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Abstract

In this paper, we focus on the skill formation when considering the trade impacts on labor markets. Although workers are identical as unskilled labor, they differ in their productivity as skilled. Workers become skilled by incurring the training costs. Introducing the above settings into a trade model with monopolistic competition, we show that trade opening enhances skill formation. This is because trade enriches the varieties of differentiated goods and raises the utility of a worker for a given income. This effect works stronger for the skilled than for the unskilled although it makes all agents better off, leading to higher skill formation. However, it may be accompanied by rises in the real wage disparity between skilled and unskilled workers and by rises in the skilled wage inequality. Finally, we examine the possible effects of foreign direct investment on the labor market structure as well.

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Keywords: trade, skill formation, monopolistic competition, wage inequality, FDI

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1 Introduction

During the past two decades, the volume of trade has risen than ever before. In fact, the world merchandise trade volume index for manufactures (1950=100) rose from 2929 in 1995 to 5454 in 2005 (WTO [35]). This indicates that the trade has come to play a more and more important role in the current economy, which is also convinced by the world wide proliferation of Regional Trade Agreements (RTAs).[1] Moreover, trade now occupies a significant share in the world economic activities: World Bank [33] reported that exports of goods and services account for 24.6 percent of world GDP in 2000.

This trend has prospered the analysis of trade effects on various economic activities. Especially, in the face of the new established facts regarding differences in firms' performances in the trade environment (see Bernard and Jensen [9][10], among others), impacts of trade in the presence of heterogeneous firms have been intensively studied by papers such as Melitz [28], Helpman et al [20], and Antras and Helpman [4].[23] These papers developed monopolistic competition models with heterogeneous firms, and shed light on the trade impacts on the industrial structure and firms. In their models, workers are identical and their focus is not on worker heterogeneity but on differences in the firm level productivity. However, it is also a traditionally-well-known fact that *workers are heterogeneous.* Then, it would be worth asking how trade could interact with labor markets when workers are heterogenous.

Regarding the labor market, rises in the percentage of skilled labor have been observed in many developed countries during the past few decades. For instance, from 1983 to 2002, the U. S. manufacturing sector has experienced 37 percent increases in employment in high-skill occupations regardless of its contraction during that period (Federal Reserve Bank of New York [13]). This trend is also confirmed by Barro and Lee [7] In parallel,.increases in (real) wage gap between skilled and unskilled workers and rises in wage dispersion within groups (residual inequality) have been distinct. Acemoglu [1] reported that during the past two decades, the college wage premium in the United States has increased at almost twice. Lemieux [24] provided empirical evidences on rising wage dispersion (variance) regarding workers with higher education. Many researches such as Baldwin and Cain [6], Berman et al [8], Bloom and Brender [11], Katz and Autor [21] supported these findings in many of the older industrial economies of Europe and the United States. These trends were observed also in Hong Kong, Korea, Singapore, Taiwan (Fields [15]) and Mexico (Hanson and Harrison [18]).

Whereas possible explanations for these trends have been widely investigated from the viewpoint of skill-biased technological progress (see Acemoglu [1]), there is still room for exploring other possible causes.[4] In fact, some researchers have considered trade as a significant candidate. Richardson [31] (p. 36) surveyed the empirical studies and concluded regarding the impacts of trade on wage disparity as "...Taken together, they[recent empirical contributions] suggest to me an important role for trade, close to or larger than its 10-15 percent share of U.S. output: not tiny, but not overwhelming either..." Also, Feenstra [14] enumerated more recent studies that support this view. Given the drastic increases of trade during the past decade, it would be safe to consider trade as one of the

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[1]In 2006, there exist 211 RTAs, and among them, 194 were concluded after 1980 (WTO [34]).

[2]Mannase and Turrini [25] considered a model in which heterogeneity of firms arises from the difference in the skill of entrepreneurs and obtained similar results regarding industrial changes due to trade openness to those shown in Melitz [28].

[3]For recent surveys, see Baldwin [5], Greenaway and Kneller [16] and Helpman [19].

[4]Skill-biased technical progress raises the demand for skilled labor and skilled worker wages.

important factors that affect the skill composition and the wage structure.

The conventional wisdom in the trade theory suggests that the skilled-unskilled wage gap in developed countries increased since international trade with relatively skill-scarce developing countries raised the relative price of skill-intensive goods and the demand for skilled labor in developed countries (the Stolper-Samuelson effect). More recently, Acemoglu [2] suggested that international trade, via the Stolper-Samuelson effect, enhances the skill-biased technical change (i.e., technological progress in the skill intensive sector) and raises the demand for skilled labor, which can account for increases in the wage gap.[5] However, most evidences in the United States suggest a declining or constant relative price of skill-intensive goods between the early 1970's and mid-1990's in which the share of imports from developing countries in the United States GDP increased over fourfold (see, Lawrence and Slaughter [23], and Sachs and Shatz [32]). In addition, Berman et al [8] showed empirically that recent rapid increases in demand for skilled labor in the United States manufacturing sector are mainly attributed to the within industry changes, not to the between industry changes. These evidences are not fully consistent with the Stolper-Samuelson effect, inducing us to look for other candidates.

