2}}\Big)\Big) + f_t + \epsilon_{i,t}, \quad (1)$$

where Y is the outcome variable of interest, either the skill premium or the ratio of high- to low-skilled hours. The identifying source of variation is across country differences in changes in export percentage. The coefficient of interest, β_1, represents the effect of changes in the log of export share on the log of the skill premium or the log of high- to low-skilled hours. I include year fixed effects, f_t and cluster standard errors at the country level. The plots in Figure 1 correspond directly to Columns 1 and 5 in Table 1. The former shows a weak negative relationship between changes in export share and the skill premium, while the latter shows a strong positive relationship between changes in export share and changes in the ratio of high- to low-skilled workers.

	(1) wages	(2) wages	(3) wages	(4) wages	(5) hours	(6) hours	(7) hours	(8) hours
Exports/GDP	-0.095*	-0.095	0.007	-0.146	0.184***	0.218***	0.194	0.187**
	(0.049)	(0.059)	(0.066)	(0.099)	(0.048)	(0.070)	(0.108)	(0.075)
Group	All	Hi-S	Mid-S	Low-S	All	Hi-S	Mid-S	Low-S
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Country	Country	Country	Country	Country	Country	Country	Country
N Obs	249	102	63	84	249	102	63	84

Table 1: **Skill Premium and Skill Composition by Exports, Short Run.** Columns (1) to (4) show the relationship between changes in export share and changes in the skill premium. Columns (5) to (8) show the relationship between changes in export share and changes in the ratio of high- to low-skilled hours worked. Data source: World Input-Output Database, Socio-Economic Accounts and World Bank World Development Indicators. All variables defined in two-year log differences for odd years, 1995-2009.

The Stolper-Samuelson theorem predicts that trade increases the demand for skilled labor in skill-abundant countries, but decreases it in skill-scarce countries. I test this prediction by grouping countries by their skill abundance in 1995, as high-, middle- and low- skilled[3]. Columns 2-4 of Table 1 show that the near zero relationship between exports and the skill

[3]For the results in Table 1, I define a country as skill abundant if more than 18% of their labor force was high-skilled in 1995 ("Hi-S"), as skill scarce if less than 10% of the labor force was high-skilled in 1995 ("Low-S"), with the remaining countries forming the middle skilled group ("Mid-S"), which produces intuitive groupings at natural break points. I try a variety of alternate specification, following similar principals, and the results are robust to alternate specifications.

premium is persistent across countries regardless of initial skill abundance, while Columns 6-8 show the positive relationship between skill utilization and exports does not depend on initial skill abundance.

In Appendix B, I consider several alternate specifications of the short run relationships and find similar results. The positive relationship between skill intensity and exports is robust to taking one, two or three year differences in alternate years, while alternate specifications show either no relationship or a slight negative relationship between the skill premium and exports. Alternate definitions of trade (imports or total trade shares) yield similar results. I also specify a panel regression, testing the relationships using country and year fixed effects and reach similar conclusions. Finally, regressions using log exports and log GDP as a control variable yield similar results.

2.3 Skill Premium, Skilled Hours and Exports, Long Run

I further investigate the relationship between exports, the skill premium and skilled hours in the long run. The left panel of Figure 2 illustrates the relationship between exports and the skill premium in ten year differences from 1995 to 2005. As before, I find no relationship between changes in exports and changes in the skill premium.

The right panel of Figure 2 illustrates a strong positive association between changes in high-skilled hours and changes in the export share. I use ten year differences as educational attainment data some countries is imputed as constant after 2005. However, as I show in Table 2, I find similar results using ten year differences in 2005, twelve year differences in 2007 and fourteen year differences in 2009 for countries with available data.

Columns 1-3 of Table 2 show no relationship between changes in export share and the skill premium in the long run. Columns 4 of Table 2 shows a positive relationship between increases in export share and increases in skilled hours over the ten year horizon, while Columns 5 and 6 show similar coefficients over the twelve and fourteen year horizons for the countries with available data.

The findings in this section are consistent with the recent literature in that they suggest

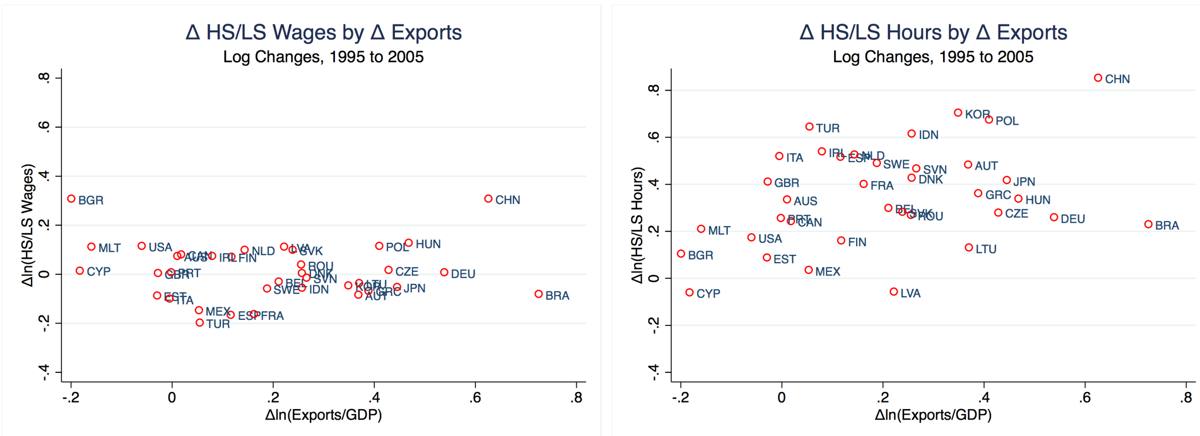

Figure 2: **Skill Premium and Skill Intensity by Export Percentage, Long Run.** The left panel shows the relationship between changes in export share and changes in the skill premium. The right panel shows the relationship between changes in export share and changes in the ratio of high- to low-skilled hours worked. Data source: World Input-Output Database, Socieo-Economic Accounts and World Bank World Development Indicators. All variables defined in ten year log differences.

	(1)	(2)	(3)	(4)	(5)	(6)
	wages	wages	wages	hours	hours	hours
Ex/GDP, 10yr Change	-0.019			0.346*		
	(0.116)			(0.173)		
Ex/GDP, 12yr Change		0.079			0.283	
		(0.115)			(0.199)	
Ex/GDP, 14yr Change			0.055			0.243
			(0.116)			(0.185)
N Obs	36	33	32	36	33	32

Table 2: **Skill Premium and Skill Composition by Exports, Long Differences.** Columns (1) to (3) show the relationship between changes in export share and changes in the skill premium. Columns (4) to (6) show the relationship between changes in export share and changes in the ratio of high- to low-skilled hours worked. Data source: World Input-Output Database, Socieo-Economic Accounts and World Bank World Development Indicators. Columns 1 and 4 are ten year differences from 1995 to 2005; Columns 2 and 5 are twelve year differences from 1995 to 2007; Columns 3 and 6 are fourteen year differences from 1995 to 2009.

a link between trade and demand for skilled labor in all countries, regardless of initial skill abundance, is consistent with the findings of Goldberg and Pavcnik (2007) that trade increases inequality in developing countries in contrast to the Stolper-Samuelson predictions. However, my findings are surprising in that the link is through skill intensity rather than the skill premium. These data are later and cover a wider set of countries, and imply a more complicated picture of the relationship between trade and skill. Models that only take into account changes in demand for skilled labor can only account for changes in the price of skill, not in its quantity. In the next section, I develop a model that can explain these novel facts in both the short and long run.

