Labor Heterogeneity and the Margins of Exports *

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Abstract

This paper investigates how changes in skilled and unskilled labor supply affect different margins of exports. Using bilateral trade data in manufacturing sectors of 34 countries from 1995 to 2010, we find that most of the impact of skilled labor on exports goes through the intensive margin, whereas most of the effect of unskilled labor works through the extensive margin. These outcomes result from the impact of labor skill composition on the productivity cut-off of exporters. We also find that the impact of skilled and unskilled labor on trade margins depends on the country's income level and types of product. The results indicate that the effect of skilled labor is greater for low-income countries and differentiated products, while that of unskilled labor is greater for high-income countries and homogeneous products.

Keywords: extensive margin; intensive margin; labor heterogeneity; export dynamics; labor skill

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1 Introduction

The recent availability of micro data has allowed economists to investigate the two margins in international trade, namely the extensive and intensive margins. The extensive margin of exports represents the width of exports, and the intensive margin

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represents the depth of exports. These two margins have different welfare implications for export growth.[1] An increase in the intensive margin means that the country exports a greater volume of each product, which may worsen the terms of trade and decrease the exporter's welfare. In contrast, a rise in the extensive margin can improve welfare by increasing the market share of the exporter and diversifying exports against trade shocks. Despite the need to differentiate the two margins, the literature yields mixed results as to which margin is the more important venue for trade growth. In some studies, the extensive margin is reported to play a more important role (Evenett and Venables, 2002; Hummels and Klenow, 2005), while in others, the main venue is the intensive margin (Felbermayr and Kohler, 2006; Eaton et al., 2008; Helpman, Melitz and Rubinstein, 2008; Amiti and Freund, 2010).

The discussion of the extensive and intensive margins of trade started drawing an increased attention since the arrival of the 'new' new trade theories, in particular the seminal work by Melitz (2003). We provide a new mechanism that affects the two margins of trade, based on a model in Luong (2012). By including different types of labor (skilled versus unskilled labor) in the model, he shows that in addition to the *within-firm* effect (i.e., more managers/skilled labor implies more varieties supplied; more workers/unskilled labor produce greater quantity per product line), the change of labor composition also induces a *between-firm* effect that leads to firms' entry to/exit from the export market. This new effect is a result of the multiple-product feature which is now the subject of a growing literature (e.g., Bernard, Redding and Schott, 2010, 2011). Putting these results in our context, we show that more skilled labor could lower the number of varieties exported, due to severe competition leading to the exit of exporting firms. An increase in the unskilled labor could reduce production costs, inducing more firms to enter the foreign market and raising the extensive margin. Moreover, since firms have different productivity and thus different sales per product line, the entry and exit of exporting firms will also affect the intensive margin of exports. The result is different from what canonical factor-proportions models would predict, which is a contribution of our paper.

Another contribution of this paper is to provide empirical evidence showing how an increase in different types of labor influences the two margins of trade.[2] By merging the trade data from UN Comtrade and labor data from Economic Analysis and Statistics (EAS) Division of OECD, we construct a sample with 34 countries over a period of 16 years, from 1995 to 2010. The estimated results show that most of the impact of skilled labor goes to the intensive margin: a 10% increase in skilled labor raises the intensive margin by 5%, and it raises the extensive margin by only 1.4%. By contrast, the impacts of unskilled labor on the two margins are about equal: a 10% increase

[1] A recent paper by Arkolakis et al. (2012) shows that trade elasticity and the import penetration ratio are the sufficient statistics to determine total welfare gains from trade. We focus on the composition of trade and how labor supply affects this composition.

[2] There is a strand of literature that investigates the relative importance of the two margins regarding the effect of country size and trade costs on the total volume of trade (see Hummels and Klenow, 2005; Armugo-Pacheco, 2006; Baldwin and Di Nino, 2006; Bernard et. al., 2007; Crozet and Koenig, 2010; Lawless, 2010).

in unskilled labor raises the extensive margin and the intensive margin by 2.27% and 2.25%, respectively. The decomposition method applied in this paper shows that 78% of the impact of skilled labor occurs in the intensive margin, while for unskilled labor the share is 50%. These results cannot be solely explained by the within-firm effect, and they show that the new mechanism, the between-firm effect, is impressively strong.

