Trade, skill formation and inequality: a monopolistic competition perspective

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Abstract

This paper focuses on the skill formation in considering the impacts of trade 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 enhances skill formation and lowers the nominal income inequality, which are consistent with the observed facts. Although these changes make all agents better off, it works stronger for skilled workers than for unskilled workers, leading to larger inequality in utility (real income). Finally, we examine the possible effects of foreign direct investment on the labor market structure as well.

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Key words: trade, skill formation, monopolistic competition, inequality

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1 Introduction

During the past two decades, the volume of international trade has risen than ever before. In fact, the world merchandise trade volume index for manufacturers (1950=100) rose from 2929 in 1995 to 5454 in 2005 (WTO [38]). This indicates that the trade has come to play an increasingly 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 of the world economic activities: the World Bank [36] reported that exports of goods and services accounted for 24.6 of the world GDP in 2000.

This trend has spurred the analysis of trade effects on various economic activities. In particular, in the face of new established facts regarding differences in the performance of firms in the trade environment (see Bernard and Jensen [10][11], among others), the impact of trade in the presence of heterogeneous firms has been intensively investigated by studies such as Melitz [31], Helpman et al. [21], and Antras and Helpman [4]. [2][3] These scholars developed monopolistic competition models with heterogeneous firms and uncovered 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 level of productivity of firms. However, it is also well known that *workers are heterogeneous*. Then, it would be interesting to ask how trade could interact with labor markets when workers are heterogeneous.

With regard to the labor market, increases in the percentage of skilled labor have been observed in many developed countries over the past few decades. For instance, from 1983 to 2002, the U.S. manufacturing sector has experienced a 37-percent increase in employment in high-skill occupations regardless of its contraction during that period (Federal Reserve Bank of New York [14]). This trend has also been confirmed by Barro and Lee [8].

Whereas possible explanations for this trend has been widely investigated from the view-point of skill-biased technological progress (see Acemoglu [1]), there is still room for exploring other possible causes.[4] Given the drastic increases of trade during the past decade, it would be worth considering trade as one of the important factors that affect the skill composition.

Conventional wisdom in trade theory suggests that the demand for skilled labor and the skilled-unskilled wage gap in developed countries have increased since international trade with relatively skill-scarce developing countries raised the relative price of skill-intensive goods(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 increases the demand for skilled labor and widens the wage gap.[5]

Of course, as pointed out by Krugman [25] (p. 66-68), even after the rapid proliferation of trade, trade constitutes only a certain part of the total spending in developed countries. This implies that the direct effects of trade on income distribution may be limited and not

[1] In 2006, there were 211 RTAs, and among them, 194 were concluded after 1980 (WTO [37]).

[2] Mannase and Turrini [28] considered a model in which the heterogeneity of firms arises from differences in the skills of entrepreneurs and obtained results regarding industrial changes due to trade openness that were similar to those of Melitz [31].

[3] For recent surveys, see Baldwin [5], Greenaway and Kneller [17], and Helpman [20].

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

[5] In relation to this, Matsuyama [30] pointed out that, if the technology of the transportation sector is skill-intensive, technical progress in this sector enlarges the trade amounts and widens the wage gap.

be dominant. However, if we consider other factors such as technological changes or changes in skill formation behavior that amplify the trade effects, the overall trade effects on income distribution can be significant. In fact, some researchers have found empirical evidences to consider trade as a significant candidate for a basis of the income distribution. Richardson [34] (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 [15] enumerated more recent studies that support this view.

Then the subsequent point to be examined is the consistency between the predictions made by the existing models and the observed facts. Most evidence in the United States suggests a declining or constant relative price of skill-intensive goods between the early 1970s and mid-1990s, in which the share of imports from developing countries in the United States GDP increased over fourfold (see Lawrence and Slaughter [26] and Sachs and Shatz [35]). In addition, Berman et al. [9] showed empirically that recent rapid increases in demand for skilled labor in the United States manufacturing sector can be mainly attributed to within-industry changes and not to between-industry changes. These evidences are not entirely consistent with the the Stolper-Samuelson effect, which prompts us to look for other possibilities.

Here, in order to motivate our model, we present some stylized facts on the relationship between trade and skill formation and that between trade and income inequality by using data on EU15 countries for the years 1995 to 2005. All data are taken from the website of Eurostat (http://epp.eurostat.ec.europa.eu). We examine two relationships by simple regressions. As the proxy for the skill formation, we use the youth education attainment level (E), which is measured by the share of the population aged 20 to 24 having completed at least upper secondary education. Income inequality (I) is measured by the ratio of total income received by the population of the top quantile to that received by the population of the lowest quantile. Trade (T) is represented by the share of the value of imports and exports of item goods in GDP.[6] Also, we consider the following variables that could possibly affects E and I: the GDP per capita (G) in purchasing power standards (EU25=100), the real GDP growth rate (GR), the share (R) of R&D expenditure in GDP, and the share (PE) of the total public expenditure on education in GDP.[7] G and GR describe the overall economic condition in each country and R represents the degree of technological progress. PE captures the effects of government. Regression results are provided in Tables 1 and 2.