3 Closed Economy Model

In Section 2, I presented puzzling evidence that increases in exports are associated with increases in the quantity rather than the price of skilled labor. Understanding this puzzle requires understanding how both demand and supply of skilled labor respond to trade in general equilibrium. To capture the fact that trade is associated with skill intensity in the data, regardless of a country's initial skill-abundance, I nest existing models of heterogeneous firms and skill-biased productivity. To reconcile the long run association between trade and skill intensity rather than the skill premium, I add agents' educational choice. To account for the short run association of trade with skill intensity, and to motivate changes in educational choice despite skill premium stability, I add educated agents' occupational choice. These ingredients are sufficient to explain the observed facts. This model has rich predictions for firms that can be taken to the data. Moreover, this is a tractable model that can be calibrated and used for counterfactual exercises.

3.1 Preferences, Educational and Occupational Choices

There is a continuum of agents with identical constant elasticity of substitution (CES) preferences over a continuum of product varieties, Ω:

$$U = \left(\int_{\Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}, \quad (2)$$

where $q(\omega)$ is the quantity of variety ω and $\sigma > 1$ is the elasticity of substitution between varieties.

Agents are heterogeneous in ability, and face an educational choice which determines their skill level. Each agent has schooling ability, $a \sim F(a)$, distributed continuously on the support $[0,1]$ and faces a binary schooling choice. If he does not attend school ($s = 0$) he incurs no schooling cost, becomes a low-skilled worker and earns the low-skilled wage, w_ℓ. If he attends school ($s = 1$), he incurs a schooling cost which is inversely related to his ability:

$$C(s = 1|a) = c_s(1 - a), \tag{3}$$

where c_s is the cost incurred by the agent with the lowest ability. An agent of ability a attends school if his expected income, I, conditional on schooling exceeds the low-skilled wage plus schooling costs:

$$E(I|s = 1) \geq w_\ell + c_s(1 - a). \tag{4}$$

Schooling costs are monotonic in ability and expected income from schooling is independent of ability[4], ensuring a single crossing property in educational choice. For a wide range of production technologies, it is easy to show there exists an interior threshold $a^* \in (0,1)$ such that only the workers with an ability $a > a^*$ choose to be educated. Letting N be the exogenously defined mass of workers in an economy, the mass of low-skilled workers is given by $N_\ell = N * (1 - F(a^*))$.

An educated agent may either start a firm or become a high-skilled worker, earning the high-skilled wage, w_h. An educated agent has a management productivity draw $z \sim G(z) : (0, \infty) \rightarrow [0,1]$ which determines the productivity of her firm if she decides to become and entrepreneur. Letting $\pi(z, w_h, w_\ell)$ denote the profits from running a firm with productivity z given high- and low-skilled wages, then an educated agent becomes an entrepreneur if:

$$\pi(z, w_h, w_\ell) \geq w_h. \tag{5}$$

[4] It is sufficient for the benefits of schooling to be weakly increasing in ability.

3.2 Technology and Firms' Decisions

Each firm hires n_h units of high-skilled labor and n_ℓ units of low skilled labor to produce a single product variety. The production technology is skill-biased in productivity, as in Burstein and Vogel (2016), such that a firm with productivity z produces:

$$F(z, n_\ell, n_h) = Az\left[\alpha^{\frac{1}{\rho}}\left(z^{\frac{\phi}{2}}n_h\right)^{\frac{\rho-1}{\rho}} + (1-\alpha)^{\frac{1}{\rho}}\left(z^{\frac{-\phi}{2}}n_\ell\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}, \tag{6}$$

where $\phi > 0$ governs the degree of skill-bias in productivity. High- and low- skilled labor are combined with a CES technology where $\rho > 1$ is the elasticity of substitution and $\alpha \in (0, 1)$ is a share parameter governing the relative importance of each skill type in the production process. $A > 0$ is a common technology parameter.

Equation (6) implies that the relative share of high- to low-skilled labor at a firm run by a manager with knowledge z is given by:

$$\frac{n_h}{n_\ell} = \frac{\alpha}{1-\alpha}\left(\frac{w_h}{w_\ell}\right)^{-\rho} z^{\phi(\rho-1)}. \tag{7}$$

Equation (7) shows that the share of high-skilled workers is increasing in a firm's productivity. The higher ϕ and ρ, the greater the dispersion in high- to low-skilled labor shares across productivity draws. The higher the skill premium, lower the share of high-skilled workers at all firms, with sensitivity increasing in skill elasticity. A firm's total cost is given by $TC(F(z, n_\ell, n_h)) = w_\ell n_\ell + w_h n_h$. Combining this with Equations (6) and (7) yields a firm's constant marginal cost:

$$MC(z) = w_\ell \frac{(1-\alpha)^{\frac{1}{1-\rho}}}{Az}\left(z^{\frac{-\phi}{2}(\rho-1)} + \frac{\alpha}{1-\alpha} z^{\frac{\phi}{2}(\rho-1)}\left(\frac{w_h}{w_\ell}\right)^{(1-\rho)}\right)^{\frac{1}{1-\rho}} \tag{8}$$

Equation (8) demonstrates that a firm's overall production costs are decreasing in management productivity as long as $\phi < 2$.[5] As a firm's reliance on high-skilled workers is increasing in productivity, the lower the skill premium, the faster marginal costs decline

[5] In the calibration I follow Burstein and Vogel (2016) and set $\phi = 1$

with productivity.

As in Bernard, Jensen, Eaton and Kortum (2003) (BEJK), firms compete both within and across varieties. Competition across varieties is standard and common to the literature on heterogeneous firms and trade. Direct, Bertrand competition occurs within each variety between prospective entrepreneurs, defined as educated agents who would choose entrepreneurship conditional on being a monopolist. Three departures from the BEJK framework are necessary to incorporate the fact that each firm represents a unique entrepreneur. First, the probability that a firm faces direct competition is increasing in the share of prospective entrepreneurs. This ensures that a reduction in the share of prospective entrepreneurs does not counterintuitively harm those who reman. Second, to rationalize the occupational choice decision, Bertrand competition between prospective entrepreneurs in the same variety considers their outside option, w_h. Third, as each entrepreneur is an agent, the mass of product varieties Ω is endogenously determined by the mass of producing entrepreneurs.

An educated agent always has the outside option of becoming a high-skilled worker and receiving the high-skilled wage, w_h. Therefore, an educated agent will only ever become an entrepreneur if her profits, $\pi^m(z, w_h, w_\ell)$ as a monopolist are at least the high-skilled wage. A prospective entrepreneur is an educated agent for whom this is true. Defining z^* as the productivity for which $\pi^m(z^*, w_h, w_\ell) = w_h$, the mass of prospective entrepreneurs, M is:

$$M = N\big(1 - G(z^*)\big)\big(1 - F(a^*)\big). \tag{9}$$

By assumption, each prospective entrepreneur faces at most one domestic competitor,[6] with probability $\nu = (M/N)^\lambda$. The probability of facing a competitor is increasing in the share prospective entrepreneurs M/N and $\lambda > 0$ is a shape parameter determining how the share of prospective entrepreneurs affects the probability of direct competition.

All prospective entrepreneurs draw productivity from the same distribution. Therefore, if a

[6]This is consistent with Burstein and Vogel (2016) who depart from BEJK by modeling two competitors in each country drawn from an identical distribution, with the first-best being the more productive of the two and the second-best being the less productive. As the distribution of marginal costs cannot be solved analytically due to the production function, the loss from this assumption is minor.

prospective entrepreneur faces direct competition, she faces one with a productivity drawn from the distribution of prospective entrepreneurs, whose PDF is given by:

$$h(z) = \begin{cases} 0 & \text{if } z < z^* \\ \frac{g(z)}{\left(1-G(z^*)\right)} & \text{if } z \geq z^*. \end{cases} \tag{10}$$

In addition to observing her own productivity, z, a prospective entrepreneur observes whether or not she faces a rival, and if she does, observes the rival's productivity and makes a frictionless entry decision.

