Inequality and International Trade: The Role of Skill-Biased Technology and Search Frictions

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Abstract

A competitive search model of the labor market is embedded into a small open economy with firm and worker heterogeneity. Search frictions generate equilibrium unemployment and income inequality between identical workers, in addition to income differences between skill groups. Numerical simulations of the model reveal that an increase in trade is likely to increase within-group inequality and decrease unemployment, while the effect on the skill premium is ambiguous. Overall the effect of trade on the labor market is minor if only a small fraction of the labor force is employed in exporting and import-competing industries.

Keywords: Competitive Search, Income Inequality, International Trade, Skill-biased Technology

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1 Introduction

The past three decades have seen a marked rise in income inequality and a boom in international trade, in developed and developing countries alike (see Goldberg and Pavcnik (2007) for a survey documenting these facts). Seemingly unrelated, a well-documented stylized fact in international economics is that exporting firms are typically more productive and employ higher skilled workers than non-exporters (e.g. Bernard et al., 2007). Yet, only recently has research on the distributional effects of globalization focused on the link between firm heterogeneity and the reallocation of workers within an industry. This literature stresses the interaction of skill-biased technology and firm heterogeneity in the effect of increased trade on income inequality: in such an environment, a trade liberalization causes a reallocation of workers within an industry towards the most productive (exporting) firms and increases the skill premium (e.g. Yeaple, 2005).

In this paper, I combine this reallocation mechanism with a competitive search model of the labor market. As in Kaas and Kircher (2011), firms are large in the sense that they are not restricted to hiring only one worker (as in a standard search model) and they commit to long term contracts. This allows the incorporation of a competitive search framework into a small open economy model featuring monopolistic competitive firms with heterogenous productivity, as in Melitz (2003). In the model, firms produce differentiated varieties using a skill-biased technology (in that larger, more productive firms employ relatively more high-skilled workers). With these features, the model lends itself to a quantitative analysis of the importance of the interplay between skill-biased technology, firm heterogeneity and search frictions for the labor market outcomes of a trade liberalization.

After a trade reform, only the most productive firms within an industry begin to export due to the fixed cost incurred for exporting. Since these firms have a higher skill intensity than non-exporters, a trade reform increases the relative demand for high-skilled workers in that industry. In addition to the skill premium, the model also features unemployment and residual (within-group) inequality, both of which are generated by the labor market frictions. More productive firms have a stronger incentive to fill their vacancies and post them in submarkets with a high vacancy filling rate. However, in order to compensate workers for the correspondingly lower job-finding rate, these submarkets offer more lucrative contracts. Differences in firm productivity thus translate into residual wage inequality.

I then present a numerical analysis of the model and investigate the relationship between trade and inequality through the lens of the model. For the analysis, parameters are chosen to be in line with empirical estimates in order to show the qualitative implications as well as to give an idea of the quantitative strength of the mechanisms at work in the model. Within an industry, a trade liberalization increases the demand for high skilled workers. As in a traditional trade model, trade also causes a reallocation of resources across industries. Import-competing industries shrink while the exporting industries expand. If the comparative advantage industry is more high-skill intensive than the import-competing one, the within industry effect is amplified. On the other hand, the within effect is muted or possibly overturned if the comparative advantage industry is relatively low-skill intensive. However, to the extent that across industry reallocation of workers is often found to be weak in the data, a trade liberalization is likely to cause a small increase in the skill premium.

In the simulations, within-group inequality increases independently of the nature of the comparative advantage industry. This result is consistent with the one in Helpman et al. (2010), albeit generated by a different mechanism; employment at the most productive firms paying higher wages increases, which increases within-group inequality by dispersing the labor force across different firms. This effect is stronger in the comparative advantage industries and it is stronger for low-skilled workers than for high-skilled workers. Lastly, the simulations reveal a small decrease in unemployment as a result of a trade reform, as the overall number of vacancies for both types of workers increases. However, the overall effect of trade on labor market outcomes is small. In the numerical simulations, as in most economies, only a small fraction of the labor market is directly affected by trade, limiting the increase in both within and across-group inequality; in the simulations, inequality increases significantly less than the total increase reported for most economies over the past decades.

This paper is related to an active literature on trade and inequality – Harrison et al. (2011) provide an extensive survey of its various facets. In particular, the model in this paper is close to other work combining search models of the labor market with trade models in order to study labor market implications of international trade. Davidson et al. (2008a, 2008b) study the effect of offshoring on the skill premium in a random search model with skill-biased technology and Ritter (2012) uses a directed search model with a skill-biased technology to study the effect of trade on both the skill premium and residual inequality.[1] King and Stähler (2011) embed a directed search model into a general equilibrium trade model to study the effect of trade on unemployment, but do not address the question of inequality. These papers highlight individual channels for the effect of international trade on the labor market and, as is common in search models, they follow the one-worker-one-firm modeling approach. Consequently, they cannot combine the search model of the labor market with the standard monopolistic-competitive model with heterogeneous firms (dominant in much of the international trade literature) and they are not well-suited for a quantitative analysis.

Finally, Helpman et al. (2010) develop a model in which ex-ante identical workers are randomly matched with heterogonous firms employing multiple workers. Workers receive unobserved productivity shocks and more productive firms screen workers more intensely, giving rise to within-group inequality. An advantage of the competitive search framework used in the present paper is that it naturally generates income inequality among otherwise identical workers without relying on unobserved heterogeneity and screening. Moreover, because of the firms' commitment to long term contracts, the competitive search equilibrium is constrained efficient, in contrast with the random search model featuring the Stole-Zwiebel bargaining solution that induces firms to over-hire.[2]

2 Model

I consider a small open economy in a stationary equilibrium. Time is discrete and lasts forever. There is a large number of workers and firms in the economy; the mass of workers is normalized to one and the mass of firms is determined in equilibrium. Workers can be of two types, high-skill (h) and low skill (u), and the fraction of high skill workers is given by $\bar{h}$. Workers are infinitely lived,

[1]Costinot and Vogel (2010) and Burstein and Vogel (2012) investigate the interplay between skill-biased technology, trade and inequality outside a search model of the labor market.

[2]See Hawkins (2011) for a discussion of the role of commitment to overcome over-hiring. In fact, the random search model with multi-worker firms and Stole-Zwiebel bargaining features an additional inefficiency stemming from a congestion externality that low marginal product firms impose on high marginal product firms and which cannot be overcome with commitment even if the Hosios (1990) condition holds. In general, the competitive search equilibrium internalizes such externalities (Moen, 1997).

risk-neutral and discount the future at rate β. They are endowed with one unit of productive time each period.