[Please insert Tables 1 and 2 around here]

For the most cases, the results of the Hausman test support the fixed wage model. From Table 1, we can see that *trade enhances the skill formation.* Also, higher GDP leads to higher

[6] We also considered the share of the value of imports and exports of services in GDP. However, this affects E and I only insignificantly.

[7] All the share and growth rate variables are normalized using a logit transformation $X = \log(x) - \log(1-x)$. These variables essentially takes values between 0 and 1. In contrast, the error term in the regression is assumed to take any values between $-\infty$ to $+\infty$. In order to make variables to be consistent with the error term, we applied the logit transformation.

skill formation, which can be interpreted as that good economic conditions allow people to receive higher education. Other variables affect skill formation only insignificantly. Table 2 shows that *trade lowers the (nominal) income inequality,* which cannot be explained by the existing models. Here, higher GDP also reduces the income inequality, whereas technological progress enlarges the income inequality.[8] These results encourage us to develop a new channel through which trade affects the labor market in a way that trade increases the skilled labor share and reduces the income inequality.

Given the current importance of trade between developed countries, it would be natural to seek a channel through which trade between developed countries affects the skill composition and the income structure.[9] Moreover, in contrast to the existing studies that shed light on the trade effects on the labor demand side (e.g., technological progress or technology choice), our primary focus is on *the trade effects on the labor supply side* in an environment in which developed countries trade with each other.[10] In this paper, we present a trade model with monopolistic competition a la Dixit and Stiglitz [13] 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 embed vertical labor heterogeneity within the Krugman [24] model of trade under monopolistic competition and increasing returns.[11]

Using this model, we will show that trade opening increases the skilled worker ratio and lowers the nominal income inequality. However, it is also shown that trade enlarges the utility (real income) gap and the wage dispersion of skilled workers. In our model, trade allows people to consume wider varieties of goods and lowers the price index of consumption goods, which leads to the higher welfare of all agents. However, it increases the real skilled income more than the real unskilled income. This encourages even less productive workers to become skilled, which enlarges the wage dispersion among skilled workers. Since supply of skilled workers increases, the nominal wage ineome of skilled declines, leading to the lower income inequality. *Thus, our model shows that trade induces skill formation without the Stolper-Samuelson effect and the skill-biased technical progress, and can also explains the decreases in the income inequality caused by trade.* These results show that trade improves the welfare of all people and lowers the nominal income inequality even though it may worsen real income inequality. We also study the effects of changes in the trade environment and the

[8]The latter finding is consistent with the arguments of skill-biased technological progress.

[9]Yeaple [39] went this direction by adopting a monopolistic competition model of trade. He focused on the interaction among monopolistic competition, (exogeneous) skill distribution of workers, and firm technological choice and showed that a reduction in trade costs benefits firms that choose relatively more skill-biased technology, which increases the share of such firms accompanied by increases in wage rates for highly skilled workers. Hence, this model cannot investigate whether trade affects skill composition, and moreover, the prediction regarding income inequality does not reconcile with the observed fact.

[10]Ishikawa [22] developed a Heckscher-Ohlin-Samuelson model with increasing returns in skill formation, in which scale economies in human capital enable a large country to specialize in the production of a skilled-labor-intensive good and trade with a small country that specializes in the production of an unskilled-labor-intensive good. Hence, it captures the role of skill formation in the North-South trade, whereas we analyze the role of skill formation in the North-North trade. In this sense, these two studies complement each other.

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

effects of Foreign Direct Investment (FDI) and prove that FDI, if firms prefer it to exporting, enhances skill formation.

This paper is organized as follows. In Section 2, we present a basic model and analyze the autarky economy. Section 3 introduces trade and shows how trade affects skill formation and inequality. In Section 4, we consider the effects of FDI. Section 5 concludes the paper.