To rationalize the Bertrand competition game between two prospective entrepreneurs, each prospective entrepreneur considers her opponent's outside option, w_h. Let two prospective entrepreneurs have productivites z and z' with $z' < z$. Define$p^m(z)$ as the monopolist price of the prospective entrepreneur with productivity z and $\tilde{p}(z')$ as the minimum price at which the prospective entrepreneur with productivity z' would earn at least w_h in profits. Then the prospective firm with productivity z produces and charges prices $p(z, z')$

$$p(z, z') = \min\{p^m(z), \tilde{p}(z')\}, \tag{11}$$

rationalizing the entry decisions of both prospective entrepreneurs. Thus, as in BEJK, the most efficient prospective entrepreneur produces and the second most efficient determines mark-ups.

Each firm produces a single variety. Therefore, the mass of producing firms, MP, maps one-to-one into the variety space Ω. In the closed economy, the mass of producing firms is given by:

$$MP = M\left((1-\nu) + \frac{1}{2}\nu\right). \tag{12}$$

This model of competition nests other existing models of trade with heterogeneous firms. Without skill-biased productivity, letting $\nu = 1$, letting firms' outside option be earning zero, and letting MP be constant, this model is a one-sector version of BEJK. Adding skill-biased productivity recovers a one-sector version of Burstein and Vogel (2016). Letting $\nu = 0$ and $MP = M$ this model nests Melitz (2003).

Before summarizing the aggregate production quantities and inputs in this economy, it is useful to define some additional notation. First, let $P(z)$ be the contribution of all firms with productivity z to the price index, P:[7]

$$P(z)^{1-\sigma} = (1-\nu)p^m(z)^{1-\sigma} + \nu \int_{z^*}^{z} \big((p(z,z')\big)^{1-\sigma} h(z')dz' \tag{13}$$

$$P = \left(M \int_{z^*}^{\infty} P(z)^{1-\sigma} g(z)dz\right)^{\frac{1}{1-\sigma}}. \tag{14}$$

Let $Q \equiv U$, then the quantity of a variety is $q(\omega)$ sold at price $p(\omega)$ is $q(p(\omega)) = Q(p(\omega)/P)^{-\sigma}$. Using these standard definitions and Equations (10), (9) and (11), I define $Q(z)$ as the average quantity and $R(z)$ as the average revenue of a firm with productivity z:

$$Q(z) = (1-\nu)q\big(p^m(z)\big) + \nu \int_{z^*}^{z} q\big(p(z,z')\big)h(z')dz' \tag{15}$$

$$R(z) = (1-\nu)q\big(p^m(z)\big)p^m(z) + \nu \int_{z^*}^{z} q\big(p(z,z')\big)p(z,z')h(z')dz', \tag{16}$$

with aggregate revenues, $R = PQ = M \int_{z^*}^{\infty} R(z)h(z)dz$.

Finally, Equation (7) gives the ratio of high- to low-skilled labor at a firm of productivity z and Equation (6) can be used to solve for the number of high- and low-skilled workers that a firm of productivity z needs to produce a given quantity q, $d_h(z|q)$ and $d_\ell(z|q)$, respectively. Since firms face constant marginal costs, define the average high- and low-skilled workers of

[7] For notational convenience, Equation (13) has a PDF that integrates to less than one, this is accounted for in Equation (14) by using M instead of MP.

a firm with productivity z as:

$$D_h(z) = d_h\big(z|Q(z)\big) \tag{17}$$

$$D_\ell(z) = d_\ell\big(z|Q(z)\big). \tag{18}$$

The average profits of a firm with productivity z are thus given by:

$$\Pi(z) = R(z) - w_h D_h(z) - w_\ell D_\ell(z) \tag{19}$$

3.3 Equilibrium

Definition 1. An equilibrium is defined by wages w_ℓ, w_h, education threshold a^*, productivity threshold z^* and aggregate revenues $R = PQ$ such that goods markets clear, agents at the ability threshold are indifferent between schooling and non-schooling, educated agents at the prospective entrepreneurial threshold are indifferent between starting a firm and becoming high-skilled workers, and labor markets clear:

$$E(I|s=1) \geq w_\ell + c_s(1-a^*) \tag{20}$$

$$\pi^m(z^*, w_h, w_\ell) = w_h \tag{21}$$

$$M\int_{z^*}^{\infty} D_\ell(z)h(z)dz = N_\ell \tag{22}$$

$$M\int_{z^*}^{\infty} D_h(z)h(z)dz = N_h \tag{23}$$

$$R = PM\int_{z^*}^{\infty} Q(z)h(z)dz = w_\ell N_\ell + w_h N_h + M\int_{z^*}^{\infty} \Pi(z)h(z)dz \tag{24}$$

In the closed economy, the supply of low-skilled workers is determined by the education threshold, a^*, while the supply of high-skilled workers is determined by a^* the entrepreneurial threshold z^* and the probability of competition ν. Relative demand for high-skilled workers depends on the productivity distribution $G(z)$ and the prevalence and quality of direct competition for producing firms.

4 Open Economy Model

In an open economy, firms face additional direct and indirect competition from foreign firms as in BEJK. The departures from BEJK made in the closed economy model are relevant in their effect on the prevalence and quality of direct competition as well as changes to indirect competition. As in the standard BEJK framework, there are J (potentially asymmetric) countries. Firms exporting from country i to country j face iceberg trade costs, $\tau_{i,j} > 0$ and fixed costs $f_{e,j}$.[8]

Consistent with the closed economy competition structure, firms face one prospective entrepreneur in their own market and up to two in each other market. Define ν_i as the probability that a firm from country i faces competition from at least one prospective entrepreneur. Then probability of facing no direct competitors is given by:

$$(1-\nu_i) = \left(1 - \left(\frac{M_i}{N_i}\right)^{\lambda}\right) \prod_{J-i} \left(1 - \left(\frac{M_j}{N_j}\right)^{2\lambda}\right). \tag{25}$$

This formulation ensures that, as in the closed economy setting, the probability of competition depends on the share of agents in each economy, so trade makes each firm more likely to face a competitor.

Let the marginal cost of a firm from country i with productivity z_i producing in country j be $c_{i,j}(z_i) = \tau_{i,j} MC(z_i)$. Let K index potentially competing entrepreneurs ($K = 2J - 1$) and define the PDF of this firm's best competitor, $\mu_{i,j}(z_i')$ such that:

$$\int_{z_i^1}^{z_i^2} \mu_{i,j}(z_i') dz_i' = \prod_K H\Big(z_k : c_{i,j}(z_k) = c_{i,j}(z_i^2)\Big) - \prod_K H\Big(z_k : c_{i,j}(z_k) = c_{i,j}(z_i^1)\Big) \tag{26}$$

[8] I assume firms face fixed costs of entry into country j equal to the high-skilled wage in country j, $f_{e,j} = w_{h,j}$. If $f_{e,j} < w_{h,j}$, the asymmetry in outside options may result in a less efficient foreign competitor producing. If $f_{e,j} > w_{h,j}$, there is a secondary entry margin a la Melitz (2003), which I abstract from.

for all productivities $z_i^1 \in (0, \infty)$, $z_i^2 \geq z_i^1$. Equation (26) translates the ordering of firms in the marginal cost space into country i's productivity space, analogous to h(z) in the closed economy. Notice, $\mu_{i,j}(z_i')$ first order stochastically dominates $h(z_i')$, which is to say trade makes direct competition stiffer.

Finally, each entrepreneur is a real agent. Since some prospective entrepreneurs do not face direct competition, trade also increases indirect competition through changes in the mass of varieties, as in Melitz (2003). This ensures, again, that each agent is accounted for in the aggregate.

Using these equations, it is possible to define the price index, P, aggregate revenues R as before. I further define analogously to the closed economy average quantity, high-skilled labor demand and low-skilled labor demand for a firm of productivity z_i, as $Q(z_i)$, $D_h(z_i)$ and $D_\ell(z_i)$, respectively. I leave these details to Appendix C. Equilibrium is also defined as in the closed economy model, with full details again left to Appendix C.