This paper also explores the impacts of labor on trade margins across countries with different income levels and across types of products. The estimates show that the influence of unskilled labor on both the extensive and intensive margins is increasing as countries' income level rises. In contrast, the impact of skilled labor decreases with the income levels of countries. These results are intuitive: because skilled labor is more abundant in high-income countries, it has a lower marginal product in high-income countries than in low-income countries. In terms of product type, skilled labor has a greater impact on exports of differentiated products, and unskilled labor has a larger impact on that of homogeneous products. The results are in line with our expectation, since the production of differentiated products is relatively more intensive in skilled labor than in unskilled labor.

These findings relate our paper to a strand of literature that studies skill heterogeneity and the patterns of international trade. Grossman and Maggi (2000) show that countries with a relatively homogeneous skill distribution export the goods with supermodular technology, while countries with a more diverse skill distribution export the goods with submodular technology. Bougheas and Riezman (2007) show that the country with more human capital exports the human capital-intensive goods. While these papers focus on the impact of the form of labor skill distribution on trade patterns, we study the impact of changes in labor supply of different skills on exports performance. Another paper that is related to ours is by Antras, Garicano and Rossi-Hansberg (2006). They show that Northern countries with relatively more skilled labor would export the knowledge services (which play a similar role as the extensive margin in our paper), while the Southern countries export mostly the production services (which act as the intensive margin here).

The trade margins in our paper also suggest that low-income countries might be vulnerable to trade shocks. Baxter and Kouparitsas (2000) document that terms-of-trade fluctuations are twice as large in developing countries as in developed countries. They attribute the cause of this vulnerability to the heavy reliance on exports in general, and commodity exports in particular. Broda (2004) suggests that this could also be explained by exchange rate regimes as most of developing countries adopt fixed exchange rates. We provide another explanation of this vulnerability: the data show that developing countries have lower extensive margins than developed countries. In other words, developing countries are more prone to trade shocks because their exports are less diversified compared to that of developed nations.

The organization of the paper is as follows. Section 2 describes the method of decomposing exports into the extensive and intensive margins. The theoretical framework is introduced in section 3, while our data are introduced in section 4. Section 5 presents our estimated results, and section 6 will conclude.

2 The Extensive and Intensive Margins of Exports

In trade literature, the extensive and intensive margins can be measured at the country, industry, or firm level, depending on the issue of interest. In this paper, trade margins of manufacturing sectors are calculated with product-level data. By convention, a product variety is a particular good produced (or served) in a particular country. Based on Feenstra's framework (1994), Hummels and Klenow (2005) propose a way to decompose exports into the extensive and intensive margins. Consider the total import value of an importer, country j, from all other countries. An exporter i's export share in country j's market in year t is

$$\text{export share}_{ijt} = \frac{\Sigma_{k\in I_{ijt}}\ (v_{ijkt})}{\Sigma_{k\in I_{jt}}\ (\Sigma_i v_{ijkt})} \tag{1}$$

where k is a product category defined by HS6, and v_{ijkt} is the trade value of product k that i exports to j in year t. $\Sigma_i v_{ijkt}$ is the total value of product k that country j imports from all exporters. I_{jt} is the set of products that country j imports from all countries in year t. I_{ijt} is a subset of I_{jt} containing only those products that exporter i has positive exports to country j. The *export share* is the market share of exporter i in importer j's market: it equals the export value from i to j divided by the total imports value of j.