2 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 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 two ways. First, workers must train themselves in order to become skilled, incurring a fixed training cost c (> 0) in terms of utility. Second, as presented in detail later, when workers are skilled, they are heterogeneous in productivity. 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 $\sigma = 1/(1-\rho) > 1$. In this paper, a variable associated to unemployed (respectively, employed) workers is described by a subscript u (respectively, s). The demands and utility level are given as

$$\begin{aligned} q(\delta) &= \frac{I_i}{p(\delta)^\sigma P^{1-\sigma}}, \qquad i = s, u, \\ U_u &= \frac{I_u}{P}, \\ U_s &= \frac{I_s}{P} - c, \end{aligned} \tag{1}$$

where I_i represents the wage income. $p(\delta)$ 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 rate 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. This may be interpreted as the costs of planning projects, headquarter and managing services, or R&D. The payment for skilled labor (i.e., the skilled wage rate in efficiency units) 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 one for expositional simplicity.[12] A profit maximizing firm sets a price equal to

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

Note here that all firms set an 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 [13], a larger number of varieties leads to a 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

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

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

For the sake of simplicity, we assume that an unskilled worker can become skilled by incurring once she takes training. The necessary training cost is assumed to be constant (c) in terms of utility.[13] Imagine a person who wants to obtain a certain degree of education. For that purpose, she has to bear the burdens of making an effort as well as covering the monetary costs of education, which include the opportunity costs. c captures such non-monetary costs, which are not affected by trade. Each worker is endowed with one unit of time that she inelastically spends on working. Hence, the income I_u of an unskilled worker is one. When workers are skilled, they are assumed to be heterogeneous in productivity: the productivity of a worker v is denoted by $b(v) \in [0, 1]$. $b(v)$ represents the skilled labor supply in efficiency

[12] This production structure is standard in the new economic geography literature. See Baldwin et al .

[13] Even if we consider the monetary cost of training as well, the results do not change. However, if we only consider the monetary cost, no effect of trade on skill formation is observed in our model.

units, which determines the income I_s of each skilled worker as $b(v)w_s$. We assume that the distribution of $b(v)$ is given by the distribution function $G(\cdot)$. $G(\cdot)$ is assumed to be defined over $[0,1]$ and continuously differentiable, which implies that the density function $g(\cdot)$ is continuous. It is noteworthy here that the wage income is identical to the wage rate because workers supply one unit of time for working.[14]

Each worker compares the (indirect) utility when she becomes skilled with that when she is unskilled and chooses to become skilled if the former is larger than the latter. Therefore, there is a cutoff level of productivity $b_r \in [0,1]$, 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 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. Moreover, since one unit of skilled labor is 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 increases as well, leading to a lower Price index: 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

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

[14] This does not hold with respect to the wage rate in efficiency units, which is one for the unemployed and w_s for the employed.

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

[Please insert Figure 1 around here]

In the $b_r - w_s$ plane, the zero-profit condition (10) increases in b_r and reaches infinity (zero) as b_r approaches one (zero). When the skilled labor supply is small, the economy has fewer varieties, which yields higher revenue for each firm. Free entry drives the profit of each firm to zero, which implies 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 increase to infinity. When b_r converges to one, no variety is available, and the price index increases to infinity, which eliminates 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 increase 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.

We now define Γ as

$$\begin{aligned}\Gamma &\equiv \frac{\text{RHS of (9)}}{\text{RHS of (10)}} \\ &= \frac{(\sigma-1)n(b_r) + \sigma c n(b_r)^{(\sigma-2)/(\sigma-1)}}{b_r G(b_r)}.\end{aligned}$$

Therefore, if $\sigma > 2$,

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

which implies that the RHS of (10) is larger than the RHS of (9) in the neighborhood of $b_r = 1$. From the above arguments, we know that (9) and (10) have at least one intersection in the $b_r - w_s$ plane when $\sigma > 2$ (see Figure 1 for the illustration).

Moreover, by taking the derivatives of the RHSs of (9) and (10) with respect to b_r and evaluating them at equilibrium, it is readily verified that, in the $b_r - w_s$ plane,

$$\begin{aligned}\text{the slope of } (9)|_{equilibrium} &= \frac{b_r g(b_r) w_s}{(\sigma-1)n(b_r)} - \frac{g(b_r)w_s}{G(b_r)} - \frac{w_s}{b_r}, \\ \text{the slope of } (10)|_{equilibrium} &= \frac{b_r g(b_r) w_s}{n(b_r)} + \frac{g(b_r)w_s}{G(b_r)}.\end{aligned}$$

Hence, we know that, when $\sigma > 2$, the slope of (10) is always larger than that of (9) at an intersection of the two curves. These facts imply that there exists a unique equilibrium of the model when $\sigma > 2$.

Summarizing the above arguments, we obtain the following proposition:

Proposition 1 *The model has a unique equilibrium when* $\sigma > 2$.