Firms are large relative to workers, so each firm employs multiple workers. Firms become active by paying a fixed entry cost and remain active until they are hit with an exogenous shut down shock. After entering, firms learn their productivity and then seek to recruit workers. Recruiting takes place in a frictional labor market, described in detail in the next subsection. Workers and firms remain matched until the firm is shut down or the match is exogenously separated.

The timing within a period is as follows: First, potential entrants pay the entry cost and their productivity level is revealed. At the same time, for existing firms, the separation shock (from a worker) and exit shock are realized. Second, firms make their recruitment decisions. Third, firms and workers are matched. Unemployed workers will always be able to search, even if they separated in the same period. Lastly, production takes place. Newly formed matches are not productive in the current period.

2.1 The Labor Market

The model of the labor market is similar to the competitive search model with large firms in Kaas and Kircher (2011). Firms and workers match in a frictional labor market, which is segregated into many submarkets. Firms recruit workers by posting vacancies; all firms post their vacancies into the same set of submarkets. Workers can freely choose which submarket to visit, irrespective of their employment histories. In a submarket, vacancies and workers are matched according to a constant returns matching function, so, the matching rates for vacancies and workers only depend on the unemployed-vacancy ratio in that submarket, θ. Let $m(\theta)$ denote the arrival rate of workers at vacancies, i.e. firms that post V vacancies will hire $m(\theta)V$ workers. Conversely, the job-finding probability for a worker is $m(\theta)/\theta$. The function $m(\theta)$ satisfies $m'(\theta) > 0$, $m''(\theta) < 0$, and $m(0) = 0$.

A vacancy consists of a wage offer w and all firms within a submarket post the same wage. Consequently, submarkets are characterized by the contract offer w and unemployment-vacancy ratio θ. The wage remains constant for the duration of the match, i.e. firms offer long term contracts and are committed to paying the posted flat wage until the match is separated.[3] These

[3] The assumption of flat wages is made for convenience. The competitive search framework pins down the total

long term contracts imply that there potentially is wage dispersion for identical workers within a firm, depending on the timing of their hire.

It is costly for a firm to post vacancies. The cost of posting a vacancy depends on the number of vacancies the firm posts for each type of workers and the employment stock of the firm. Let V_u and V_h denote the number of vacancies for low and high skill workers, respectively. The cost for a firm to post these vacancies is given by $C(V_u, V_h, u, h)$; C is monotone increasing and convex in V (i.e. the marginal cost of posting a vacancy is increasing in the number of vacancies posted) and weakly decreasing in the firm's employment stock. This captures various recruiting and adjustment cost which are increasing in the number of new hires.

Workers observe all posted vacancies and then decide which submarket to enter. Workers who are matched with the firm start producing in the next period and unmatched workers receive an unemployment benefit b. Matched workers and firms remain together until either the firm exits or their match is broken up. Firms exit at rate δ and existing matches break up at rate γ. Thus, an employed worker becomes unemployed at rate $\pi = \delta + (1-\delta)\,\gamma$.

2.2 The Worker's Problem

Consider a worker employed at wage w. She faces a probability π of loosing her current match and returning to the pool of unemployed workers. Let $\mathcal{J}(w)$ denote the value of being employed at wage w and $\mathcal{U}$ denote the time-invariant value of being unemployed. Then, the flow payoff of unemployment is given by $(1-\beta)\mathcal{U}$ and the surplus value from being employed at the present wage w is given by

$$\mathcal{J}(w) - \mathcal{U} = \frac{w - (1-\beta)\mathcal{U}}{1-\beta(1-\pi)}. \tag{1}$$

Unemployed workers observe the wages posted and form expectations about the corresponding market tightness in each submarket. The value of entering a submarket with wage offer w and

expected payments over the course of the employment relationship, but not a specific time path of wages. However, in a world with risk averse workers, firms would offer flat wages in a stationary equilibrium, so this assumption is not unnatural. Alternatively, firms could pay workers varying sign on bonuses and subsequently their reservation wage, as in Kaas and Kircher (2011).

tightness θ is given by

$$\mathcal{W}(w,\theta) = \frac{m(\theta)}{\theta}(1-\delta)\frac{w-(1-\beta)\mathcal{U}}{1-\beta(1-\pi)}, \tag{2}$$

which is the product of the surplus value of employment offered by firms in that submarket and the probability of being hired in that submarket.

Any submarket that attracts a positive number of workers must offer the same value of search. To see this, consider two submarkets with identical market tightness, i.e. identical job finding probabilities. If the contract offered in the first submarket promises a higher surplus than the one promised in the second submarket, the first submarket offers a higher expected value of search. Consequently, more workers will enter the first submarket, which increases the market tightness and lowers the job finding rate until both submarkets offer the same value of search. Therefore, in equilibrium, all submarkets must satisfy

$$\mathcal{W}(w,\theta) \leq \overline{\mathcal{W}},\ \ \theta \geq 0,\ \text{ with c.s.} \tag{3}$$

where $\overline{\mathcal{W}}$ denotes the equilibrium value of search in the market. Since all active submarkets must offer the same value of search in equilibrium, workers face a trade-off when deciding which submarket to enter: more lucrative contracts are more difficult to find. This trade-off between the job finding rate and the wage paid generates inequality among identical workers in equilibrium.

Lastly, the flow payoff of unemployment satisfies

$$(1-\beta)\mathcal{U}\ = b + \beta\overline{\mathcal{W}}. \tag{4}$$

2.3 The Goods Market

The economy consists of $J+1$ sectors (industries), each producing a distinct good, $Q(j)$. The first J industries (manufacturing) produce a composite good consisting of a continuum of many differentiated varieties; each firm in industry j produces one variety $k \in K_j$. Varieties produced in these first J industries are tradable. The composite good of each industry is given by the CES index:

$$Q(j) = \left[\int_{k \in K_j} y(j,k)^{\varphi} \mathrm{d}k \right]^{1/\varphi},$$

where $y(j,k)$ denotes the quantity of variety k in industry j and $\varphi \in (0,1)$ governs the elasticity of substitution between the varieties. Firms in industry $J+1$ produce a homogeneous, non-tradable good (services) which serves as the numeraire in the economy.

The final good is an aggregate of all composite goods and the homogeneous good

$$\mathbb{Q} = \prod_{j=1}^{J+1} [Q(j)]^{\zeta_j},$$

with $\sum_{j=1}^{J+1} \zeta_j = 1$, i.e. ζ_j is the fraction of aggregate income spent on good j.