Given the current importance of trade between developed countries, it would be natural to seek for a channel through which trade between developed countries affects the skill composition and the wage structure. Yeaple [36] went into this direction by adopting a monopolistic competition model of trade. He focused on the interaction among monopolistic competition, workers' skill heterogeneity, and firms' technological choice, and showed that a reduction in trade cost benefits firms that choose relatively more skill-biased technology, which increases the share of such firms accompanied by rises in wage rate for high skilled workers. However, Yeaple [36] assumed the exogenous distribution of skilled labor and hence, the skill formation was out of the scope of his analysis.

By contrast, our primary focus is on *the role of skill formation* in the environment where developed countries trade with each other. In this paper, we present a trade model with monopolistic competition a la Dixit and Stiglitz [12] and skill formation. In our model, although workers are identical as unskilled labor, their productivity as skilled labor differs from worker to worker, i.e., they are vertically heterogeneous. If a worker trains herself, she becomes skilled. Thus, we embeds vertical labor heterogeneity within Krugman [22] model of trade under monopolistic competition and increasing returns.[6]

Using this model, we will show that trade opening raises the skilled worker ratio, the skilled-unskilled real wage gap, and the wage dispersion of skilled workers (residual inequality). In our model, trade allows people to consume wider varieties of goods and lowers the price index of consumption goods, which leads to higher welfare (real wage) of all agents. However, it raises the real skilled wage more than the real unskilled wage. This induces even less productive workers to become skilled, which enlarges the wage dispersion among skilled workers. Thus, our model shows that trade induces skill formation and raises the wage gap without the Stolper-Samuelson effect and the skill-biased technical progress. In this sense, we presents a new channel (i.e., skill formation) through which international trade affects the wage structure. These results show that *the trade improves the welfare of all people although it may worsen inequality.* We also study the effects of changes in

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[5] In relation to this, Matsuyama [27] pointed out that if transportation sector's technology is skill intensive, technical progress in this sector enlarges the trade amounts and raises the wage gap.

[6] Amiti and Pissarides [3] constructed a trade model with monopolistic competition, horizontally heterogeneous workers, and skill formation. They examined the relationship between skill mismatch parameter and the agglomeration of firms. They showed that decreases in transportation costs and skill mismatch parameter induces skill formation and agglomeration of firms.

trade environment and effects of Foreign Direct Investment (FDI), and prove that FDI, if firms prefer it to export, enhances skill formation and may raise inequality.

This paper is organized as follows. In section 2, we present a basic model and analyze the autarky economy. Section 3 analyzes the case of trade opening and compare the results with those in the autarky economy. In section 4, we consider the effects of FDI. Section 5 concludes the paper.

2 Setup of the model

In this section, we introduce the basic structure of the model and explore its equilibrium. In doing so, we first construct a closed economy model, and will extend it to an open economy model in the next section.

2.1 Consumption

Consider a country in which there is a continuum of (immobile) workers of which measure is one. Each worker is endowed with one unit of time that can be spent on working. Workers are either skilled or unskilled. Skilled and unskilled workers differ in the following two points. First, workers must train themselves in order to become skilled by incurring the fixed training cost c (> 0) in terms of utility. Second, as we will see in detail later, when workers work as skilled, they are heterogeneous in productivity, which is denoted by b. Each worker is assumed to have an identical utility function of the CES form:

$$U_u = \left[\int_{\delta \in \Delta} q(\delta)^\rho d\delta \right]^{1/\rho}, \qquad \text{if the worker is unskilled,}$$

and

$$U_s = \left[\int_{\delta \in \Delta} q(\delta)^\rho d\delta \right]^{1/\rho} - c, \qquad \text{if the worker is skilled.}$$

where δ is the index of differentiated goods and the measure of the set Δ represents the mass of available goods. $q(\delta)$ is the consumption of good δ. ρ is a positive constant satisfying $0 < \rho < 1$. This implies that the differentiated goods are substitutes and that the elasticity of substitution between two differentiated goods is $\sigma = 1/(1 - \rho) > 1$. Let w_s and w_u denote the skilled and unskilled wage rate, respectively. The wage income I_i is given as: $I_s = bw_s$ and $I_u = w_u$. The demands and utility level are given as

$$q(\delta) = \frac{I_i}{p(\delta)^\sigma P^{1-\sigma}}, \qquad i = s, u, \tag{1}$$

$$U_u = \frac{I_u}{P},$$

$$U_s = \frac{I_s}{P} - c.$$

$p(\delta)$ is the price of variety δ, and P is the price index defined as

$$P = \left[\int_{\delta \in \Delta} p(\delta)^{1-\sigma} d\delta \right]^{1/(1-\sigma)}. \tag{2}$$