Hereafter, we assume that this inequality holds, which is consistent with the markup rate estimated by Hall [18].[15] As σ becomes smaller, the monopoly power of each firm becomes stronger, and the price p goes up (see (3)). This increases the price index, which, in turn, reduces the value of nominal income and the incentive to become skilled. Moreover, no 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 very strong.

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

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

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

$$\left. \frac{dW}{db_r} \right|_{equilibrium} = -\frac{cg(b_r)}{(\sigma - 1)} < 0. \tag{12}$$

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

Skill formation by one worker enables people to consume another kind of goods. This lowers the price index, which suggests that skill formation exhibits pecuniary external economies. Therefore, combined with the positive training cost, skill formation is inefficiently low. It must be noted here that, if the training cost c is zero, it is socially desirable to increase the number of skilled workers iff $bw_s > 1$, whereas workers have the incentive to become skilled iff $bw_s > 1$. Thus, the private and social incentives coincide in this case, and skill formation is socially optimal. The result of Proposition 2 and (11) can be referred to when we consider the effects of trade or FDI on national welfare.

3 Trade impacts

Now, we will 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 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 its destination.[16] This modification does not change the number of varieties (7) produced in

[15] Hall [18] showed that many industries in the United States have a 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.

[16] We can introduce the fixed costs of exporting as in Melitz [31] without changing any results. For expositional simplicity, we assume no fixed costs of exporting, which implies that firms always choose to export.

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

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

Using (3), (7), and (13), the skill formation condition (6) can be written as

$$w_s = \frac{1}{b_r}\left\{1 + \left(\frac{\sigma c}{\sigma - 1}\right)\left[n(b_r)\left(1 + mT^{1-\sigma}\right)\right]^{1/(1-\sigma)}\right\}. \tag{14}$$

The profit of a firm now becomes

$$\pi = (p-1)\frac{(1 + mT^{1-\sigma})AI}{p^{\sigma}P^{1-\sigma}} - w_s, \tag{15}$$

leading to the fact that the pricing behavior of firms and zero-profit condition are unaltered and given by (3) and (10), respectively. An equilibrium is summarized by the pair (b_r^X, w_s^X) that satisfies (10) and (14). The superscript X represents the case of the trading economy.

[Please insert Figure 2 around here]

The closed-economy equilibrium is described by (9) and (10), whereas the open-economy equilibrium is determined by (14) and (10). Since the zero-profit condition is the same for the two cases, the difference in the result comes from the difference in the locus of the skill-formation condition. A simple comparison between (9) and (14) shows that, in the $b_r - w_s$ plane, trade opening shifts the skill-formation condition downward, as described in Figure 2. We can see from this figure that trade opening enhances skill formation. Under trade, people can consume wider varieties of differentiated goods and enjoy lower price indexes 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. Because the incentive to be skilled and obtain a higher income becomes stronger, more workers train themselves to become skilled. Thus, proliferation of trade (WTO [38]; World Bank [36]) and skill formation (Federal Reserve Bank of New York [14]; Barro and Lee [8]) can proceed in the same direction.

This result has a significant welfare implication. Because the price index declines, the utility of unskilled workers increases by trade opening. Among skilled workers, some become skilled after trade opening, whereas others are already skilled under autarky. Declines in the price index imply increases in the utility of already skilled workers. From (6), we can see that the utility of a marginal worker (i.e., a worker with productivity b_r) increases and, hence, that of newly skilled workers also increases. Thus, *trade opening profits everyone*. Of course, the national welfare also increases: because the zero-profit condition is unaltered by trade, (11) still applies to the economy under trade. In addition, the larger utility of unskilled and marginal workers under trade than under autarky readily verifies that trade increases the national welfare. However, (12) still holds, and the undersupply of skill cannot be resolved. The following proposition summarizes the above arguments.

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

Behind the fact that more variety of goods are produced in each country, the production structure also changes. A 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:

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

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., the nominal unskilled wage = 1) becomes high relative 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."

The average productivity among skilled workers is

$$B_s = \int_{b_r}^{1} b \frac{g(b)}{1 - G(b_r)} db. \tag{16}$$

Differentiating this with respect to b_r yields

$$\begin{aligned} \frac{dB_s}{db_r} &= -\frac{b_r g(b_r)}{1 - G(b_r)} + \frac{g(b_r)}{[1 - G(b_r)]^2} n(b_r) \\ &> -\frac{b_r g(b_r)}{1 - G(b_r)} + \frac{g(b_r)}{[1 - G(b_r)]^2} \int_{b_r}^{1} b_r g(b) db \\ &= 0. \end{aligned} \tag{17}$$

Hence, trade opening, via declines in b_r, reduces the average productivity among skilled workers and, hence, the average nominal wage and hence income of skilled workers $B_s w_s$.[17] Given that the income of unskilled workers is normalized to one, this implies that the income inequality declines.