I next examine the impact of trade distinguishing each mechanic of my model. Skill-bias in productivity, occupational choice and educational choice each play a key role in determining the changes in the demand and supply for skilled labor following a reduction in trade barriers.

4.1 Impact of Trade: the Role of Skill-Biased Productivity

First, I consider the impact of trade in the presence of skill-biased productivity only, shutting down both channels affecting skill supply. As discussed in the previous section, my model nests a one-sector version of Burstein and Vogel (2016). As in their model, trade increases the relative demand for skilled labor, increasing the skill premium if factor endowments are fixed:

Theorem 1. *A symmetric reduction in trade barriers between two symmetric countries increases relative demand for high-skilled labor. If the share of high-skilled labor is fixed, this increases the skill premium.*

A reduction in iceberg trade costs, $\tau_{i,j}$, decreases in the cost of exports. As $\tau_{i,j} > 1$, a firm in country $i \neq j$ that becomes a lower cost producer in country j as a result of a reduction in trade barriers must have pre-trade costs lower than the previous best producer. As the two countries are symmetric, the firm in country i must be more productive $z_i > z_j$. Therefore, all shifts in production resulting from a reduction in trade barriers are shifts from lower to higher productivity firms. As shown in Equation (7), higher productivity firms rely more heavily on high-skilled labor, so relative demand for high-skilled labor increases. If relative supply is constant, the skill premium must increase.

Theorem 1 is trivially extended to a multi-country setting. For asymmetric countries or asymmetric reductions in trade barriers, it requires an quantitative solution. However, it remains the case that in general reductions in export barriers are the most beneficial to the most productive firms, as they are most likely to benefit by being able to newly export to a foreign market. Meanwhile, the least productive firms are the most likely to be hurt by a reduction in import barriers, as they are more likely to face a better competitor from a foreign market. Solving Equations (17) and (18) using pre-trade barrier reduction wage rates, relative demand for high-skilled labor in country j increases if:

$$\int_{z_j^*}^{\infty} \Delta D_h(z_j)h(z_j)dz_j > \int_{z_j^*}^{\infty} \Delta D_\ell(z_j)h(z_j)dz_j, \tag{27}$$

which in practice will be the case unless marginal costs associated with the firm productivity draw are highly asymmetric across countries. This is unlikely to be true in equilibrium, as one country with systematically higher (or lower) marginal costs will fail to have a labor market clearing equilibrium. Again, if labor endowments are fixed, this straightforwardly increases the skill premium.

This pattern of demand is consistent with my empirical finding that trade is associated with an increase in relative demand for skilled labor in all countries, regardless of their initial skill abundance. However, as trade is associated with skill intensity rather than the skill premium, skill supply must also adjust.

4.2 Impact of Trade: the Role of Occupational Choice

I now consider the impact of trade when adding occupational choice for educated agents. This can be thought of as the short-run impact of a trade liberalization, before agents can respond through the educational choice channel. Trade affects labor markets through the occupational channel in three ways. First, trade induces entrepreneurial exit. Second, this increases the relative supply of high-skilled workers, reducing the skill premium if certain conditions are met. Third, the profits of remaining firms increase, increasing the benefit of becoming a high-skilled worker. I outline each of these predictions.

Theorem 2. *A reduction in iceberg trade costs induces entrepreneurial exit through direct competition and a reduction in prospective entrepreneurs through indirect competition.*

A reduction $\tau_{i,j}$ causes entrepreneurs to exit through two channels. First, entrepreneurs who newly face a direct foreign competitor with lower costs due to the reduction in $\tau_{i,j}$ exit and become high-skilled workers. Second, as increased direct competition lowers prices, P, indirect competition also increases. This Melitz (2003) channel implies that the monopoly profits of the least productive firm in country i, $p^m(z_i^*)$ decline, while Theorem 1 stipulates that absent changes in relative supply, w_h increases. Thus, prospective entrepreneurs with productivity z_i^* exit as $p^m(z_i^*) < w_h$. Entrepreneurial exit through these two channels implies:

Theorem 3. *A reduction in iceberg trade costs increases skill supply. If the skill ratio of exiting firms (including their entrepreneur) is larger than the average skill ratio prior to the trade cost reduction, the occupational choice channel reduces the skill premium.*

The first part of Theorem 3 follows directly from Theorem 2 as each educated agent is either an entrepreneur or an high-skilled worker. The second part of Theorem 3 states that occupational choice mitigates the skill premium if the exit of entrepreneurs increases the supply of high-skilled workers by more than it increases the relative demand for skilled workers (as more skilled entrepreneurs remain). Letting $ExP(z_j)$ be the probability that a firm in country j with productivity z_j exits as a result of a reduction in trade barriers then entrepreneurial exit acts to decrease the skill premium if:

$$\frac{\int_{z_j^*}^{\infty} 1 + D_h(z_j)h(z_j)ExP(z_j)dz_j}{\int_{z_j^*}^{\infty} D_\ell(z_j)h(z_j)ExP(z_j)dz_j} > \frac{N_{h,j}}{N_{\ell,j}}, \tag{28}$$

where $D_h(z_j)$, $D_\ell(z_j)$, N_h and N_ℓ are calculated using equilibrium values prior to a reduction in trade barriers. Relative demand for high-skilled labor is increased through both the skill-bias channel (leading to the exit of entrepreneurs through direct competition) and the occupation choice channel (leading to the exit of prospective entrepreneurs). This implies an increased benefit from education.

There are several forces affecting the relative benefit of education. First, increases in the skill premium increase the return to education. Second, firms that expand their production by newly entering a foreign market increase their profitability, also increasing the return to an education. Third, indirect competition increases through a reduction in prices of some varieties, however, as Theorem 2 implies, the mass of producing firms, MP, decreases following a reduction in iceberg trade costs, making the effect through the price index ambiguous. Finally, as some of the least productive prospective entrepreneurs exit, surviving entrepreneurs are more likely to produce as a monopolist, increasing both their own prices and increasing the price index. Though the exact gains must be quantified, the majority of forces push towards increased profits of surviving firms and thus increased returns to education.

The occupational choice channel is consistent with the short run implications of the data. Trade increases not only the demand for high-skilled labor, but also its supply. Thus, it is possible for skill intensity to increase in association with increased trade and for the skill premium to remain stable. The entrepreneurs who do not exit gain from trade. Therefore, educated agents gain relative to uneducated agents. Increased gains from education incentivize more agents to attend school.

4.3 Impact of Trade: the Role of Educational Choice

In the long run, agents can adjust through both the occupational and educational channels. As trade increases the value of education through a combination of an increase in the skill premium and an increase in firm profits, the education threshold, a^*, decreases, increasing the mass of educated agents. This increases skill intensity and also increases direct and indirect competition across entrepreneurs.

The increase in the share of high-skilled workers is mechanical - increasing the mass of educated agents increases the supply of high-skilled workers, which puts downward pressure on the skill premium. However, an increase in educated agents also increases the share of prospective entrepreneurs, and producing entrepreneurs.

Theorem 4. *An increase in the share of prospective entrepreneurs and producing entrepreneurs increases direct and indirect competition. This increases relative demand for skilled labor.*

As in Equation (9), increasing a^* mechanically increases the share of prospective entrepreneurs M (holding z^* constant). Increasing M increases ν and increases direct competition, meaning producing entrepreneurs are more productive on average. Moreover, this increases indirect competition both through an increase in firm productivities and in the mass of producing firms, MP. Thus, as described previously, z^* as described through the occupational choice channel. This also increases relative demand for skilled labor as the least productive entrepreneurs exit.

As these two effects of increased education increase both the demand and supply of skilled labor, the general equilibrium impact on the skill premium must be evaluated quantitatively. The first channel benefits remaining uneducated agents relative to educated agents. The second channel benefits high-skilled workers relative to surviving entreprenerus. The implications of addition educational attainment to the model are consistent with an association between increased trade and increased skill intensity in the long run, along with continued skill premium stability.