Let P_j denote the ideal price index for industry j:

$$P_j = \left(\int_{k \in K_j} p(j,k)^{\frac{-\varphi}{1-\varphi}} \right)^{\frac{\varphi-1}{\varphi}}$$

and by normalization $P_{J+1} = 1$. Utility maximization implies the following demand function for each variety of the differentiated good j

$$y(j,k) = A_j \, p(j,k)^{\frac{-1}{1-\varphi}},$$

where $A_j = \zeta_j \mathbb{Y} (P_j)^{\frac{\varphi}{1-\varphi}}$ is a demand shifter that each firm takes as given and $\mathbb{Y}$ denotes aggregate income. Demand for the homogeneous good $J+1$ is given by

$$y(J+1) = \zeta_{J+1} \mathbb{Y}.$$

2.4 The Firm's Problem in a Tradable Industry

An industry is modeled akin to Melitz (2003), amended by the frictional labor market described above. At the beginning of the period, a potential firm can enter by paying a fixed cost f_e in units of the numeraire good (services). After entering, the firm draws its productivity s from some distribution $G(s)$. The productivity level remains constant for the life of the firm. Active firms must pay a per period fixed cost of f_p to stay active and are subject to an exit shock, δ.

Firms produce output according to the following production function:[4]

$$y(s,u,h) = \bar{a}\left[\lambda_u u^{\sigma} + (s^{\rho} + \lambda_h h^{\rho})^{\frac{\sigma}{\rho}}\right]^{\frac{1}{\sigma}},$$

where u and h denote the number of low and high skill workers employed. $\rho < 0$ governs the degree of complementarity between firm and worker productivity and $\sigma \in (0,1)$ the degree of substitutability between high and low skill workers, λ_u and λ_h are positive constants, and $\bar{a}$ is an industry specific productivity parameter. Industries may differ with respect to all these production parameters. Furthermore, $\sigma < \varphi$, i.e. workers of different skill levels are more complementary (or less substitutable) than varieties within the industry.[5]

Firms have access to the differentiated goods market in another country (world market). However, in order to export, the firm has to pay a per period fixed cost f_x. Also, there is an variable cost (iceberg cost): in order to sell one unit on the world market, the firm has to ship $\tau_x > 1$ units. Let the two countries be named H (home) and X (export) and the quantities sold of each variety q_H and q_X, respectively. Profit maximization for an exporting firm requires the firm to equalize the marginal revenue across markets. Taking into account the iceberg cost and the exchange rate e, this implies the following relative quantities sold by an exporting firm:

$$\frac{q_H}{q_X} = \left(\frac{A_X}{A_H}\right)\tau_x^{\frac{-\varphi}{1-\varphi}}\, e^{\frac{-1}{1-\varphi}}.$$

Then, the firm's total revenue is

$$\mathbf{R} = \left[A_H + \mathbb{I}_x \tau_x^{\frac{-\varphi}{1-\varphi}} e^{\frac{1}{1-\varphi}} A_X\right]^{1-\varphi} y^{\varphi},$$

where $\mathbb{I}_x$ is an indicator variable that equals one if the firm decides to export and zero otherwise.

[4] To simplify notation, I will suppress the industry index j if there is no risk of confusion.

[5] Estimates for the elasticity of substitution between college graduates and the rest of the labor force lie in the range of 1.3-1.5. This contrasts with estimates for the elasticity of substitution between varieties of 2-10.

2.4.1 The Incumbent's Problem

The incumbent's objective is to choose its vacancy posting and export decision to maximize the firm's discounted profit stream. When making the vacancy posting decision, the firm takes the equilibrium value of search as given, i.e. the firm realizes that any submarket must satisfy (3). Let W_u and W_h denote the wage bill committed to low and high skill workers, respectively, and $\hat{x}$ next period's value of any variable x. The Bellman equation for an active firm is given by

$$\begin{aligned}\mathcal{V}(s,u,h,W_u,W_h) &= \max_{(\mathbb{I}_x,w_u,w_h,\theta_u,\theta_h,V_u,V_h)} A(\mathbb{I}_x)\bar{a}\left[\lambda_u u^\sigma + (s^\rho + \lambda_h h^\rho)^{\frac{\sigma}{\rho}}\right]^{\frac{\varphi}{\sigma}} \\ &\quad -W_u - W_h - C(V_u,V_h,u,h) - f_p - \mathbb{I}_x f_x \\ &\quad +\beta(1-\delta)\mathcal{V}(\hat{s},\hat{u},\hat{h},\hat{W}_u,\hat{W}_h)\end{aligned} \tag{5}$$

subject to

$$\hat{u} = (1-\gamma_u)u + m(\theta_u)V_u \tag{6}$$

$$\hat{h} = (1-\gamma_h)h + m(\theta_h)V_h \tag{7}$$

$$\hat{W}_i = (1-\gamma_i)W_i + m(\theta_i)V_i w_i, \quad i = u,h \tag{8}$$

$$V_i \geq 0, \quad i = u,h \tag{9}$$

$$w_i = (1-\beta)\mathcal{U}_i + \frac{\theta_i}{m(\theta_i)}\frac{(1-\beta(1-\pi))}{(1-\delta)}\overline{\mathcal{W}}_i, \quad \theta_i > 0, \quad i = u,h \tag{10}$$

where $A(\mathbb{I}_x) = \left[A_H + \mathbb{I}_x \tau^{\frac{-\varphi}{1-\varphi}} e^{\frac{-1}{1-\varphi}} A_X\right]^{1-\varphi}$.

The set of constraints can be reduced by substituting the constraint on the wages offered, (10), into the law of motion for the wage bill, (8). The resulting first order conditions lead to

$$C_{V_i} \geq \beta\overline{\mathcal{W}}_i \frac{m(\theta_i) - \theta_i m'(\theta_i)}{m'(\theta_i)}, \quad V_i \geq 0, \quad i = u,h \tag{11}$$

$$A(\mathbb{I}_x)\hat{B}_i - \hat{C}_i - (1-\beta)\mathcal{U}_i = \frac{\overline{\mathcal{W}}_i}{1-\delta}\left[\frac{1}{m'(\theta_i)} - \frac{\beta(1-\pi)}{m'(\hat{\theta}_i)}\right] \tag{12}$$

where $\hat{B}_i = \frac{\partial \bar{a}\left[\lambda_u \hat{u}^{\sigma} + \left(s^{\rho} + \lambda_h \hat{h}^{\rho}\right)^{\frac{\sigma}{\rho}}\right]^{\frac{\varphi}{\sigma}}}{\partial i}$, $i = \hat{u}, \hat{h}$.

The first equation describes the optimal trade-off between the number of vacancies posted and the market tightness. The firm can increase hiring either by increasing the yield per vacancy or by posting more vacancies. Increasing the yield per vacancy is costly because a high vacancy filling rate for the firm implies a low job finding rate for the workers. In order to offer the equilibrium value of search, the posted contract must promise high future wages for the hired worker. On the other hand, an increase in vacancies has a direct cost, C_V.