2.2 Production

We assume that the unskilled labor is the numeraire. Thus the unskilled wage income is equal to one: $w_u = 1$. Differentiated goods are produced in a monopolistic competitive market. Each firm supplies one variety and in order to begin production, it must employ one unit of skilled labor in efficiency units. The payment for skilled labor w_s represents the fixed cost for production. For the production of one unit of output, β units of unskilled labor are necessary. Hence, the marginal cost is described by β, which is also normalized to be one for the expositional simplicity. The profit maximizing pricing behavior of a firm is to set a price equal to

$$p = \frac{\sigma}{\sigma - 1}. \tag{3}$$

Note here that all firms set the equal price under the constant markup pricing rule. Therefore, the price index (2) becomes

$$P = n^{1/(1-\sigma)} p, \tag{4}$$

where n is the number of varieties (i.e., the number of firms). As seen in standard monopolistic competition models a la Dixit and Stiglitz [12], larger number of varieties leads to lower price index, which improves the indirect utility of workers for a given income level. Using (3) and (4), the profit of a firm becomes

$$\pi = (p - 1) \frac{AI}{p^\sigma P^{1-\sigma}} - w_s$$
$$= \frac{AI}{n\sigma} - w_s.$$

AI describes the aggregate income. We assume the free entry and exit of firms, which drives the firm's profit to zero:

$$w_s = \frac{AI}{n\sigma}. \tag{5}$$

2.3 Skill formation

To keep things simple, we assume that an unskilled worker can become skilled by incurring once he/she takes training. Each worker is endowed with one unit of time that can be spent on working. However, workers are heterogeneous in productivity b when working as skilled. b represents the skilled labor supply in efficiency units, which determines the wage income of each skilled worker as bw_s. As unskilled, workers supply one unit of labor and obtain the wage income of 1. We assume that the distribution of b is given by the distribution function $G(b)$. $G(b)$ is assumed to be defined over $(0,1)$ and continuously differentiable, implying that the density function $g(b)$ is continuous.

Each worker compares the (indirect) utility when he/she becomes skilled with that when unskilled, and chooses to be skilled if the former is larger than the latter. Therefore, there is a cutoff level of productivity b_r, under which the utility of being skilled (see (1)) is equal to the utility of being unskilled. b_r is determined by the arbitrage behavior of workers, which is given by

$$\frac{b_r w_s}{P} = \frac{1}{P} + c. \tag{6}$$

We call this as the skill formation condition.

Because the number of total workers is normalized to one, $1 - G(b_r)$ workers are skilled and $G(b_r)$ workers are unskilled. Because b represents the productivity of a skilled worker,

$\int_{b_r}^{1} bg(b)db$ describes the total skilled labor supply. Also, one unit of skilled labor being necessary for the production of one variety, the number of varieties n is given by

$$n = n(b_r) \equiv \int_{b_r}^{1} bg(b)db, \qquad \frac{dn(b_r)}{db_r} = -b_r g(b_r) < 0, \tag{7}$$

where $n(b_r)$ is positive for $b_r \in (0,1)$. As the skilled worker ratio increases, the number of varieties available in the economy rises. Substituting (7) into (4), we have

$$P = n(b_r)^{1/(1-\sigma)}p, \qquad \frac{dP}{db_r} = \frac{pn(b_r)^{\sigma/(1-\sigma)}dn(b_r)/db_r}{1-\sigma} > 0. \tag{8}$$

Using (3) and (8), (6) can be rewritten as

$$w_s = \frac{1}{b_r}\left[1 + \left(\frac{\sigma c}{\sigma - 1}\right)n(b_r)^{1/(1-\sigma)}\right]. \tag{9}$$

2.4 Equilibrium and its efficiency property

Aggregate income AI is given as

$$
\begin{aligned}
AI &= w_s \int_{b_r}^{1} bg(b)db + w_u G(b_r) \\
&= w_s n(b_r) + G(b_r).
\end{aligned}
$$

Substituting this into (5) and solving it with respect to w_s, we obtain

$$w_s = \frac{G(b_r)}{(\sigma - 1)\, n(b_r)}. \tag{10}$$

An equilibrium is summarized by a pair (b_r^a, w_s^a) that satisfies (9) and (10). The superscript a represents the variables are related to the closed economy (autarky) case.

In the $b_r - w_s$ plane, the zero profit condition (10) is increasing in b_r and goes to infinity (zero) as b_r approaches one (zero). When the skilled labor supply is small, the economy has less varieties, which yields higher revenue for each firm. Free entry drives the profit of each firm to zero, implying that the skilled wage rate is high. Hence, the zero-profit condition is depicted as an upward-sloping curve. In the skill formation condition (9), when b_r converges to zero, the arbitrage of workers requires that the skilled wage must goes up to infinity. When b_r converges to one, no variety is available and the price index increases to infinity, which extinguishes the relative attractiveness of being skilled for a given skilled wage rate. Thus, in order for the skill formation condition to be satisfied, the skilled wage must also rise to infinity. In fact, because $\lim_{b_r \to 0} n(b_r) > 0$ and $\lim_{b_r \to 1} n(b_r) = 0$, we can easily see that the skill formation condition diverges to infinity as b_r goes to either zero or one.

Now define Γ as

$$
\begin{aligned}
\Gamma &\equiv \frac{\text{RHS of (9)}}{\text{RHS of (5)}} \\
&= \frac{(\sigma - 1)n(b_r) + \sigma c n(b_r)^{(\sigma-2)/(\sigma-1)}}{b_r G(b_r)}.
\end{aligned}
$$

Therefore, if $\sigma > 2$,

$$\lim_{b_r \to 1} \Gamma = 0 < 1,$$

which implies that RHS of (5) is larger than RHS of (9) in the neighborhood of $b_r = 1$. From the above arguments, we know that (9) and (5) have at least one intersection in the $b_r - w_s$ plane when $\sigma > 2$ (see Figure 1 for the illustration).