5 External Validation

In addition to predicting the observed facts from Section 2, the model has testable implications relating to firms. First, the model suggests the profits of surviving firms increase following a reduction in trade barriers. Second, it implies that trade reduces entrepreneurship through the occupational choice channel. I find suggestive evidence for each empirically.

First, I test the prediction that surviving firms' profits increase on average. If the share of firms is constant or decreasing (as the model predicts), and labor's share of GDP declines, the average profits of surviving firms' profits must increase. I examine the association between trade and the labor to capital ratio using WIOD and WDI data. In the WIOD, the capital share is defined as the residual of GDP less wages paid to employees. In the model, this corresponds to the entrepreneurial share.

	(1)	(2)	(3)	(4)
	L/K	L/K	L/K	L/K
Exports/GDP	-0.177**	-0.320**	-0.353*	-0.102
	(0.070)	(0.125)	(0.187)	(0.104)
Group	All	Hi-S	Mid-S	Low-S
Year FE	Yes	Yes	Yes	Yes
Cluster	Country	Country	Country	Country
N Obs	247	102	61	84

Table 3: **Labor Share by Exports, Two Year Differences.** This table shows the relationship between the changes exports and changes in the share of GDP going to labor. Data source: World Input-Output Database, Socio-Economic Accounts and World Bank World Development Indicators, years 1995-2009. All variables defined in two year log differences.

In Table 3, I present evidence that trade is negatively associated with the labor to capital ratio in the short run, consistent with the prediction that surviving entrepreneurs gain from trade. This finding also runs contrary to models in which trade increases skill demand through a reduction in the costs of other inputs that are complimentary with high-skilled labor. If this were the case, we would not expect relative gains to accrue to high-skilled labor rather than firms. This offers support for the skill-bias productivity mechanic driving changes in productivity, and for the occupational choice channel driving distributional gains towards surviving entrepreneurs.

International entrepreneurship data suffer from a limited availability and cross country differences in how it is defined. However, such data are available with consistent definitions for US states. I obtain data on wages and hours by education level for US states from 2002-2016 from IPUMS-USA database (ACS sample), state level trade data from the International Trade Administration and state level GDP data are from the Bureau of Economic

Analysis.

First, as a baseline, I run the same analyses I conducted with the international sample to establish the presence of a similar pattern in US states. Table 4 shows results for the stacked two year difference specification on the association between trade, the skill premium and skill intensity in US states. Like the cross country results, Column 1 indicates no relationship between changes in exports and changes in the skill premium. Column 2 indicates a positive relationship between changes in exports and changes in skill intensity in US states.

	(1) wages	(2) hours	(3) self- employment
Exports/GDP	-0.006	0.088*	-0.063**
	(0.013)	(0.050)	(0.024)
Year FE	Yes	Yes	Yes
Cluster	State	State	State
N Obs	350	350	350

Table 4: **State Skill Premium, Skill Composition and Self Employment by Exports, Two Year Differences.** This table shows the relationship between the changes exports and changes in the skill premium and changes in relative high-skilled hours. Data source: IPUMS-USA, International Trade Administration, Bureau of Economic Analysis. All variables defined in two year log differences from 2002-2016.

I next examine further the relationship between trade and entrepreneurship at the state level. As Column 3 of Table 4 shows, there is a negative relationship between state level exports and state level entrepreneurship. This finding supports my model's prediction of an exit of entrepreneurs in the short run following a liberalization.

These findings provide extended validation of the model. In addition to being consistent with the observed empirical facts in Section 2, I find suggestive empirical evidence of the model's predictions about the profitability of remaining entrepreneurs and the exit of entrepreneurs in association with an increase in trade.

6 Quantification

I now turn to the quantification of the model. First, I calibrate a three-country version of the model, matching data from the US, China and the rest of the world (R.O.W.) prior to China's entry into the WTO. I then simulate reduction in trade barriers that produces an increase in China's export share similar to the observed increase following its WTO entry. I evaluate the impact of this shock on the Chinese labor market[9] without any adjustments in skill supply, with adjustments through the occupational channel only, and with adjustments through both the occupational and educational channels. I find responses in skill intensity and the skill premium similar in magnitude to the associations with trade seen in the data. Finally, to further understand the relationship between occupational and educational choice, I evaluate the counterfactual impact of a reduction in education costs relative to the baseline period. This exercise demonstrates a policy implication of this model: reducing the education costs helps not only the agents who are newly educated, but also the remaining uneducated agents and both high- and low-skilled workers relative to firms.

6.1 Calibration

I calibrate a three country version of my model for China, the US and R.O.W. and match data to a 1999 baseline year, prior to China's entry to the WTO. I take values for some of the preferences and technology parameters from the literature. I take elasticity the elasticity of substitution across product varieties, σ, and I select the degree of productivity bias, ϕ, from Burstein and Vogel (2016). I set the elasticity of substitution between high- and low-skilled labor, ρ, to the consensus value reported in Giannone (2018), as the value calibrated by Burstein and Vogel (2016) is low relative to the range reported in the literature. Finally, to get the distribution of productivities, $G(z)$, I follow Burstein and Vogel (2016) and let the productivity draw of agent k given by $z_k = u_k^{-\theta}$, where u_k is the realization of a draw from the exponential distribution. For the distribution of ability, $F(a)$, I assume a Uniform $[0, 1]$ distribution. A summary of values and sources is shown in Table 5.

[9] I find similar effects in the US and R.O.W. labor markets, though the effects are muted as the relative size of the shock is smaller.

Parameter	Value	Definition	Source/Target
σ	2.7	demand elasticity	Burstein and Vogel (2016)
ϕ	1	degree of skill bias	Burstein and Vogel (2016)
ρ	2.13	skill elasticity of substitution	Giannone (2018)
θ	0.22	productivity shape parameter	Burstein and Vogel (2016)

Table 5: **Parameters from Literature**

The remaining parameters are calibrated jointly. There are two parameters common across countries: the shape of the probability of direct competition, λ, and skill share parameter, α. There are two country-specific parameters for each country j: a common productivity draw, A_j, and maximum schooling costs, $c_{s,j}$. Finally, there are six bilateral iceberg trade costs, $\tau_{i,j}$, for a total of fourteen parameters. I match these to target moments for the rate of entrepreneurship in the US, the US skill premium, GDP levels, the share of high-skilled workers in each country and bilateral trade flows. I normalize US GDP and A_{US}, leaving thirteen jointly calibrated parameters and thirteen moments.

Table 6 summarizes the target moments and their data and model values. For the share of skilled hours, I group middle-skilled workers with the high-skilled workers for skill scarce countries. As detailed in Appendix B, the results of my empirical analysis are robust to this alternative grouping of high-skilled and middle-skilled workers. I also follow Burstein and Vogel (2016) and terminate the solution algorithm when export and import shares approximate their true value, which in practice also means bilateral flows are similar. Full details of the solution method are available in Appendix D.

6.2 China's Entry into the WTO

To examine the relevance of the model's mechanisms, I examine the quantitative impact of China's entry into the WTO on the market for skilled labor. To simulate this episode, I estimate a symmetric reduction in its iceberg trade costs with the US and R.O.W., increasing Chinese export share by roughly eleven percentage points, similar to the increase from 2001

Target	Data	Model
US Skill premium	1.98	2.01
US entrepreneurship rate	11%	14%
China to US GDP	0.11	0.11
R.O.W. to US GDP	1.76	1.75
% High-Skilled, US	29%	31.1%
% High- and Mid-Skilled, China	31%	32.2%
% High- or High/Mid-Skilled, R.O.W.	28%	28.8%
Export %, US	8%	8.5%
Export %, China	19%	19.1%
Export %, R.O.W.	7%	5.8%
Import %, US	10%	9.8%
Import %, China	14%	13.6%
Import %, R.O.W.	6%	5.4%

Table 6: **Target moments and model values**

to 2004.[10] I consider the impact of this shock on skill intensity and the skill premium in three settings: without agent choice channels, with only the occupational choice channel and with occupational and educational choice channels. The first represents the implied short run effect on the market for skilled labor without supply adjustments. The second represents the short run effect, while the third represents the long run effect. Table 7 summarizes the impact of this trade expansion.