The second equation describes the evolution of the firm's hiring plan. The expression on the left-hand side is the net marginal revenue of an extra hire. If the marginal revenue is high next period, the yield per vacancy is high today (recall that a worker hired today will start producing tomorrow.) Since a high yield implies that the offered wage is also high, (12) states that firms that have a high marginal revenue will grow quickly and pay higher wages.

Also note that all hiring decisions are independent of the firm's total payroll. From the viewpoint of the firm, total payroll is sunk because of commitment to the promised payments. As a consequence, posting wages (or contracts) overcomes the problem of over-hiring in search models using the Stole-Zwiebel bargaining solution since the contracts of existing workers are unaffected by new hires.[6]

There is no uncertainty for firms after they enter; each firm of type s follows a deterministic employment path. Therefore, the firm's state space can be reduced to productivity and age; age is a sufficient statistic to infer a firm's employment stock and wage bill, conditional on its productivity. Let the recruitment policy functions of firm s at age a be denoted $g^{\theta}(s,a)$ and $g^{V}(s,a)$. The employment level of each firm of type s and age $a \geq 1$ is given by

$$u(s,a) = \sum_{t=0}^{a-1} g^{V_u}(s,t) m(g^{\theta_u}(s,t))(1-\gamma)^{a-t-1} , \tag{13}$$

$$h(s,a) = \sum_{t=0}^{a-1} g^{V_h}(s,t) m(g^{\theta_h}(s,t))(1-\gamma)^{a-t-1} ; \tag{14}$$

[6] See for example Helpman et al. (2010), Cosar et al. (2011); a detailed discussion of the role of commitment to future payments (though not necessarily fixed wages) can be found in Hawkins (2011).

and $u(s,0) = h(s,0) = 0$ as the initial employment level.

A firm begins exporting if the increase in revenue exceeds the fixed cost of accessing the world market. This depends on the firm's employment stock and productivity level:

$$\mathbb{I}_x(s,u,h) = \begin{cases} 0 & \left(\left[A_H + \tau^{\frac{-\varphi}{1-\varphi}} e^{\frac{-1}{1-\varphi}} A_X \right]^{1-\varphi} - A_H^{1-\varphi} \right) y^{\varphi} < f_x \\ 1 & \text{otherwise} \end{cases} \tag{15}$$

Since y is monotone increasing in s, u and h, it follows from (15) that exporting firms are larger and more productive than non-exporters, consistent with empirical findings. Note that the decision to start exporting this period does not affect this period's hiring decision, but rather previous period's hiring. It follows from (12) that a firm increases its recruiting efforts if next period's marginal revenue is high. This implies that, in anticipation of beginning to export tomorrow, the firm increases its hiring efforts today. This is consistent with recent empirical evidence which finds that firms typically start growing before they start exporting (e.g. Molina and Muendler, 2010).

2.4.2 The Entrant's Problem

After entering, the firm's productivity level is revealed. At that point, the firm makes a decision whether or not to remain in operation. Let $g^e(s)$ denote the optimal continuation decision by an entering plan, with $g^e(s) = 1$ for firms that remain active. As $\mathcal{V}$ is increasing in s, the optimal continuation policy for an entering firm to stay is a cut-off productivity level $\tilde{s}$:

$$g^e(s) = \begin{cases} 0 & s < \tilde{s} \\ 1 & s \geq \tilde{s} \end{cases} \tag{16}$$

where $\tilde{s}$ satisfies:

$$\mathcal{V}(\tilde{s}, 0, 0, 0, 0) = 0.$$

Firms that continue to operate then post vacancies according to an incumbent's policy functions. Note that there is no endogenous exit by firms after their first period in a stationary environment because there is no further uncertainty after the productivity shock has been revealed.

2.5 The Firm's Problem in the Non-tradable Industry

The non-traded good industry is perfectly competitive in the goods market but firms still face the same labor market frictions as in the traded goods industries. Firms produce output according to the following decreasing returns production function:

$$y(s,u,h) = \bar{a}\left[\lambda_u u^{\sigma} + (s^{\rho} + \lambda_h h^{\rho})^{\frac{\sigma}{\rho}}\right]^{\frac{\alpha}{\sigma}},$$

where u and s denote the number of low and high skill workers employed, $\rho < 0$ and $\sigma, \alpha \in (0,1)$. As in the differentiated goods industries, firms' productivity s is revealed upon entry and constant over time. Thus, the firm's problem is almost identical to the one described above and thus omitted.

2.6 Equilibrium

In equilibrium, entering firms must make zero expected profits, i.e.

$$f_e = \int_s \max\left\{\mathcal{V}(s,0,0,0,0);\ 0\right\}\, dG(s). \tag{17}$$

Let $N_0(j)$ denote the number of newly entering firms that satisfies (17) for each industry j. Since firms only exit exogenously after the first period, the stationary distribution of firms over productivity and age is

$$f(s,a) = (1-\delta)^a N_0\, g^e(s) dG(s). \tag{18}$$

As discussed above, a firm's employment path is deterministic and age and productivity are a sufficient statistic to infer the firm's remaining state variables. The distribution of firms over productivities and employment levels, $f(s,u,h)$, can be inferred from (13) and (14) in combination with (18). Therefore, (18) is the aggregate state variable of the economy.

The following gives the definition of the equilibrium for this economy; the details describing how to compute the equilibrium can be found in the Appendix.

Definition. A stationary competitive search equilibrium for the small open economy consists of a value functions for workers $\left\{\mathcal{W}_i(w,s),\, \overline{\mathcal{W}}_i\right\}_{i=u,h}$, value functions $\mathcal{V}(s,u,h,W_u,W_h)$ and associated policy functions $g^{V_u}(s,a), g^{V_h}(s,a), g^{\theta_u}(s,a), g^{\theta_h}(s,a),\ g^e(s), \mathbb{I}_x(s,a)$ for firms, an invariant distribution of firms $f(s,a)$, a mass of entering firms $N_0(j)$, aggregate income $\mathbb{Y}$, a price index for each industry $P(j)$, and an exchange rate e, such that

1. Workers' search decisions maximize their utility, i.e. (3) holds.

2. The firms' policy functions solve (5).

3. The free entry condition, (17), holds.

4. The aggregate resource constraint holds.

5. Markets clear.

6. Trade is balanced.

7. The distribution of firms is time invariant.

3 Trade and Inequality

In the model, a trade reform induces a reallocation of workers towards exporting firms, who are more productive and hence have a higher skill intensity. While it is obvious that exporting firms will hire more workers, the extent to which the trade reform will increase the relative demand for skilled workers (and hence inequality) depends on the relative skill intensity of exporting firms. Industries differ in their skill intensity and not all industries export equally, so a trade liberalization also induces some across industry reallocation of workers towards the comparative advantage industries. Differently from the within industry reallocation, the across industry allocation might increase or decrease the relative demand for skilled workers, depending on the relative skill intensity of the comparative advantage industries. In order to shed some light on the relative importance of these two channels, this section explores some of the quantitative features of this model through numerical simulations.