This export share is then decomposed into the extensive and intensive margins. The extensive margin is an index that measures the relative number of products that a country exports to a market. It equals the number of products that i exports to j, relative to the total number of products that j imports from all countries, with each product weighted by its total import value of country j ($\Sigma_i v_{ijkt}$).

$$\text{extensive}_{ijt} = \frac{\Sigma_{k\in I_{ijt}}\ (\Sigma_i v_{ijkt})}{\Sigma_{k\in I_{jt}}\ (\Sigma_i v_{ijkt})} \tag{2}$$

The intensive margin is defined as

$$\text{intensive}_{ijt} = \frac{\Sigma_{k\in I_{ijt}}\ (v_{ijkt})}{\Sigma_{k\in I_{ijt}}\ (\Sigma_i v_{ijkt})} \tag{3}$$

It equals the ratio of country i's export value relative to all countries' export value in market j, for those products that country i has positive exports in j. A high intensive margin indicates that country i's market share is large within those products that it exports to the importer's market.

From equations (1), (2) and (3), country i's export share in country j equals the product of its extensive margin and intensive margin:

$$\underbrace{\frac{\Sigma_{k\in I_{ijt}}\ (v_{ijkt})}{\Sigma_{k\in I_{jt}}\ (\Sigma_i v_{ijkt})}}_{\text{the export share}} = \underbrace{\frac{\Sigma_{k\in I_{ijt}}\ (\Sigma_i v_{ijkt})}{\Sigma_{k\in I_{jt}}\ (\Sigma_i v_{ijkt})}}_{\text{the extensive margin}} \times \underbrace{\frac{\Sigma_{k\in I_{ijt}}\ (v_{ijkt})}{\Sigma_{k\in I_{ijt}}\ (\Sigma_i v_{ijkt})}}_{\text{the intensive margin}} \tag{4}$$

For instance, in the year 2010, the export share, intensive margin, and intensive margin of China in the U.S. market is 0.24, 0.90, and 0.27, respectively. These numbers show that China exports 90% of HS6 products that U.S. imports from all countries in the sample. Within these 90% products, China's market share is 27%. The total export share of China in the U.S. market is thus 90%×27%=24%. Note that these trade margin are calculated by importer-year: they measure the *relative* export performance of each exporter in an importer-year, and do not represent *absolute* trade volumes. Equation 4 also shows that after taken natural logs, the export shares can be decomposed into the extensive and intensive margins additively (i.e., ln(export share) = ln (extensive) + ln (intensive)). These trade margins are the dependent variables in the estimations.

3 Theoretical Framework

Our model, which is taken from Luong (2012), is similar to the conventional trade models, which is a small open economy consisting of heterogeneous firms, a la Melitz (2003). We depart from this set up on two important features. First, each firm can supply one or more varieties. The multiple-product feature is important and crucial in our analysis as it enables us to decompose the firm activities into two categories: the extensive tasks and the intensive tasks. Grossman and Rossi-Hansberg (2008) categorize tasks into the the high-skilled ones and the low-skilled ones, which leads to the second important feature of our model. According to Nelson-Phelps (1966) hypothesis, the extensive tasks are innovation and production management, which require skilled workers and can increase scopes of firms. Indeed, in order to invent new products, scientists have to be hired to work in R&D. Managing different product lines, which could have business conflicts (e.g., the cannibalization effect), is also a complex task.

There are two factors in this economy: skilled labor and unskilled labor. Using unskilled labor as our numeraire (i.e. their wage is normalized to 1), we denote w the relative wage of skilled labor. The high-skilled activities (which are related to innovation) require only skilled labor, and the low-skilled activities (which are the simpler, repetitive production process) use only unskilled labor. In particular, to supply n product lines, the number of skilled workers required to hire is:

$$F(n) = n^m, m > 1$$

On the intensive front, as in the Melitz (2003) framework, each firm is free to enter the market after paying an entry, sunk cost f_e (in terms of unskilled labor). Upon entry, the firm draws its productivity level θ from the exponential distribution with the following probability distribution function:

$$g(\theta) = \gamma e^{-\gamma\theta}.$$

The lower γ is, the more heterogeneous the firms are in their productivity level. This productivity dictates how much an unskilled worker can produce. The usual free entry condition also applies here. To summarize, we can break down the firm problem into 3 steps:

- Step 1: The firm decides whether or not to enter the market with an entry cost f_e. Upon entry the firm makes a productivity draw.