Proposition 5 *Trade opening decreases the nominal income inequality between skilled and unskilled workers.*

Propositions 1 and 5 are consistent with the observed facts shown in Introducion.

The next question is how these changes affect income inequality within groups. In this paper, our focus is on skilled workers, and we oversimplified the features of unskilled workers,

[17] 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. [33] for an example of a monopolistic competition model with the pro-competitive effect.

which makes us to hesitate to refer to the income inequality among unskilled workers. Hence, we examine only the inequality among skilled workers. We employ the coefficient of variation as an index of inequality. The coefficient of variation CV_s is defined as the ratio of the standard deviation S_s to the mean $B_s w_s/P$:

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

where S_s is given as

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

After some (tedious) calculations, we have

$$CV_s = \left\{ \frac{\int_{b_r}^{1} b^2 g(b) db}{B_s^2 \left[1 - G(b_r)\right]} - 1 \right\}^{1/2}. \tag{18}$$

Whether or not dCV_s/db_r is positive depends on the type of distribution $G(b_r)$ we consider. In the remainder of this section, as a benchmark, we specify $G(b_r)$ as the uniform distribution.

Under the Pareto distribution, (18) can be rewritten as

$$CV_s = \frac{1 - b_r}{(1 + b_r)\sqrt{3}}.$$

Differentiating this with respect to b_r, we find

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

As shown in (17), trade opening induces less productive workers to become skilled and hence, raises the skilled wage dispersion:

Proposition 6 *Under the uniform distribution of productivity, trade opening increases the income inequality among skilled workers.*

Lemieux [26] showed the trends in the variance of wages unexplained by observed characteristics, which measures the inequality within groups, in the United States over the past three decades and showed that the inequality for groups with higher education increased more than that for groups with lower education. Given the rapid proliferation of trade, the result of Proposition 4 indicates that trade may have played a certain role in generating the stylized facts shown in Lemieux [26].

Although the utility (real income) of all workers rises by trade opening, it is not clear that workers are equally better off. Especially, it is possible that there is asymmetry in gains from trade between skilled and unskilled workers. To see this, we first examine the changes in the average utility of skilled workers. It may or may not increase because the productivity of newly skilled workers is lower than that of already skilled workers. 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; and (ii) P declines as b_r decreases.[18] These declines in the price index may increase the average utility $B_s w_s / P$ of skilled workers.

Under the uniform distribution, the average skilled utility 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[19]

$$\frac{B_s^X w_s^X}{P^X} - \frac{B_s^a w_s^a}{P^a} > 0. \tag{19}$$

Hence, trade opening increases the average utility of skilled workers. We can further examine whether or not the skilled-unskilled utility gap $UG = B_s w_s / P - 1/P$ widens. Note here that the utility $1/P$ of unskilled workers increases irrespective of the type of $G(b_r)$. Simple calculations show that

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

From this, we can readily see that, whereas trade opening benefits unskilled workers, skilled workers enjoy trade benefits more than unskilled workers do. This widening of the utility gap gives less productive workers an incentive to become skilled, which reduces the average productivity.

Proposition 7 *Under the uniform distribution of productivity, trade opening benefits the skilled workers more than the unskilled workers.*

A few comments are in order. First, inequalities between skilled and unskilled or among skilled workers may be seen as a social problem. We do not intend to argue the pros and cons of this view. However, it would be worth mentioning that, behind the changes in (nominal or real) inequality, people may become better off via trade.

Second, here, we consider only the inequality between skilled and unskilled workers and that among skilled workers and not the total income inequality. Here, the effect on the total income inequality is determined by the abovementioned effect regarding two inequalities and the effect on the skill composition of workers. The former amplifies the total inequality. However, since more workers become 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.

[18] See (8) and (13).

[19] We already know that $b_r^X < b_r^a$ and $P^X < P^a$.

Once the economy is open, the trade environment affects skill formation. An increase in the number m of trading countries and a decline in the trade cost T shift the skill-formation condition downward, leading to decreases in b_r^X (i.e., increases in the skilled worker fraction) and declines in the nominal income inequality between skilled and unskilled workers. It also lowers the price index, and, hence, increases the skilled-unskilled utility gap and makes all people better off. Moreover, smaller b_r^X deepens the large-item, small-scale production.