Shutting down skill supply channels, the skill premium increases by 2.57%. While Burstein and Vogel (2016) do not report coefficient estimates for their counterfactual exercise, an effect of this magnitude is in line with their estimated country-level effects. Activating the occupational choice channel and allowing entrepreneurs to exit increases the relative supply of skilled labor. Adding the occupational choice channel, the share of high-skilled workers increases by 1.05%. Comparing log changes in high- to low-skilled labor and log changes in exports, I find a short run ratio of 0.106, a little less than 60% of the coefficient on the relationship between trade and skill intensity in Column 5 of Table 1. In the model, this is

[10] China was admitted to the WTO in December, 2001. From 1995 to 2001 China's export share fluctuated between 18% and 21%. Its export share in 2001 was 20%, while it was 31% in 2004.

	Without Adjustment	Occupational Adjustment	Occupational and Educational Adjustment
Skill premium (w_h/w_ℓ)	2.57%	0.20%	-4.27%
% High-skilled	-	1.05%	3.01%
% Entrepreneurs	-	-1.21%	-0.88%
Labor Share	-1.80%	-1.74%	-1.67%
%Exports	12.2%	12.3%	12.1%

Table 7: **China's Entry to WTO**: Changes in the skill premium and skill intensity in China after a reduction in trade barriers by skill supply adjustment channels: no adjustment, occupational adjustment only, occupational and educational adjustment.

sufficient to almost eliminate the skill premium increases (0.20%), in line with the short run findings in the data.

Allowing agents to select their level of education increases educational attainment. This is because of the additional profits earned by remaining entrepreneurs, as labor share declines by 1.74% despite a reduction in entrepreneurship when allowing for occupational choice. Increased educational attainment further increases the supply of high-skilled workers, and thus skill intensity goes up by 3.01%, while the skill premium goes down by 4.27%. Again, converting to log changes in high- to low-skilled labor and log changes in trade, this is an effect of 0.312, compared to a coefficient of 0.346 estimated in Column 4 of Table 2. The reduction in the skill premium is large relative to the empirical prediction, however, I do find the increase in the mass of firms relative to occupational choice increases relative skill demand. Comparisons to the regression coefficients are summarized in Table 8.

These results support the quantitative relevance of the skill-bias mechanism in increasing relative demand for skilled labor and of the occupational choice channel in increasing its supply in the short and long run, respectively. Without changes in skill supply, the skill premium increases. Occupational choice can explains an increase in skill intensity rather than the skill premium in the short run in association with increased trade. Increased educational attainment in the long run further increases the share of high-skilled workers. It also increases the mass of firms, increasing competition and demand for high-skilled labor.

	Model Implied Coefficient	Empirical Coefficient
Δ log(HS/LS hours), short run	0.106	0.184
Δ log(HS/LS wages), short run	0.005	-0.095
Δ log(HS/LS hours), long run	0.312	0.346
Δ log(HS/LS wages), long run	-0.103	-0.019

Table 8: **Labor market responses to trade**: Short run and long run impact of trade, model and data.

Turning to examine the welfare implications of trade, I find that factor reallocation through the occupational and educational choice channel increases the total welfare gains from trade relative to the baseline that ignores labor reallocation effects. Moreover, each channel has substantially different allocation implications for low-skilled workers, high-skilled workers and firms.

	Without Adjustment	Occupational Adjustment	Occupational and Educational Adjustment
Total Welfare	5.17%	6.67%	7.27%
Low-Skilled Workers	0.37%	0.38%	4.19%
High-Skilled Workers	2.97%	0.57%	-0.26%
Average Entrepreneur	11.2%	25.8%	24.0%

Table 9: **Welfare Impact of China's Entry to WTO**: Changes in welfare in China after a reduction in trade barriers by skill supply adjustment channels: no adjustment, occupational adjustment only, occupational and educational adjustment.

Table 9 examines the total welfare impact of trade with skill-biased productivity only, adding occupational choice and adding educational choice. Total welfare increases when adding occupational choice as a result of the fact that unlike Column 1 where there is no entrepreneurial exit, non-producing firms add to the labor force as the entrepreneurs become high-skilled workers. This increases total production capacity, boosting total welfare. Notice, however, that this change does little to benefit low-skilled workers, who despite their decreased factor abundance do not see their wages increase relative to the skill-bias only case. Rather, the gains accrue almost entirely to the surviving entrepreneurs who benefit from the increase in high-skilled labor keeping down increases in the high-skilled wage.

Adding in educational choice, on the other hand, is a large boon to low-skilled workers. They benefit from two channels of factor reallocation. First, low skilled workers are more scarce, boosting relative wages. Second, the mass of potential entrepreneurs increases, increasing competition among firms, and lowering margins, increasing the welfare of all workers. An increase in educational attainment increases total welfare as well as the mass of highly productive entrepreneurs increases.

6.3 Skill-biased Technological Change

An alternate channel that may affect the skill premium is technological change. A uniform shift in technology that increases the reliance on high-skilled labor is captured by an increase in α. Examining an increase in reliance on high-skilled labor that results in an increase in the skill premium without occupational or educational adjustment similar to that of the reduction in trade barriers highlights the importance of competition in driving changes in the supply of skilled labor.

	Without Adjustment	Occupational Adjustment	Occupational and Educational Adjustment
Skill premium (w_h/w_ℓ)	2.60%	2.02%	0.63%
% High-skilled	-	0.15%	0.72%
% Entrepreneurs	-	-0.17%	-0.08%
Labor Share	-1.15%	-0.02%	0.03%
%Exports	2.47%	0.21%	0.34%

Table 10: **Technological Change**: Changes in the skill premium and skill intensity in China after an increase in α by skill supply adjustment channels: no adjustment, occupational adjustment only, occupational and educational adjustment.

As shown in Table 10, there is considerably less occupational switching compared to the case of China's entry into the WTO. This results from a smaller increase in competition, as fewer firms are able to expand into foreign markets as a result of this change than from the reduction in trade barriers. Not surprisingly, the skill premium remains high when allowing for occupational choice, at 2.02% rather than 2.60%. Nevertheless, fewer agents shift their educational attainment as the share of profits accrued by firms remains relatively stable.

These findings indicate the importance of trade in inducing movement in the supply of skilled labor compared to a shift in demand for skilled labor from a technological change. The critical difference is trade's role in increasing competition to the benefit of the most productive firms and the detriment of the least productive firms. This leads to large changes in the decisions of educated agents, strongly affecting skill supply. Conversely, most of the effect of skill biased technological change is felt more uniformly across firms resulting in less elastic skill supply and leading to a general equilibrium increase in the skill premium in the short run.

6.4 Reduction in Education Costs

Finally, I examine the impact of a policy reducing education costs by 20% relative to the calibrated baseline economy. This increases the share of educated agents, mechanically increasing the share of high-skilled workers. I consider two cases: one in which the mass of producing firms is fixed and all additional educated agents become high-skilled workers, and another in which newly educated agents may provide high-skilled labor. This exercise allows me to isolate the role of the interaction between occupational and educational choice channels following an increase in educated agents.