[Please insert Figure 1 around here]

Summarizing the above arguments, we obtain the following proposition:[7]

Proposition 1 *The model has an interior equilibrium when $\sigma > 2$.*

Hereafter, we assume this inequality holds, which is consistent with the markup rate estimated by Hall [17].[8] As σ becomes smaller, the monopoly power of each firm gets stronger and the price p goes up (see (3)). This induces more and more workers to become skilled, and all workers become skilled when σ comes very close to one. In order for the model to have an interior solution, the firm's monopoly power must not be such strong.

Before moving the analysis of trade, it is worth examining the welfare properties of the skill formation in this model. In this paper, we adopt the Benthamite welfare function as a welfare criterion:

$$W = \int_{b_r}^{1} \left(\frac{b w_s}{P} - c \right) g(b) db + \frac{1}{P} G(b_r) \tag{11}$$
$$= \frac{\sigma G(b_r)}{(\sigma - 1) P} - c \left[1 - G(b_r) \right],$$

where we used (10). Note here that the skilled worker fraction increases as b_r decreases. Differentiating (11) with respect to b_r and evaluating it at an equilibrium (substituting (6) and (10) into it), we have

$$\left. \frac{dW}{db_r} \right|_{equilibrium} = -\frac{c g(b_r)}{(\sigma - 1)} < 0.$$

Proposition 2 *The equilibrium level of skilled worker fraction is inefficiently low.*

Although skill formation by one worker enables other people to consume another variety of goods, this effect is not recognized by workers who decide whether or not to become skilled, which implies that the skill formation has a positive externality. As indicated by the conventional wisdom, this leads to the under-supply of skilled workers. This result and (11) can be referred to when we consider the effects of trade or FDI on the national welfare.

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[7]The condition $\sigma > 2$ assures only that at least one interior equilibrium exisits and does not imply the uniqueness of it.

[8]Hall [17] showed that many industries of the United States have the markup rate $\sigma/(\sigma - 1)$ between 1.5 to 3 (see Table 5). Given his warning regarding overestimation (see p.939), this range of the markup rate is consistent with our assumption.

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3   Trade, skill formation and the (skilled) wage structure

Now assume that the economy is open and consider a world (or a trade bloc) that is composed of $1 + m$ countries whose economies are of the type that was described in the previous section. We assume that the differentiated goods are traded with the standard iceberg trade cost. Hence, $T > 1$ units of a good must be shipped in order for one unit to arrive at destination.[9] This modification dose not changes the number of varieties (7) produced in one country. Here, we consider a symmetric equilibrium in which all countries have the same number of varieties, the same price index, and the same skilled worker share. In this open economy, the price index (2) becomes

$$P = \left[n(b_r)p^{1-\sigma}\left(1 + mT^{1-\sigma}\right)\right]^{1/(1-\sigma)}. \tag{12}$$

Using (7), (3) and (12), the skill formation condition (6) can be written as

$$w_s = \frac{1}{b_r}\left\{1 + \left(\frac{\sigma c}{\sigma - 1}\right)\left[n(b_r)\left(1 + mT^{1-\sigma}\right)\right]^{1/(1-\sigma)}\right\}. \tag{13}$$

The profit of a firm now becomes

$$\pi = (p - 1)\frac{(1 + mT^{1-\sigma})AI}{p^\sigma P^{1-\sigma}} - w_s, \tag{14}$$

leading to the fact that the pricing behavior of firms and zero profit condition are unaltered and are given by (3) and (10), respectively. An equilibrium is summarized by a pair (b_r^X, w_s^X) that satisfy (10) and (13). The superscript X represents the case of trading economy.

The closed economy equilibrium is described by (9) and (10) whereas the open economy equilibrium is determined by (13) and (10). Since the zero profit condition is the same for two cases, the difference in the result comes from the difference in the locus of the skill formation condition. Simple comparison between (9) and (13) shows that in the $b_r - w_s$ plane, trade opening shifts the skill formation condition downward as described in Figure 2.

[Please insert Figure 2 around here]

We can see from this figure that the trade opening enhances the skill formation. Under trade, people can consume wider varieties of differentiated goods and enjoy lower price index than under autarky. This implies that people enjoy higher utilities from the same income under trade than under autarky. Hence, trade increases the relative importance of nominal income to training disutility, leading to the downward shift of the skill formation condition as described in Figure 2. Because the incentive to be skilled and obtain higher income gets stronger, more workers train themselves to become skilled. Thus, proliferation of trade (WTO [35]; World Bank [33]) and skill formation (Federal Reserve Bank of New York [13]; Barro and Lee [7]) can proceed in the same direction.

This result has a significant welfare implication. Because the price index declines, the utility of unskilled rises by trade opening. Among skilled workers, some become skilled

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[9]We can introduce the fixed costs of export as in Melitz [28] without changing any results. For the expositional simplicity, we assume no fixed costs of export, which implies firms always choose to export.

after trade opening whereas others are already skilled under autarky. Declines in the price index implies rises in the utility of already skilled workers. From (6), we can see that the utility of marginal worker (i.e., a worker with productivity b_r), and hence, the utility of new skilled workers also increases. Thus, *trade opening profits all people.* Of course, the national welfare also rises: because the zero-profit condition is unaltered by trade, (11) still applies to the economy under trade. And larger utility of unskilled and marginal workers under trade than under autarky readily verifies that trade raises the national welfare. The following proposition summarizes the above arguments.