3.1 Parameterization

The hypothetical economy consists of three industries: two traded industries and a non-traded industry (services). Most of the parameters are chosen to be in line with the empirical estimates found in the literature and/or to generate reasonable moments of the model, but it is important to stress that this is a simulation exercise and the parameters are not calibrated to match any specific labor market or any specific trade scenario. The goal is to qualitatively assess the model and investigate the possible magnitude that can be expected in a full quantitative exercise.

The model period is one year and, accordingly, $\beta = 0.96$. The fraction of high skill workers in the labor force is set to 30% , i.e. $\bar{h} = 0.3$. The elasticity of substitution between different varieties, governed by φ, is set to be 8. An elasticity of this magnitude is reasonable for narrowly defined industries (e.g. Broda and Weinstein, 2010). Since trade occurs within such industries, it is the appropriate choice even though the stylized example only consists of 3 industries. The expenditure shares κ_j are selected in order to ensure the autarky employment in tradeable industries is one third that of the service sector and that both tradable industries have the same overall employment (with different skill compositions). This relatively small – although realistic – size of the traded sector is one of the reasons the model predicts the overall effect of international trade on inequality to be rather small. Lastly, the industry-wide productivity $\bar{a}_j$ is set such that the autarky price ratio between all industries is 1.[7]

Firms exit at rate $\delta = 0.1$ and low and high skill workers separate at rate $\gamma_u = 0.15$ and $\gamma_h = 0.1$, respectively, implying an average tenure at the time of separation of 6.67 years for low-skilled workers and 10 years for high-skilled workers. Firms' productivities are exponentially distributed with parameter $\lambda = 1$. For the elasticity of substitution between skilled labor and technology and skilled and unskilled labor, I select 0.625 and 1.33, respectively, which is similar to the values reported in Katz and Murphy (1992) and Krusell et al. (2000). These elasticities are the same across industries and imply that more productive firms employ relatively more high-skill labor than less productive firms; within an industry, the most productive firm uses high-skill labor about 15% more intensively than the least productive firm.[8] The differences in skill intensities between industries stems from variations in the weights λ_u and λ_h. They are set such that the ratio of low-skill to high-skill workers is 1.94 in the high-skill intensive industry and 2.59 in the low-skill intensive industry (overall 2.26). In other words, the high-skill industry uses high skilled

[7] Alternatively, one could normalize the productivities to 1 and determine the relative price in equilibrium.

[8] The elasticities could be different across industries, further amplifying the effects. However, to avoid having too much variation in parameters and making the results less transparent, I set them to be the same.

workers about 35% more intensively. While this may seem small at first, recall that these are two (manufacturing) industries in the same economy.

The cost function for posting vacancies follows the specification used in Cosar et al. (2010) with full separability between the two skill groups in hiring:

$$C(V_h, V_u, h, u) = a\left(V_h^{\eta_1} h^{\eta_2} + V_u^{\eta_1} u^{\eta_2}\right)$$

Using the values from that paper, $\eta_1 = 2.3$ and $\eta_2 = 0.7$, implies that there are increasing marginal costs of posting vacancies, which generates transition dynamics on the level of the firm. However, the convexity is not very strong and consequently convergence in the model is relatively fast: depending on its size, a firm reaches more than 50% of its steady state employment stock within 3-4 years, and more than 90% in 8-10 years. Nevertheless, these size differences are an important source of within-group inequality. In order to grow fast, young firms offer higher wages than older firms that only need to do replacement hiring. The value of a is set to match an unemployment rate of high skill workers of 4.2%. Lastly, the matching function is Cobb-Douglas with elasticity of 0.5. The key parameters are listed in Table 3.1 and the targets used in Table 3.2.

3.2 Simulation Results

Autarky. The results for the autarky equilibrium are summarized in Table 3.3. The level of the skill premium and the unemployment rates are of a reasonable magnitude. In line with Hornstein et al. (2010), the within-group dispersion generated by the model is small; the resulting wage distribution can be seen in Figures 3.1 and 3.2. Over 90% of all workers within one group receive almost identical wages.[9] As in Kaas and Kircher (2011), young firms wish to grow quickly and offer higher wages; their high offers generate the noticeable long tail of the wage distribution. However, while the model fails to deliver the level of residual inequality found in the data, qualitatively the predictions are in line with the data – controlling for age, both larger and fast growing firms pay higher wages. Consequently, I evaluate the model's prediction for the link between trade and

[9] Adding on-the-job search could potentially increase the level of wage dispersion to a level more in line with the data. Unfortunately, adding on-the-job search increases the computational difficulty greatly, as the distribution of wages paid within a firm becomes a state variable in the firm's problem (i.e. the quit rates depends on the wages paid).

inequality relative to the autarky equilibrium.

Two Trade Scenarios. After computing the autarky equilibrium, I open up the economy. The trade liberalization can take on two forms: in the first scenario, the economy has a comparative advantage in the high-skill intensive industry, while in the second it has a comparative advantage in the low-skill industry. Note that the economy will import and export varieties in both industries but the relative price between the two industries in the world market may differ from the relative price in autarky, giving the economy a comparative advantage in one industry and a comparative disadvantage in the other.

In both scenarios, the world market prices and the cost of exporting are chosen such that the industry with the comparative advantage exports 40% if its output, while the other industry exports 25%. More specifically, in scenario 1, the world market relative price is equal to the autarky relative price and iceberg and fixed cost are set to obtain a 40% exporting share in the high-skill and a 25% export share in the low skill industry. For scenario 2, both the iceberg and fixed cost are set to be the same as in scenario 1 and the prices are adjusted such that the export shares are reverted. Tables 3.5 and 3.4 summarize the results for the two trade scenarios.

Output and Employment. In both scenarios, imports and exports make up around 19% of GDP. While the gains from trade are small in both scenarios (between 0.5 and 1%), they are smaller when the economy has a comparative advantage in the high-skill intensive industry. This can be attributed to the world market prices necessary to generate high exports in the low-skill industry; in scenario 1, the world market relative price is equal to the autarky relative price, while in scenario 2 the relative price is close to 1.25. At constant relative prices, the gains from trade stem from intra-industry trade and there is very little worker reallocation across industries. In that scenario, the high-skill industry exports more as firms in that industry are relatively more productive. In scenario 2, the differences between autarky and world market relative prices allows more firms in the low-skill industry to export, but it also causes additional gains from trade through a stronger reallocation between industries. The country is less similar to the rest of the world and can exploit its comparative advantage.