Table 11 presents results of this exercise. In both cases, skill intensity increases and the skill premium declines. However, in the second case the decline in the skill premium is less severe as some of these additional educated agents become entrepreneurs. This both decreases the mass of additional high-skilled agents and increases the competition among entrepreneurs. As competition increases, relative demand for high-skilled labor increases and entrepreneurial share declines. This implies that, just as occupational choice worked to transfer gains from

	Occupational Adjustment	Occupational and Educational Adjustment
w_h/w_ℓ	-9.02%	-6.92%
% High-skilled	4.09%	3.14%
% Entrepreneurs	-	0.61%
Labor Share	-0.17%	0.18%
Export Percentage	1.20%	-0.13%

Table 11: **Reduction in Education Costs**: This table shows changes in the skill premium and skill intensity following a 20% reduction in education costs

high-skilled workers to surviving entrepreneurs in the short run, occupational choice works to transfer some of the losses to high-skilled workers from increased educational attainment to entrepreneurs when educational attainment increases.

A reduction in education costs is different from a worker retraining program in that workers move up the global skill ladder rather than from one sector to another. This exercise demonstrates the benefit such a program has for low-skilled workers. It reduces the supply of low-skilled workers, increasing their relative wage. Moreover, it directly increases the wage of those who are educated. Furthermore, it increases market competition, reducing prices by increasing the share of firms, which increases labor share.

6.5 Trade War

Finally, I examine the potential consequences of a trade war resulting in a symmetric 20% increase in iceberg trade costs between all countries. Table 12 examines the impact for the US of such a policy. While factor reallocation through the occupational choice channel partially offsets the standard welfare losses from trade, the educational choice channel accelerates losses as decreases in educational attainment make the average firm less productive.

Looking at the effect of a trade war on different types of workers, without factor adjustment, low-skilled workers gain slightly in relative terms, but are harmed like all other types of

	Without Adjustment	Occupational Adjustment	Occupational and Educational Adjustment
Total Welfare	-4.89%	-4.58%	-4.78%
Low-Skilled Workers	-4.67%	-4.00%	-4.28%
High-Skilled Workers	-5.60%	-3.21%	-2.94%
Average Entrepreneur	-4.62%	-9.01%	-8.86%

Table 12: **Welfare Impact of Trade War**: Changes in welfare in US after a 20% increase in iceberg trade costs by skill supply adjustment channels: no adjustment, occupational adjustment only, occupational and educational adjustment.

workers. The occupational choice channel offsets skill premium decreases in the case of the trade war, just as they offset skill premium increases in the case of a trade liberalization and results in lower welfare for the average entrepreneur as the worst entrepreneurs enter. Low-skilled workers are harmed in both absolute and relative terms by the reduction in educational attainment as the factor of production becomes more abundant and firms become less productive.

7 Conclusion

Understanding the relationship between trade and inequality requires understanding the general equilibrium effects of trade on the relative demand and supply of skilled labor. Using recent cross country data, I present a puzzling empirical fact: trade is positively associated with skill intensity, but not with the skill premium. This is true regardless of initial skill abundance and for both short and long differences. This is consistent with an association between increases in trade and increases in both the demand and supply of skilled labor.

To understand the relationship between trade, skill intensity and the skill premium, I develop a general equilibrium model of trade featuring skill-biased productivity, and agents who make educational and occupational choices. Skill-bias productivity captures the fact that trade liberalizations increase relative demand for skilled labor in all countries regardless of skill-abundance. Educational choice captures long run increases in the relative supply of skilled labor, while occupational choice captures the association between trade and skill intensity rather than the skill premium in the short run. Though the skill premium does not increase in the short run due to the occupational choice channel, increases in the profits of remaining firms induces additional educational attainment. I calibrate this model and simulate China's entry into the WTO, finding qualitative results for labor market responses that are similar to the documented empirical facts.

This paper has clear implications for the general equilibrium impact of trade on inequality. The endogenous response of agents' supply of skilled labor substantially mitigates the impact of trade on the skill premium. In the short run, reductions in inequality as measured by the skill premium mask the relative gains of educated agents to uneducated agents through the gains to surviving firms. In the long run, increased educational attainment reduces both the skill premium and the profits of entrepreneurs as competition increases. Counterfactual policy exercises show that reducing schooling costs can increase labor's share and reduce inequality between educated and uneducated agents. This suggests programs targeting broad-based education may be more effective at mitigating the inequality effects of trade than sector-specific retraining programs.

This paper suggests the importance of the role of agents for understanding the dynamics of competition and trade. Entrepreneurs, like workers, are agents who make a choice about occupation. Increasing direct and indirect competition among firms is beneficial to workers, but if they types of agents who are most likely to start firms are also more likely to earn a higher wage, the benefits of increasing the number of educated agents may not be as widely shared. Moreover, the more widely shared are the benefits of increased educational attainment and increased competition, the harder it is for policy to incentivize individual agents to become educated or engage competitively. Thus, policy addressing changes in inequality across skill groups following either trade liberalizations or other changes in competition or production technologies, must take into account the magnitude of both demand and supply responses.

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A Data Construction

Data from the World Input Output Database, Socio Economic Accounts, 2013 release. The database has 40 countries, however, I drop Taiwan as it is not included in my other dataset. I drop Russia as its data series on attainment mimics the Czech Republic exactly and I drop Luxembourg as changes in the Labor Force Survey drastically alters its attainment measure. Several other countries have imputations for attainment at various points, but I only drop observations later in the sample where imputed values are assumed constant due to the end of a data series. I impute values for relative hours 2003 due to a known classification error. I drop Indonesian data from 1998 as trade data from that year is an outlier. I run counterfactuals excluding small economies with more volatile data (Cyprus, Malta and Luxembourg) and find similar results.

The WIOD data are constructed from micro data on hours and wages by skill group from each country. Unfortunately, these include some imputations for years not covered by local surveys. This is one reason I use the stacked two year differences in my main specification as it not only smooths year to year errors but it better reflects changes in observed data. Nevertheless, for some countries in the later years of the sample there is not data after a certain year. The WIOD generally assumes a constant imputation in this case, and I drop these observations.

Data on hours and wages in the WIOD reflect, to the best efforts of the survey, data on employees. This is reflected directly in my model. The capital share is simply the residual of GDP and the total wage bill.

State level data are from IPUMS-USA, using the American Community Survey sample from 2001-2016. Skill groups are classified according to six attainment levels, but I consolidate to most closely reflect the high-skilled group measured in the WIOD data. State level exports are taken from the International Trade Administration and state level GDP is from the Bureau of Economic Analysis.

B Robustness

B.1 Alternate Short Run Horizon

I check the sensitivity of my short run results to the time horizon and find they are robust to using one, two and three year differences.

	(1) wages	(2) wages	(3) wages	(4) hours	(5) hours	(6) hours
Ex/GDP, 1yr Change	0.032			0.093**		
	(0.051)			(0.042)		
Ex/GDP, 2yr Change		-0.095*			0.184***	
		(0.049)			(0.048)	
Ex/GDP, 3yr Change			0.013			0.121*
			(0.058)			(0.066)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Country	Country	Country	Country	Country	Country
N Obs	497	249	142	497	249	142

Table 13: **Skill Premium and Skill Composition by Exports, SR Differences.** This table shows the relationship between the changes exports and changes in the skill premium and changes in relative high-skilled hours. Data source: World Input-Output Database, Socieo-Economic Accounts and World Bank World Development Indicators. One, two and three year log differences.

B.2 Alternate Specification of Trade

I examine whether the definition of trade matters for my short run results. While there is good theoretical reason to emphasize exports, I find similar results using imports or total trade volumes.

	(1) wages	(2) wages	(3) wages	(4) hours	(5) hours	(6) hours
Exports/GDP	-0.095*			0.184***		
	(0.049)			(0.048)		
Imports/GDP		-0.044			0.094***	
		(0.044)			(0.031)	
Trade/GDP			-0.089**			0.168***
			(0.038)			(0.040)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Country	Country	Country	Country	Country	Country
N Obs	249	249	249	249	249	249

Table 14: **Skill Premium and Skill Composition by Exports, Alternate Trade Definitions.** This table shows the relationship between the changes exports, imports, total trade and changes in the skill premium and changes in relative high-skilled hours. Data source: World Input-Output Database, Socieo-Economic Accounts and World Bank World Development Indicators. Two year log differences.