Proposition 3 *Trade opening enhances the skill formation (i.e., lowers b_r and raises the skilled worker fraction $1 - G(b_r)$), and raises the utility of all workers.*

Moreover, production structure also changes. Smaller b_r implies increases in the number of varieties produced in one country (see (7)). It also leads to decreases in the output per firm:

$$\text{output per firm} = \frac{G(b_r)}{n(b_r)}, \qquad \frac{d(\text{output per firm})}{db_r} = \frac{b_r g(b_r) \left[n(b_r) + G(b_r) \right]}{n(b_r)^2} > 0.$$

The numerator is the aggregate output in one country, and the denominator is the number of firms in one country.

Proposition 4 *Trade opening increases the number of varieties produced in one country, and lowers the output per firm.*

The cost of hiring an unskilled worker (i.e., nominal unskilled wage = 1) becomes high relatively to the cost of hiring a skilled worker (w_s) , inducing more firms to enter the economy but to produce less, thus leading firms to a more intensive "large-item, small-scale production."

Although the utility, and hence the real wage of already and new skilled workers rises with trade opening, the average real wage of skilled workers may or may not increase. This is because the productivity of new skilled workers is lower than that of already skilled workers. Hence, although trade raises the new skilled workers by inducing them to become skilled, it may change the wage structure in a way in which the average skilled real wage may decline. Hereafter, we examine what changes in the wage structure accompanies the trade opening.

The average productivity among skilled workers is

$$B_s = \int_{b_r}^{1} b \frac{g(b)}{1 - G(b_r)} db. \tag{15}$$

Differentiating this with respect to b_r yields

$$\begin{aligned}
\frac{dB_s}{db_r} &= -\frac{b_r g(b_r)}{1 - G(b_r)} + \frac{g(b_r)}{\left[1 - G(b_r) \right]^2} n(b_r) \\
&> -\frac{b_r g(b_r)}{1 - G(b_r)} + \frac{g(b_r)}{\left[1 - G(b_r) \right]^2} \int_{b_r}^{1} b_r g(b) db \\
&= 0.
\end{aligned} \tag{16}$$

Hence, trade opening, via declines in b_r, reduces the average productivity among skilled workers, and hence the average nominal wage of skilled workers $B_s w_s$.[10] New goods being available, the price index P also declines (i.e., $P^X < P^a$), which is confirmed by the following two facts: (i) the price index under trade P^X is lower than the price index under autarky P^a for a given b_r, (ii) P declines as b_r decreases.[11] These declines in the price index may raise the average real wage $B_s w_s / P$ of skilled workers. Whether or not this is true depends on the type of distribution $G(b_r)$ we consider. In the remaining of this section, as a benchmark, we specify $G(b_r)$ as the uniform distribution and demonstrate that trade opening in fact raises the average real wage of skilled workers. Note here that the real wage $1/P$ of unskilled workers rises irrespective of type of $G(b_r)$.

Under the uniform distribution, the average real skilled wage can be rewritten as

$$\frac{B_s w_s}{P} = \frac{1}{2}\left(1 + \frac{1}{b_r}\right)\left(c + \frac{1}{P}\right),$$

which implies that[12]

$$\frac{B_s^X w_s^X}{P^X} - \frac{B_s^a w_s^a}{P^a} > 0.$$

Hence, trade opening raises the average real wage of skilled workers. This is not the end of the story. We can further examine whether or not the skilled-unskilled wage gap $WG = B_s w_s / P - 1/P$ enlarges. Simple calculations show that

$$
\begin{aligned}
WG^X - WG^a &= \frac{1}{2}\left(1 + \frac{1}{b_r^X}\right)\left(c + \frac{1}{P^X}\right) - \frac{1}{P^X} - \frac{1}{2}\left(1 + \frac{1}{b_r^a}\right)\left(c + \frac{1}{P^a}\right) + \frac{1}{P^a} \\
&> \frac{1}{2}\left(1 + \frac{1}{b_r^a}\right)\left(\frac{1}{P^X} - \frac{1}{P^a}\right) - \left(\frac{1}{P^X} - \frac{1}{P^a}\right) \\
&= \left(\frac{1}{P^X} - \frac{1}{P^a}\right)\left[\frac{1}{2}\left(1 + \frac{1}{b_r^a}\right) - 1\right] > 0.
\end{aligned}
$$

From this, we can readily see that whereas trade opening benefits unskilled workers, skilled workers enjoy trade benefits more than do unskilled workers. These rises in wage gap give less productive workers to become skilled, which reduces the average productivity.