Proposition 8 *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 [40] 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. In addition, from 1986 to1999, international trade grew faster than the GDP, and the growth of foreign direct investment (FDI) was higher than international trade (Markusen [29]). In 2003, the total inward and outward FDI for the OECD countries amounted to 384.4 billion and 576.3 billion U.S. dollars, respectively (OECD [32]). This evidence confirms that the importance of multinational firms has recently increased and these firms are now the key players in the world economy. Moreover, Markusen [29] 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. In this section, we do this by comparing exports to FDI.

Let us assume that firms can supply goods to foreign countries via FDI as well. However, for the sake of analytical simplicity, we assume that firms have to choose from the following two alternatives: one is to supply goods only via FDI, and the other is to supply goods only via exporting. If a firm chooses the former, it needs no trade cost ($T = 1$) but has to establish one plant in each trading country and hire f_I units of skilled labor in order to establish one plant, which suggests that the total payment for skilled labor becomes $(1+mf_I)w_s$. If a firm chooses the latter, it needs no skilled labor for foreign plants but has to bear trade costs. Under this setting, we tried to determine the conditions under which firms prefer FDI to exporting and how the choice by firms is connected to skill formation.

Under FDI, the price index (2) becomes

$$P = \left[np^{1-\sigma}(1+m)\right]^{1/(1-\sigma)}. \tag{20}$$

The number of varieties in each country n is given by

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

From this and (13), the worker's arbitrage condition (6) becomes:

$$w_s = \frac{1}{b_r}\left\{1+\left(\frac{\sigma c}{\sigma-1}\right)\left[n(b_r)\left(\frac{1+m}{1+mf_I}\right)\right]^{1/(1-\sigma)}\right\} \tag{21}$$

The profit of a firm under FDI is given as

$$\pi = (p-1)\frac{(1+m)AI}{p^{\sigma}P^{1-\sigma}} - (1+mf_I)w_s. \tag{22}$$

Taking the difference in the price index (difference between (8) and (13)) into consideration, we can investigate under which condition firms prefer FDI to exporting by comparing (15) with (22). A simple comparison gives

$$\begin{aligned} \pi \text{ under FDI } &> \pi \text{ under export} \\ \Leftrightarrow f_I &< \frac{(1-T^{1-\sigma})}{1+mT^{1-\sigma}}. \end{aligned} \tag{23}$$

Since (22) again leads to the zero-profit condition (10), the difference between the locus of (14) and that of (21) generates the difference between skill formation under exporting and that under FDI. Comparing these two equations, it is evident that (14) locates above (21) iff (23) holds. Hence, when the fixed skilled labor requirement for FDI is small, FDI enhances skill formation. In addition, the term $(1-T^{1-\sigma})/(1+mT^{1-\sigma})$ is a decreasing function of the number of trade partners, m, and the transportation cost, T. Hence, when the number of trade partner countries is small, or the transportation costs are high, FDI enhances skill formation.

Proposition 9 *Firms prefer FDI to exporting iff* $f_I < (1-T^{1-\sigma})/(1+mT^{1-\sigma})$. *In this case, compared to exporting, FDI enhances skill formation.*

The condition described in Proposition 9 requires that the fixed costs of FDI be small, the transport cost of goods be large, or the number of trading countries be small. Among these three requirements, the first two obviously enable firms to earn more 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 9 is equivalent to requiring that it be more profitable for firms to achieve FDI than to export goods. Furthermore, a higher profit 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 revealed the possible impacts of international trade on a worker's skill formation and income distribution. We showed that trade enhances skill formation, leading to decreases in the nominal income inequality between skilled and unskilled workers and increases in it among skilled workers. Although these changes make all workers better off, the utility gap between skilled and unskilled workers increases. The effects of changes in trade environments and of FDI are also examined. Thus, we demonstrated that skill formation can play an important role when the relationship between trade and labor markets is considered.

An interesting implication of our framework is to shed light on the fact that globalization can benefit all people via skill formation but may worsen inequality.

It is of value to report some possible extensions. First, we considered only symmetric countries. However, trade between countries of different sizes should also be investigated. The importance of this issue is suggested by the fact that we often observe RTAs between large and small countries (such as the 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 a large country but may harm skill formation in a small country. However, it is still possible that the small country will become better off due to the availability of a wider range of varieties. Second, multinational firms should be considered in more detail. We adopted a highly, perhaps too, simplified way to show that all countries and firms are symmetric, which implies that all firms choose FDI or no firms do. However, in the real world, it may be easier for firms to establish their plants in some countries than in others or for firms to combine trade with FDI. In order to understand the full implications related to FDI, we should incorporate these more realistic features. Third, incorporating the framework developed in this paper into a model with heterogeneous firms a la Melitz [31] may give us implications that can be compared with empirical results regarding trade effects on heterogeneous firms. It would be particularly interesting to explore how the interaction between trade and skill formation affects the allocations of heterogeneous workers to heterogeneous firms.