B.3 Alternate Definition of High to Low Skilled Labor

Worker skill is defined as low, middle and high skilled. For my main results, I group middle and low skilled workers together. However, high-skilled workers make up a very small percentage of total hours in skill-scarce countries and low-skilled workers make up a very small share in high-skilled countries. Here, I consider a measure of skill where high-skill includes middle-skill workers for skill scarce countries. I again find similar results to my main analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
	wages	wages	wages	hours	hours	hours
Ex/GDP, 1yr Change	0.025			0.076**		
	(0.040)			(0.034)		
Ex/GDP, 2yr Change		-0.065*			0.124***	
		(0.038)			(0.039)	
Ex/GDP, 3yr Change			0.005			0.082
			(0.048)			(0.053)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Country	Country	Country	Country	Country	Country
N Obs	497	249	142	497	249	142

Table 15: **Skill Premium and Skill Composition by Exports, Alternate HS Definitions.** This table shows the relationship between the changes exports, imports, total trade and changes in the skill premium and changes in relative high-skilled hours. Data source: World Input-Output Database, Socio-Economic Accounts and World Bank World Development Indicators. Two year log differences.

B.4 Panel Specification with Country Fixed Effects, Exports and GDP Separate

I examine sensitivity to the first difference specification by looking at a panel regression with country and year fixed effects. I find similar results.

C Proofs and Derivations

C.1 Derivation of Marginal Costs

The ratio of high-skilled to low-skilled labor for a firm with management quality z is given by:

	(1)	(2)	(3)	(4)
	wages	wages	hours	hours
Exports/GDP	-0.027		0.227**	
	(0.109)		(0.103)	
Exports		-0.019		0.274***
		(0.105)		(0.092)
GDP		0.047		-0.114
		(0.130)		(0.110)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Cluster	Country	Country	Country	Country
N Obs	249	249	249	249

Table 16: **Skill Premium and Skill Composition by Exports, Panel.** This table shows the relationship between exports, the skill premium and relative high-skilled hours. Data source: World Input-Output Database, Socieo-Economic Accounts and World Bank World Development Indicators. Data in log levels with country fixed effects.

$$\frac{n_h}{n_\ell} = \frac{\alpha}{1-\alpha}\left(\frac{w_h}{w_\ell}\right)^{-\rho} z^{\phi(\rho-1)}$$

Plugging into the production function, a firm with this yields (normalizing $w_\ell = 1$):

$$F(z, n_\ell, n_h) = Az\left[\alpha^{\frac{1}{\rho}}\left(z^{\frac{\phi}{2}} n_h\right)^{\frac{\rho-1}{\rho}} + (1-\alpha)^{\frac{1}{\rho}}\left(z^{\frac{-\phi}{2}} n_\ell\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$$

$$Az^{1-\frac{\phi}{2}}\left[\alpha^{\frac{1}{\rho}}\left(\frac{\alpha}{1-\alpha}\left(\frac{w_h}{w_\ell}\right)^{-\rho} z^{\phi+\phi(\rho-1)} n_\ell\right)^{\frac{\rho-1}{\rho}} + (1-\alpha)^{\frac{1}{\rho}}\left(n_\ell\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$$

$$= Az^{1-\frac{\phi}{2}}(1-\alpha)^{\frac{1}{\rho-1}}\left[1 + \frac{\alpha}{1-\alpha} z^{\phi(\rho-1)}\left(\frac{w_h}{w_\ell}\right)^{(1-\rho)}\right]^{\frac{\rho}{\rho-1}} n_\ell$$

With total costs given by:

$$C\big(F(z, n_\ell, n_h)\big) = \left[1 + \frac{\alpha}{1-\alpha} z^{\phi(\rho-1)}\left(\frac{w_h}{w_\ell}\right)^{(1-\rho)}\right] n_\ell w_\ell$$

Rearranging, marginal costs for a firm with management productivity z are:

$$
\begin{aligned}
MC(z) &= w_\ell \frac{(1-\alpha)^{\frac{1}{1-\rho}}}{Az^{1-\frac{\phi}{2}}}\left(1+\frac{\alpha}{1-\alpha}z^{\phi(\rho-1)}\left(\frac{w_h}{w_\ell}\right)^{(1-\rho)}\right)^{\frac{1}{1-\rho}} \\
&= w_\ell \frac{(1-\alpha)^{\frac{1}{1-\rho}}}{Az}\left(z^{\frac{-\phi}{2}(\rho-1)}+\frac{\alpha}{1-\alpha}z^{\frac{\phi}{2}(\rho-1)}\left(\frac{w_h}{w_\ell}\right)^{(1-\rho)}\right)^{\frac{1}{1-\rho}}
\end{aligned}
$$

D Solution Algorithm

I solve the model in four steps, building on Burstein and Vogel (2016):

Inner Loop: Taking aggregate productivity, schooling costs, trade costs, competitiveness and labor share parameters, schooling cutoffs a_i^* and entrepreneurial cutoffs z_i^* as given, I guess the low-skilled wage and high-skilled wage in each country. Given wages and other parameters, I determine the the marginal costs of a firm of each type and its probability of producing in any given country. Using this information, I solve for the price index. Given the price index, wages and the number of workers of each type and firms, I solve for aggregate revenue R_i in each country such that the goods market clears.

I then calculate the average quantity produced and demand for high- and low-skilled labor for each productivity-type of firm. From this, I calculate aggregate demand for high- and low-skilled labor. I update my guess of wages until demand and supply of high- and low-skilled labor converge $D_\ell = N_\ell$, $D_h = N_h$ using the following iteration:

$$
\begin{aligned}
f1 &= \frac{\left(\frac{D_{\ell,1}}{N_{\ell,1}}+1\right)}{2} \\
f2_i &= \frac{\left(\left(\frac{D_{\ell,i}/D_{\ell,1}-N_{\ell,i}/N_{\ell,1}}{D_{\ell,i}/D_{\ell,1}+N_{\ell,i}/N_{\ell,1}}+1\right)+1\right)}{2} \\
f3_i &= \frac{\left(\left(\frac{D_{h,i}/D_{\ell,i}-N_{h,i}/N_{\ell,i}}{D_{h,i}/D_{\ell,i}+N_{h,i}/N_{\ell,i}}+1\right)+1\right)}{2} \\
w_{\ell,i}^{k+1} &= f1 * f2_i * w_{\ell,i}^k \\
w_{h,i}^{k+1} &= f1 * f3_i * w_{\ell,i}^{k+1} * \left(\frac{w_{h,i}^k}{w_{\ell,i}^k}\right)
\end{aligned}
$$

Middle loops: In the inner of the two middle loops, I calculate the profits of the marginal entrepreneur $\Pi(z_i^*)$ in each country. Using a bisection method, I revise the guess of z_i^*

downwards if profits exceed the high-skilled wage ($\Pi(z_i^*) > w_{hi}$) and downwards if the high-skilled wage exceeds profits.

In the outer of the middle loops, I follow the same procedure with respect to the education cutoff, revising it downwards if expected earnings exceed the low-skilled wage and upwards if the low skilled wage exceeds expected earnings at the cutoff.

Outer loop: I calculate the model implied production, relative wages and relative hours in each economy. I normalize productivity and schooling costs in the US and I revise λ up if the US share of entrepreneurs is too large and down if it is too small. I revise α up if the share of high-skilled workers in the US is too small and down if it is too large.

For all other countries, if the share of high-skilled workers is too small (large) relative to the US share, I revise schooling costs down (up). If total production is too large (small) relative to the US share, I revise productivity down (up). If exports from country i to country j are too large (small) I revise $\tau_{i,j}$ up (down). The functional forms of these revisions are similar to those in the inner loop.