Proposition 5 *Trade opening raises the skilled-unskilled real wage gap.*

The next question is how this affects the inequality. In this paper, our focus is on the skilled workers and we over-simplified the features of unskilled workers, which makes us to hesitate to refer to the overall income inequality. Hence, we examine only the income inequality among skilled workers. Lemieux [23] showed the trends in the residual inequality (i.e., wage inequality unexplained by observed characteristics, which measures the inequality within groups) in the United States over the past three decades by examining the variance of the residual computed from the estimated wage equation. His results showed that the rises in residual inequality arose from rising wage dispersion for groups with higher education and increasing in the share of groups with higher education (that had

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[10]This is the consequence of the constant mark-up pricing shown in (3). If we use a model with the pro-competitive effect in which trade raises the good price, the average nominal wage of skilled workers may increase. See Ottaviano et al [30] for an example of a monopolistic competition model with the pro-competitive effect.

[11]See (8) and (12).

[12]Notice that we already know that $b_r^X < b_r^a$ and $P^X < P^a$.

higher wage dispersion than does groups with lower education). For the sake of comparing our results to the results of Lemieux [23], We employ the coefficient of variation as an index of skilled wage dispersion. The coefficient of variation CV_s is defined as the ratio of the standard deviation S_s to the mean $B_s w_s / P$:

$$CV_s = \frac{S_s}{B_s w_s / P},$$

where S_s is given as

$$S_s = \frac{1}{P} \left[\int_{b_r}^1 (b w_s - \overline{w}_s)^2 \frac{g(b)}{1 - G(b_r)} db \right]^{1/2}.$$

After some (tedious) calculations, we have

$$CV_s = \left\{ \frac{\int_{b_r}^1 b^2 g(b) db}{B_s^2 [1 - G(b_r)]} - 1 \right\}^{1/2}. \tag{17}$$

Under the Pareto distribution, (17) can be rewritten as

$$CV_s = \left[\frac{4 \left(1 + b_r + b_r^2 \right)}{3(1 + b_r)^2} - 1 \right]^{1/2}.$$

Differentiating this with respect to b_r, we find

$$\frac{dCV_s}{db_r} = -\frac{2(1 - b_r)}{3CV_s(1 + b_r)^3} < 0.$$

As shown in (16), trade opening induces less productive workers to become skilled and hence, raises the skilled wage dispersion:

Proposition 6 *Trade opening enlarges the wage dispersion among skilled workers.*

This result is consistent with the empirical findings of Lemieux [23], indicating that trade can play an important role in enhancing skill formation and in raising the residual inequality.

A few comments are in order. First, inequalities between skilled and unskilled or among skilled workers may themselves be seen as a social problem. We don't aim to argue the pros and cons of this view. However, it would be worth mentioning that behind the trends of rising inequality, people may become better off via trade.

Second, here, we consider only the inequality between skilled and unskilled and that among skilled workers, and not the total income inequality. Here, the effect on the total income inequality is determined by the above mentioned effect regarding two inequalities and the effect on skill composition of workers. The former amplifies the total inequality. However, since more workers get skilled, the latter reduces the total inequality because it increases the ratio of people with higher income. Since the overall effect on total inequality heavily depends on the specification and parameters of the model including the distribution function $G(b)$, we just uncovered the possible channels through which trade may have effects on inequality and don't conclude about the overall effect on the total inequality.

Once the economy is open, the trade environment affects the skill formation. An increase in the number m of trading countries and a decline in the trade cost T both shift

the skill formation condition downward, leading to decreases in b_r^X and increases in the skilled worker fraction. It also lowers the price index, and hence, raises the real wage disparity and makes all people better off. Moreover, smaller b_r^X deepens the large-item, small-scale production.

Proposition 7 *An increase in the number m of trading countries or a decline in the trade cost T enhances skill formation and has similar effects on the market structure to trade opening.*

4   Trade versus FDI

Zeile [37] showed that in 1994, 42.7 percent of the total trade volume of U.S. goods imports took place within the boundaries of multinational firms, with the share being 36.3 percent for U.S. exports of goods. Also, from 1986 to1999, international trade has grown faster than GDP, and the growth of foreign direct investment (FDI) has been higher than international trade (Markusen [26]). In 2003, total inward and outward of FDI for the OECD countries amounted to 384.4 billion and 576.3 billion U.S. dollars, respectively (OECD [29]). These evidences confirm us that the importance of multinational firms has increased recently and they are now the key players in the world economy. Moreover, Markusen [26] pointed out that skilled labor endowments are strongly and positively related to FDI. Therefore, it is worth figuring out how FDI could interact with skill formation. This section do this by comparing the case of export to the case of FDI.

Assume that firms can supply goods to foreign countries via FDI as well. In that case, they face no trade cost $(T = 1)$ but have to bear fixed investment (f_I). This alters the price index (2) as

$$P = \left[np^{1-\sigma} (1 + m) \right]^{1/(1-\sigma)}. \tag{18}$$

The number of varieties in each country n is given by

$$n = n(b_r)/(1 + mf_I).$$

From this and (12), the worker's arbitrage condition (6) becomes:

$$w_s = \frac{1}{b_r} \left\{ 1 + \left(\frac{\sigma c}{\sigma - 1} \right) \left[n(b_r) \left(\frac{1 + m}{1 + mf_I} \right) \right]^{1/(1-\sigma)} \right\} \tag{19}$$

The profit of a firm under FDI is given as

$$\pi = (p - 1) \frac{(1 + m)AI}{p^\sigma P^{1-\sigma}} - (1 + mf_I)w_s. \tag{20}$$