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Dependent variable=E					
Fixed effects					
	(1)	(2)	(3)	(4)	(5)
T	0.083	0.220 **	0.230 **	0.225 *	0.214 *
	(0.112)	(0.107)	(0.108)	(0.133)	(0.125)
IG		1.745 ***	1.797 ***	1.851 ***	1.726 ***
		(0.350)	(0.353)	(0.385)	(0.400)
GR			−0.058 **	−0.041	−0.035
			(0.023)	(0.027)	(0.026)
R				−0.081	
				(0.196)	
PE					−0.529
					(0.349)
ad−R2	0.88	0.90	0.90	0.90	0.90
nob	147	147	141	129	125

Random effects					
	(1)	(2)	(3)	(4)	(5)
T	0.107	0.126	0.128	0.026	0.122
	(0.098)	(0.091)	(0.092)	0.098)	(0.101)
p value−Hausman	0.65	0.06	0.09	0.00	0.02

Table 1. Trade and skill formation.
notes: Standard errors in parentheses. *, **, and *** are10, 5, and 1 percent significance levels.

Dependent variable=I					
Fixed effects					
	(1)	(2)	(3)	(4)	(5)
T	−0.113 ***	−0.140 ***	−0.125 ***	−0.175 ***	−0.211 ***
	(0.040)	(0.040)	(0.040)	(0.047)	(0.057)
IG		−0.367 ***	−0.341 **	−0.395 ***	−0.304 *
		(0.136)	(0.132)	(0.142)	(0.166)
GR			−0.030 ***	−0.026 **	−0.019 *
			(0.008)	(0.010)	(0.010)
R				0.161 **	0.144 *
				(0.074)	(0.082)
PE					0.062
					(0.160)
ad−R2	0.92	0.93	0.93	0.93	0.93
nob	129	129	126	118	104

Random effects					
	(1)	(2)	(3)	(4)	(5)
T	−0.114 ***	−0.117 ***	−0.107 ***	−0.046	−0.056 *
	(0.036)	(0.034)	(0.033)	(0.030)	(0.032)
p value−Hausman	0.98	0.37	0.25	0.00	0.00

Table 2. Trade and nominal income inequality.
notes: Standard errors in parentheses. *, **, and *** are10, 5, and 1 percent significance levels.