- Step 2: The firm decides its scope (the number of varieties).

- Step 3: The firm's scale (i.e., output per product), together with unit price, are chosen.

With this set-up, the maximization problem can be solved backward. The monopolistic framework yields the pricing strategy as

$$p(\theta) = \frac{\sigma}{\sigma - 1}\frac{1}{\theta} \tag{5}$$

as well as the demand per variety (the intensive margin)

$$q(\theta) = \left(\frac{p(\theta)}{P}\right)^{-\sigma}\frac{R}{P} \tag{6}$$

where the industry price index P is defined as,

$$P = \left(\int p(\theta)^{1-\sigma} Mn(\theta)g(\theta)d\theta\right)^{-\frac{1}{\sigma-1}}. \tag{7}$$

The profit per variety is then

$$\pi(\theta) = \frac{R}{\sigma}P^{\sigma-1}\theta^{\sigma-1}$$

Given this profit per variety, the firm will choose its scope to maximize its total profit

$$\Pi(n,\theta) = n\pi(\theta) - w_H F(n)$$

which yields the optimal scope (the extensive margin)

$$n(\theta) = \sqrt[m-1]{\frac{\pi(\theta)}{mw_H}} \tag{8}$$

Under this setting, we can derive the following lemmas that motivate our empirical analysis:

Lemma 1 *The relative wage of skilled labor is proportional to the relative endowment of unskilled labor*
Proof. *See Appendix A.1* ■

Lemma 2 *The survival production cut-off rises with the number of skilled labor but falls with the number of unskilled labor*
Proof. *See Appendix A.1* ■

Lemma 3 *The price index falls with the number of skilled labor and increases with the number of unskilled labor.*
Proof. *See Appendix A.1* ■

Lemma 2 and Lemma 3 both point out that while more skilled labor raises the degree of competiton in a market, more unskilled labor reduces it. It is because of the multiproduct feature. Indeed, an increase in the relative endowment of skilled labor results in more varieties supplied by each firm. This effect intensifies the competitiveness in the market. In this model, how changes in labor supply affect exports can be summarized by the following two effects.

3.1 The Within-Firm Effect

An immediate implication of Lemma 3 is that with more unskilled labor, the price index increases, which raises the intensive margin according to Equation 6. Lemma 1 shows that the relative wage of skilled labor falls when there are more skilled labor, which implies that the extensive margin rises according to Equation 8.

Under this setting, we have predictions that are similar to those of factor-proportions theories:[3] Countries with more skilled labor produce more varieties and become exporters of varieties (i.e., export more types of goods), while countries abundant in unskilled labor export intensively a limited number of varieties. Since this effect occurs within a firm, we define this as the *within-firm* effect. The within-firm effect predicts that having more skilled labor will increase the number of varieties, while having more unskilled labor will increase the output per variety.

3.2 The Between-firm Effect

In addition to the within-firm effect as mentioned above, there is another effect that takes place *between firms*. On the extensive front, higher survival cut-off due to more skilled labor or less unskilled labor (Lemma 2) means there are fewer firms and therefore fewer varieties provided in the market. Unused workers, who previously employed by the exiting firms, then move to the surviving firms. More workers and also less competition because of firms' exit result in an increase in the intensive margin of the varieties supplied by the surviving firms.

This between-firm effect is the result of firm heterogeneity and the multiproduct feature, which goes in an opposite direction to that of the within-firm effect. Indeed, this effect implies that having more skilled labor will increase the output per variety and could possibly *decrease* the number of varieties. On the contrary, having more unskilled labor will increase the number of varieties and could *decrease* the output per

[3] The results will not change if we assume that the extensive tasks intensively (but not only) use the skilled labor, while the intensive tasks intensively use the unskilled labor. We want, however, to pose a stark contrast between the two types of labor, and also between their impacts on the two types of tasks. The additional channels (i.e. how skilled labor affects the intensive margin and how unskilled labor affects the extensive margin) come from the between-firm effect that will be explain later.

variety. This result is crucial in our study because failing to account for the dynamic entry and exit of firms in the export market could bias the importance of the two margins (Helpman, Melitz and Rubinstein, 2008; Besedes and Prusa, 2011).