The trade liberalization has a small positive effect on employment. Unemployment decreases for both high- and low-skilled workers. While less productive firms shrink or exit after the liberalization, this is more than made up by the growth of the more productive, exporting firms. The overall number of vacancies increases, lowering unemployment slightly for both groups.

Skill Premium. The change in the skill premium (expressed as the difference in average log wages between high- and low-skill workers) is small, only about 1 percentage point. In scenario 1, in which the economy has a comparative advantage in high-skill industries, the skill premium increases after opening to trade. Conversely, in scenario 2, in which the economy has a comparative advantage in low-skill industries, the skill premium is lower with trade than in autarky. However, the effect on the skill premium is not symmetric. If the economy's comparative advantage lies in the low-skill industries, the skill premium falls less than it increases if the comparative advantage lies in the high-skill industries. This is because there are two forces at play: the skill bias of exporting stemming from the interplay of heterogenous firms and the skill-biased technology, as well as the industry composition effect.

The industry composition effect arises because employment in the exporting industry grows significantly while employment in the importing industry shrinks significantly. This benefits the worker type that is more intensively employed in the exporting industry – the Stolper-Samuelson effect. At the same time, within an industry the demand for high-skilled workers increases as only the most productive firms with the highest skill-intensity export. If the exporting industry is high-skill intensive, the two effects work in the same direction and the skill premium is increased unambiguously (scenario 1). However, if the import-competing industry is more high-skill intensive than the exporting industry, the two effects work in opposite directions, almost cancelling each other out (scenario 2).

The small magnitude of the change in the skill premium has two reasons. Firstly, there is very little trade relative to the overall size of the economy, which limits the possible effect on the skill premium. Secondly, in the simulation, the skill-intensities do not differ as much between firms within an industry relative to the differences in skill-intensities across industries. Larger and more productive firms hire relatively more high skill workers, but, given the parameterization in this exercise, this difference is not very strong – the ratio of skill intensity between most and least productive firm is 1.15. Therefore, the across industry reallocation plays a more important role in the effect on the skill premium. Yet, consistent with empirical evidence, the model delivers very little relocation across industries and hence a small effect on the skill premium.

Residual Inequality. The simulations deliver an unambiguous increase in within-group inequality. Table 3.5 reports the relative change in inequality. Opening up to trade increases employment at the larger, more productive firms and shrinks the less productive firms. Relative to autarky, these larger and higher wage paying firms employ a larger fraction of workers. Given the initial distribution of workers, this leads to an increase in the dispersion in wages among identical workers.

Not surprisingly, dispersion increases more in the respective comparative advantage industry. In the comparative advantage industry, more firms export a larger fraction of their output, leading to a stronger within industry relocation and hence a larger increase in within-group inequality. Interestingly, the disparity between the two industries is stronger in scenario 2 when the economy has the comparative advantage in the low-skill industry: in the high-skill industry the more productive firms are relatively larger when compared to the low-skill industry. Therefore, in the low-skill industry there is more within industry reallocation necessary to export 40% of its output, causing a larger increase in residual inequality. Similarly, the effect is stronger for low-skill than for high-skill workers since high-skill workers were already more concentrated at larger firms.

Nevertheless, the simulated model generates only a moderate overall increase in residual inequality. The increase in inequality stems from the within industry change in the firm distribution within exporting industries. However, most workers are employed in non-traded industries and the firm distribution in the non-traded industries remains unchanged. Just as with the skill premium discussed above, the overall amount of trade is small, limiting its impact on inequality.

As this exercise demonstrates, the model can deliver results for the effect of trade on inequality that can explain the ambiguous findings in the data. For the skill-premium (across-group inequality), the within industry reallocation effect resembles the effect of skill-biased technological progress, while the across industry reallocation (into the comparative advantage industries) causes a Stolper-Samuelson effect. For the residual (within-group) inequality the within industry reallocation increases inequality among both high-skilled and low-skilled workers. The effect on low-skill workers is stronger and the skill intensity of the comparative advantage industry matters. However, overall the effect of trade on inequality is small as only a small fraction of the labor force is employed in tradable industries.

4 Conclusion

This paper embeds a competitive search model of the labor market into a small open economy with firm and worker heterogeneity. In addition to the presence of income differences between skill groups, search frictions generate equilibrium unemployment and income inequality between identical workers in a parsimonious way. The model therefore incorporates multiple channels through which increased trade might affect the labor market. The model is then used for a numerical exercise aimed at quantifying the potential importance of the increase in trade for the observed increase in inequality.

Simulations of the model using reasonable parameter values reveal that an increase in trade is likely to increase within-group inequality and decrease unemployment, while the effect on the skill premium is ambiguous because across and within industry effects may work in opposite directions. Overall, the effect of trade on the labor market is minor if only a small fraction of the labor force is employed in exporting and import-competing industries. The numerical exercise for the hypothetical economy reveals an increase in income inequality that represents only a fraction of the overall increase in inequality in developed economies, indicating that international trade is unlikely to have played a major role in the observed increase in inequality.

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Appendix: Equilibrium in the Open Economy

The stationary equilibrium can be computed using the following conditions:

- Searching workers indifferent between all active submarkets, (3).
- The firms' hiring decisions satisfy (11) and (12).
- Zero expected profits for newly entering firms in each industry, (17).
- Invariant distribution of firms across industries, productivity levels, and ages, (18).
- Aggregate resource feasibility (labor market clearing).
- Market clearing for all industries.
- Balanced Trade.

Labor Market Clearing

Total supply of high and low skill workers is $\bar{h}$ and $(1-\bar{h})$, respectively. Workers can be either employed or unemployed. Summing over all firms in all industries, labor market clearing requires:

$$(1-\bar{h}) = \sum_{j=1}^{J+1}\sum_{a\geq 0}\int_s \left[u(s,a)+g^{V_u}(s,t)g^{\theta_u}(s,t)\right] f(s,a,j)ds \tag{19}$$

$$\bar{h} = \sum_{j=1}^{J+1}\sum_{a\geq 0}\int_s \left[h(s,a)+g^{V_h}(s,t)g^{\theta_h}(s,t)\right] f(s,a,j)ds \tag{20}$$