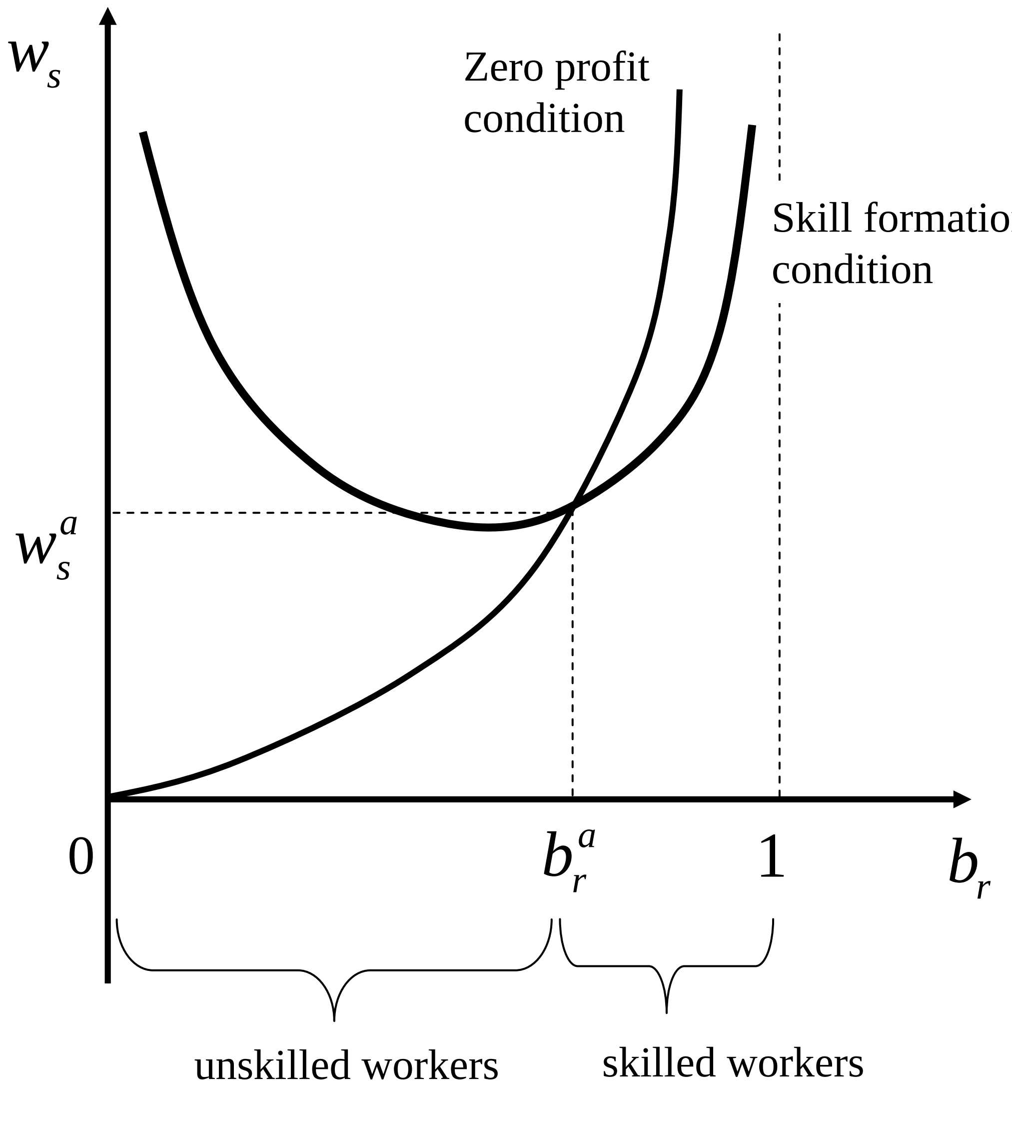

Figure1. Equilibrium

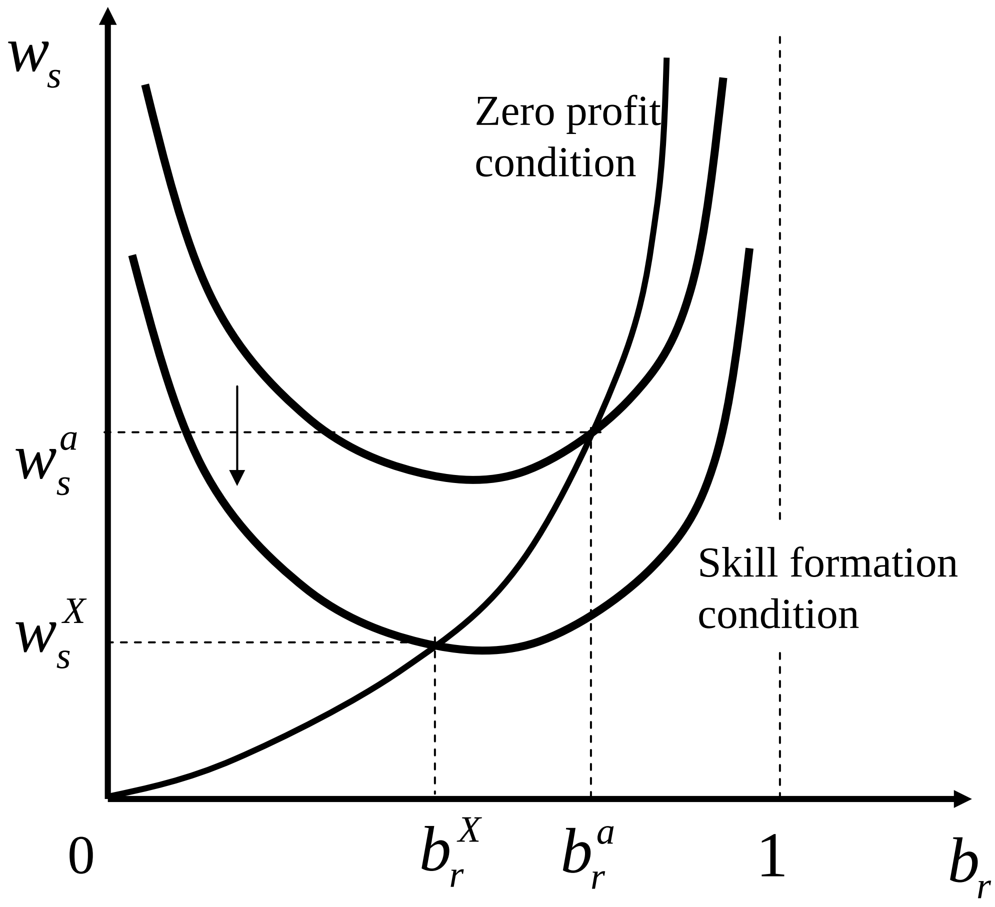

Figure 2. Impact of trade on skill formation