The estimations in this paper enable us to evaluate the relative importance of the two effects regarding the impact of labor supply on exports. If the within-firm (between-firm) effect dominates, we expect that skilled labor increases export mainly through the extensive (intensive) margin. For unskilled labor, the intensive (extensive) margin contributes more when the within-in (between-firm) effect plays a more important role.

4 Data

The section describes the measures and data source of the dependent and explanatory variables in the estimation, and presents the summary statistics of these variables.

4.1 Skilled and Unskilled Labor

As described in Section 3, labor is divided into two categories: skilled labor and unskilled labor. Production workers are defined as unskilled labor, while employees who engage in technological improvement, supervision and administrative work are characterized as skilled labor. In the literature, the white-blue collar distinction is widely used as measures of skilled and unskilled labor. Indeed, Berman, Bound and Griliches (1994) report that from 1973 to 1987, the fraction of non-production workers closely mirror that of white collar workers in the U.S. To be consistent with our discussion in Section 3, we need to find a measure of skilled labor such that it has no effect on the production process within a firm. For this purpose, we use the number of researchers as a measure of skilled labor, and all the other employment is defined as unskilled labor. This measure of skilled labor is obviously a narrower definition, compared with the conventional measures in the literature. This narrow definition, nevertheless, fits our set up in the theoretical framework, in which skilled labor only expands the number of products but plays no role in production activities.

The researcher/employment variables are obtained from the OECD Main Science and Technology Indicators, which is a biannual report. The report is prepared by the Economic Analysis and Statistics (EAS) Division of the OECD Secretariat in collaboration with the Working Party of National Experts on Science and Technology Indicators (NESTI). The total number of researchers is expressed on a full-time equivalent basis.

4.2 International Trade

We use the United Nation Comtrade data to construct the extensive and intensive margins of exports. The dataset contains the quantity and value of bilateral trade. Trade flows are recorded at the 6-digit Harmonized System (HS6), and each HS6 is considered a product k in the decomposition process in equations (1), (2) and (3).

We merge the trade data with that of labor supply, keeping countries that appear in both data sets. For every importer, we then calculate the total export share, extensive margin, and intensive margin in manufacturing sectors of each exporter that have positive exports to the importer.

4.3 Gravity-Model Variables

The data of GDP are obtained from OECD. To capture transportation cost, we include the geographical distance (in kilometers) between the two countries in the model. The common language, colony, and border are binary variables equal one if the two trading partners share a common language, had a colonial history, and share a common border. These variables are taken from the CEPII database. We also include a binary variable, FTA, which equals one if the two trading countries are in the same regional trade agreement. The information is obtained from Regional Trade Agreements Information System (RTA-IS) of WTO.

4.4 Summary Statistics

The merged sample contains 34 countries over the period 1995-2010. It covers a wide range of countries, including both small (such as Singapore) and large countries (USA, China), and both developed and developing countries.

Table 1 reports the summary statistics of the dependent and explanatory variables, and Table A.1 provides more details about the most important variables by country. On average, each exporter accounts for 3% of total imports in each market, 50% of product varieties that are imported, and 4% of the value of these products. The country with the biggest average extensive and intensive margins is Germany (0.906 and 0.201, respectively). This is not surprising since a large number of countries in OECD database are in Europe, and thus Germany's average export share is much greater than other large exporters such as China. On the other hand, Iceland is the country with the lowest average extensive and intensive margins (0.091 and 0.006, respectively). China has the largest labor force (over 700 millions), while Iceland has only 158 thousands workers. The U.S. has the greatest number of researchers (1.3 million), and Iceland has the fewest (fewer than 2,000). It is then worth noting that high-income countries (e.g. Germany) have higher extensive margin than developing countries (e.g. Argentina) in general.