Taking the difference in the price index (difference between (8) and (12)) into consideration, we can investigate under which condition firms prefer FDI to export by comparing (14) with (20). Simple comparison give

$$\pi \text{ under FDI } > \pi \text{ under export} \tag{21}$$

$$\Leftrightarrow f_I < \frac{(1 - T^{1-\sigma})}{1 + mT^{1-\sigma}}.$$

Since (20) again leads to the zero profit condition (10), the difference between the locus of (13) and that of (19) generates the difference between skill formation under export and

that under FDI. Comparing these two equations, we can see that (13) locates above (19) iff (21) holds. Hence, when the fixed skilled labor requirement for FDI is small, FDI enhance skill formation. In addition, the term $\left(1 - T^{1-\sigma}\right) / \left(1 + mT^{1-\sigma}\right)$ is a decreasing function of the number of trade partner, m, and transportation cost, T. Hence, when the number of trade partner countries is small, or transportation costs are high, FDI enhance skill formation.

Proposition 8 *Firms prefer FDI to export iff $f_I < \left(1 - T^{1-\sigma}\right) / \left(1 + mT^{1-\sigma}\right)$. In this case, compared to export, FDI enhances the skill formation.*

The condition described in Proposition 8 requires that the fixed costs of FDI is small, or transport cost of goods is small, or the number of trading countries small. Among these three requirements, the first two obviously enable firms to earn under FDI than under export. Regarding the third, if the number of trading countries is large, firms must establish plants in many countries, which increases the burden of high fixed costs under FDI. Hence, the condition described in Proposition 8 is equivalent to require that it is more profitable for firms to achieve FDI than to export goods. Furthermore, higher profits implies a stronger incentive for firms to enter the economy, making wider varieties available for consumers and lowering the price index. As shown in Section 3, a lower price index benefits skilled workers more than unskilled workers and enhances skill formation.

5   Concluding remarks

In this paper, we uncovered the possible impacts of international trade on the workers' skill formation and the wage structure. We showed that trade enhances the skill formation, and can raise the inequality between skilled and unskilled workers and that among skilled workers. The effects of changes in trade environments and of FDI are also examined. Our study showed that the skill formation can play an important role when we consider the relationship between trade and labor markets. An interesting implication of our framework is to shed light on the fact that globalization can benefit all people via skill formation but it may worsen inequality.

It is worth mentioning some possible extensions. First, we considered only symmetric countries. However, trade between countries of different size should also be investigated, of which importance is suggested by the fact that we often observe RTAs between large and small countries (such as RTA between the United States and Morocco or that between Japan and Singapore). Because of the possibility of the home market effect, international trade may work in favor of skill formation in the large country whereas it may harm skill formation in the small country. However, there is still some scope that the small country becomes better off due to the availability of wider range of varieties. Second, multinational firms should be considered more in detail. We adopted a highly (and perhaps over-) simplified way in the sense all countries and firms are symmetric, implying that all firms choose FDI or any firms do not choose it. However, in the real world, it may be easier for firms to establish their plants in some countries than in other countries, or firms would combine trade with FDI. In order to obtain full implication related to FDI, we should incorporating these more realistic features. Third, incorporating the framework developed in this paper into a model with heterogeneous firms a la Melitz [28] may give us implications that can be compared with empirical results regarding trade effects on heterogeneous firms. Especially, it would be interesting to explore how the interaction between trade and skill formation affects the allocations of heterogeneous workers to heterogeneous firms.