Goods Market Clearing

Aggregate income in the economy is given by:

$$\mathbb{Y} = \sum_{j=1}^{J+1}\sum_{a\geq 0}\int_s W(j,s,a)f(s,a,j)ds + \bar{\Pi}$$

where

$$\begin{aligned} W(s,a,j) &= \sum_{t=0}^{a-1} w_u(g^{\theta_u}(s,t,j))g^{V_u}(s,t,j)m(g^{\theta_u}(s,t,j))(1-\gamma)^{a-t-1} \\ &\quad + \sum_{t=0}^{a-1} w_h(g^{\theta_h}(s,t,j))g^{V_h}(s,t,j)m(g^{\theta_h}(s,t,j))(1-\gamma)^{a-t-1} \end{aligned} \tag{21}$$

$$\text{and} \quad w_i(\theta_i) = (1-\beta)\mathcal{U}_i + \frac{\theta_i}{m(\theta_i)}\frac{(1-\beta(1-\pi))}{(1-\delta)}\overline{\mathcal{W}}_i$$

denotes wages paid out to workers (hired in different periods) by firm (s,a,j) and

$$\bar{\Pi} = \sum_{j=1}^{J+1}\sum_{a\geq 0}\int_s \Pi(j,s,a)f(s,a,j)ds - \sum_{j=1}^{J+1} N_0(j)f_e, \tag{22}$$

$$\begin{aligned} \text{where} \quad \Pi(s,a,j) &= A(\mathbb{I}_x)\left[u^\sigma + (s^\rho+\lambda_h h^\rho)^{\frac{\sigma}{\rho}}\right]^{\frac{\varphi}{\sigma}} \\ &\quad -W(s,a,j) - C_u(V_u,u) - C_h(V_h,h) - f_p - \mathbb{I}_x f_x \end{aligned}$$

are the total profits of all firms.

Market clearing for composite goods $j = 1, .., J$ requires demand to equal domestic supply plus imports,

$$\frac{\zeta_j \mathbb{Y}}{P_j} = \left[\sum_{a \geq 0} \int_s \left[\frac{y(s,a,j)}{B_H(j)} \right]^{\varphi} f(s,a,j) ds \right]^{1/\varphi} + A_j \; (\tau_m e)^{\frac{-\varphi}{1-\varphi}} \,,$$

where $B_H(j) = \left(1 + \frac{A(j)_X}{A(j)_H} \tau_m^{\varphi/(\varphi-1)} e^{1/(1-\varphi)}\right)$.

Demand for good $J+1$ (services) comes not only from consumers, but also from firms who pay their fixed costs and recruiting costs:

$$\frac{\zeta_{J+1} \mathbb{Y}}{P_{J+1}} + \sum_{j=1}^{J+1} \left[N_0(j) f_e + \sum_{a \geq 0} \int_s \left[f_p + \mathbb{I}_x(s,a,j) f_x \right] f(s,a,j) ds \right] \tag{23}$$

$$+ \sum_{j=1}^{J+1} \sum_{a \geq 0} \int_s \left[C_u(g^{V_u}(s,t), u(s,a)) + C_h(g^{V_h}(s,t), h(s,a)) \right] f(s,a,j) ds$$

$$= \sum_{a \geq 0} \int_s y(s,a,J+1) f(s,a,j) ds.$$

Trade Balance

The demand function for each variety is given by

$$y(j,k) = A_j \, p(j,k)^{\frac{-1}{1-\varphi}}.$$

A subset K_j^F of differentiated goods in industry $j \in J$ is imported from the rest of the world. Their prices are exogenous to the economy, so one can normalize the world market price of the imported bundle:

$$\left(\int_{k \in K_j^F} p(j,k)^{\frac{-\varphi}{1-\varphi}} \right)^{\frac{\varphi-1}{\varphi}} = 1.$$

Then, the domestic price for the imported bundle $P^F = \tau_m e$, where $(\tau_m - 1) > 0$ denotes the iceberg cost of imported goods and e denotes the exchange rate. This normalization also determines the comparative advantage of the economy. While there will be trade in all tradable industries, there will be more in some than in others, depending on the autarky relative price between industries. The price index for the differentiated good in the small open economy can then be written as

$$P(j) = \left(\int_{k \in K_j^D} p(j,k)^{\frac{-\varphi}{1-\varphi}} + (\tau_m e)^{\frac{-\varphi}{1-\varphi}} \right)^{\frac{\varphi-1}{\varphi}}$$

and the demand for domestic and imported varieties is given by

$$y^D(j,k) = A_j \, p(j,k)^{\frac{-1}{1-\varphi}} \tag{24}$$

$$\text{and} \qquad y^F(j,k) = A_j \, \left(\tau_m e \, p(j,k)\right)^{\frac{-1}{1-\varphi}} \tag{25}$$

respectively.

The total expenditure on foreign goods in domestic currency is given by

$$\begin{aligned} E_F &= \sum_{j=1}^{J} \int_{K_j^F} \tau_m e \, p(j,k) y^F(j,k) \\ &= \sum_{j=1}^{J} A_j \, (\tau_m e)^{\frac{-\varphi}{1-\varphi}} \end{aligned} \tag{26}$$

where the second line uses the normalization of the foreign price level in each industry. Total export revenues are

$$R_X = \sum_{j=1}^{J} \sum_{a \geq 0} \int_s \left[e \left(\frac{y(s,a,j)}{\tau_x} \right)^{\varphi} A(j)_X^{1-\varphi} \left(\frac{1}{B_X} \right)^{\varphi} \right] \mathbb{I}_x(j,s,a) f(s,a,j) ds \ , \tag{27}$$

where $B_X = \left(1 + \frac{A(j)_H}{A(j)_X} \tau_m^{\varphi/(1-\varphi)} e^{1/(\varphi-1)}\right)$.

Finally, balanced trade requires that

$$R_X = E_F. \tag{28}$$

Table 3.1: Parameter Selection

Parameter	Value	
ρ	-.6	Elasticity of substitution between high-skill labor and technology = 0.625
σ	0.25	Elasticity of substitution between skilled and unskilled labor = 1.33
φ	0.875	Elasticity of substitution between varieties = 8
δ	0.1	Firm exit rate
γ_h	0.1	High skill worker separation rate
γ_u	0.15	Low skill worker separation rate
η_1	2.3	Curvature of vacancy cost function
η_2	0.7	from Cosar et al. (2010)
α	0.5	Elasticity of matching function
$\overline{h}$	0.3	Fraction of high skilled workers in the labor force
β	.96	Discount Factor

Table 3.2: Moments used in Parameter Selection

Target	Value
Unemployment rate high skilled workers	4.2%
Fraction of employment in services	66.7%
Fraction of employment in high-skill industries	16.7%
Fraction of employment in low-skill industries	16.7%

Table 3.3: Autarky Equilibrium

Skill Premium	0.548
Std. Dev. $log(w_L)$	0.018
Std. Dev. $log(w_H)$	0.007
Unemployment Rate H-skill	0.042
Unemployment Rate L-skill	0.070

Table 3.4: Simulation Results – Output

	Scenario 1	Scenario 2
% ΔY	0.455	1.081
(X+M)/GDP	0.189	0.191
Exports/GDP		
Sector 1	0.41	0.25
Sector 2	0.25	0.41