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w_s

Zero profit
condition

Skill formation
condition
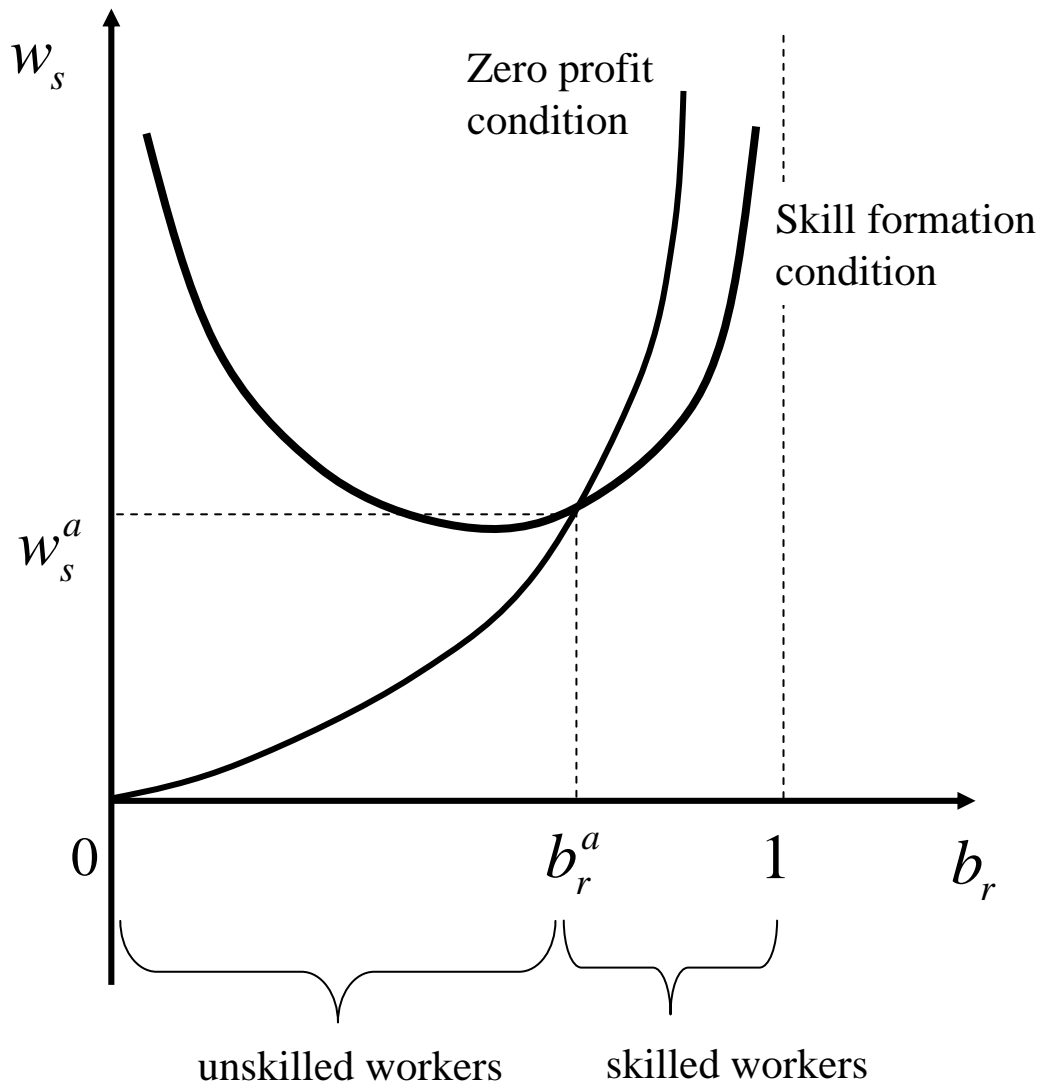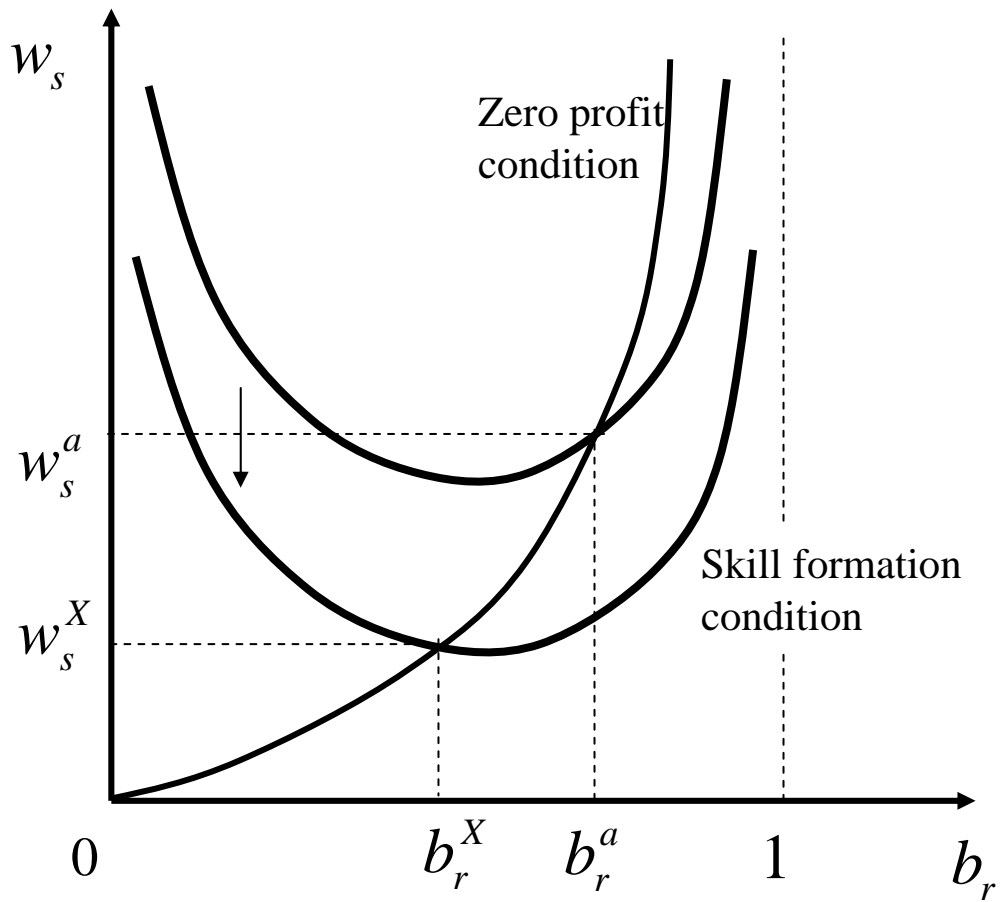
w_s^a

0 b_r^a 1 b_r

unskilled workers skilled workers

Figure1. Equilibrium

Figure 2. Impact of trade on skill formation