Table 3.5: Simulation Results – Labor Market

	Autarky	Scenario 1	Scenario 2
Unemployment Rate H-skill	0.0419	0.0411	0.0410
Unemployment Rate L-skill	0.0701	0.0692	0.0690
Skill Premium	0.548	0.558	0.541
Std. Dev. $log(w_L)$	0.0102	0.0110	0.0107
Std. Dev. $log(w_H)$	0.0077	0.0082	0.0079
%Δ (Std. Dev. $log(w_L)$), all industries		7.9	4.5
%Δ (Std. Dev. $log(w_L)$), high skill industry		14.7	9.8
%Δ (Std. Dev. $log(w_L)$), low skill industry		12.2	16.6
%Δ (Std. Dev. $log(w_H)$), all industries		6.4	3.4
%Δ (Std. Dev. $log(w_H)$), high skill industry		11.5	6.1
%Δ (Std. Dev. $log(w_H)$), low skill industry		7.4	13.4

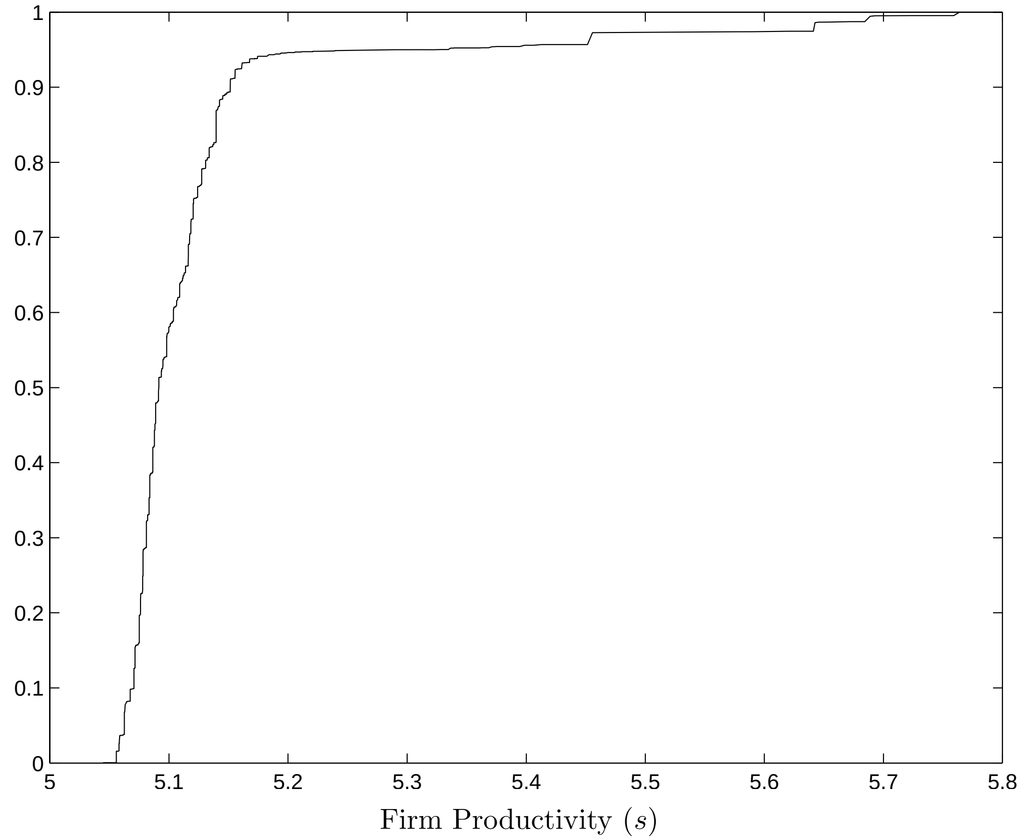

Figure 3.1: CDF: Wages of Low-skilled Workers

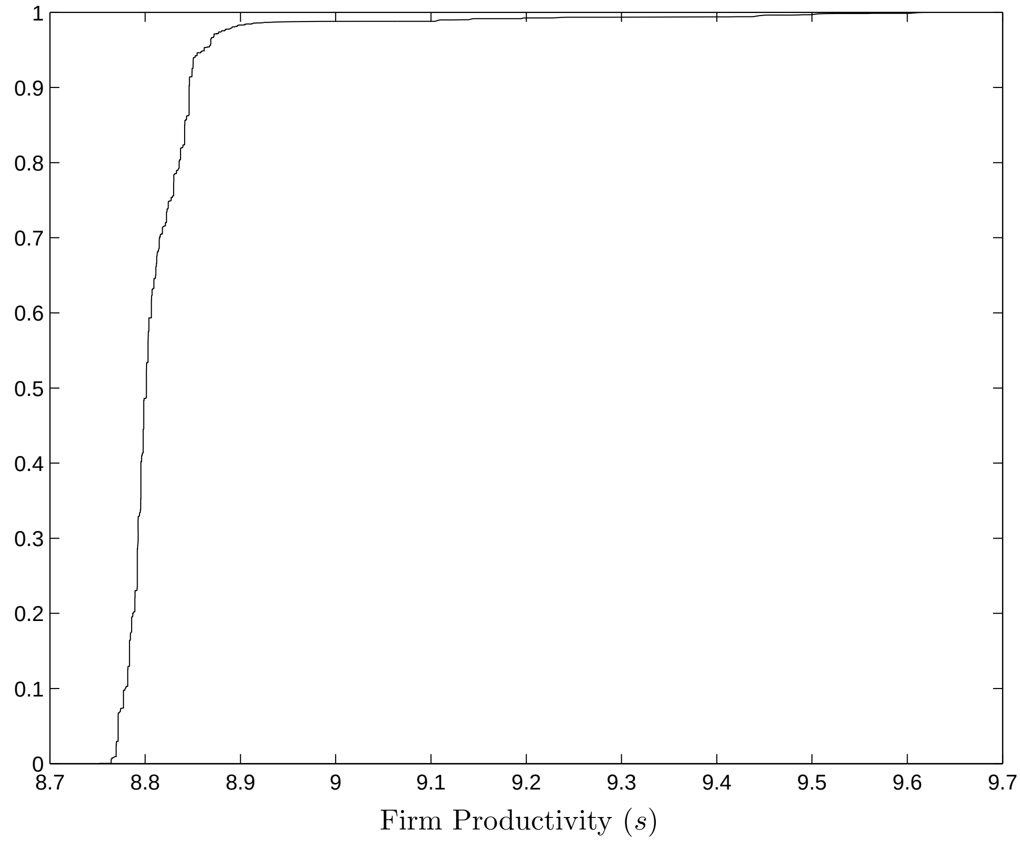

Figure 3.2: CDF: Wages of High-skilled Workers