[Insert Table 1 here]

5 Model of Estimation and Results

In this section, we construct the empirical model and present the estimated results. In addition to the benchmark case, we also estimate models that allow the effect of labor on trade to differ by country's GDP per worker and by product type.

5.1 Benchmark Estimation

The main point of the estimation, which is motivated by the model in Section 3, is to analyze how skilled and unskilled labor affect the different margins of exports. It is likely that both the within-firm and between-firm effects take place in the real world. Therefore the objective of the estimation is not to *test* any one of the two effects and to reject the other one. Instead, we try to *estimate* the relative importance of the two effects in the influence of labor supply on exports.

We expand the gravity model by decomposing the size of exporters, which is measured by GDP, into total employment and GDP per worker. We then separate the total employment into skilled and unskilled labor. The empirical model specification is:

$$\begin{aligned} \ln \mathrm{trade}_{ijt} &= \beta_0 + \beta_1 \ln \mathrm{Skill}_{it} + \beta_2 \ \ln \mathrm{Unskill}_{it} + \beta_3 \ln \mathrm{GDPPW}_{it} \\ &\quad + \beta_4 \ln \mathrm{GDP}_{jt} + \beta_5 \mathrm{Language}_{ij} + \beta_6 \mathrm{Colony}_{ij} \\ &\quad + \beta_7 \ln \mathrm{Distance}_{ij} + \beta_8 \mathrm{Border}_{ij} + \beta_9 \mathrm{FTA}_{ijt} + \mu_t + u_{ijt} \end{aligned} \tag{9}$$

The dependent variables are the export share, the extensive margin, and the intensive margin of the exporting country i in the importing country $j's$ market at time t. Each trade margin is regressed on the same set of explanatory variables as in equation 9. Note that skilled labor (Skill_{it}), unskilled labor ($\mathrm{Unskill}_{it}$), and GDP per worker (GDPPW_{it}) are variables of the exporters, while GDP_{jt} is a variable of the importers. These variables and distance are in log terms. The dummy variables $Language_{ij}$, $Colony_{ij}$ and $Border_{ij}$ take the value 1 when the trading countries share a same language, a colonial history and a common border. The dummy FTA_{ijt} takes the value 1 if countries i and j have a trade agreement effective at time t. Year fixed effects are included in the model.

A discussion about the measures of labor supply is in order. In the estimation, we include log of skilled and unskilled labor as two explanatory variables, instead of including the relative labor supply (i.e., skilled labor/unskilled labor) as in models based on factor proportions theories. According to the theoretical model in Section 3, the relative importance of the within-firm and between-firm effects can be different for the two types of labor. Including both skilled and unskille labor enables us to identify which effect is more important for each type of labor. Estimating the effect of relative labor supply, nevertheless, imposes a restriction that the dominating effect is the same for both types of labor (since in that case, only the relative labor supply matters). As a result, we include the two types of labor supply in the benchmark estimation, and use the relative labor supply in a robustness check in Section 5.4.

The benchmark model is estimated by OLS. Estimated coefficients and standard errors are reported in Table 2. The regressors of interest here are the skilled and unskilled labor. An increase in either skilled or unskilled labor improves the exporter's overall export share. Column 1 shows that a 10% increase in skilled labor will raise an exporter's manufacturing export share in a market by 6.4%. The increase can be decomposed into a 1.4% increase in the extensive margin (Column 2) and a 5% increase in the intensive margin (Column 3). The intensive margin accounts for 78% of skilled labor's influence, while the extensive margins accounts for 22%. A 10% increase in unskilled labor will increase export share by 4.5%, which can be decomposed into a 2.3% increase in the extensive margin and a 2.2% increase in the intensive margin. In terms of the influence of unskilled labor on exports, the extensive margin accounts for a slightly larger share than does the intensive margin.

The results show that skilled and unskilled labor have significantly positive effects on both margins. From the theoretical model, it is evident that both the within-firm and between-firm effects take place in the sample. We can infer the relative importance of the two effects by examining the contribution of each margin. The results show that the intensive margin dominates in the effect of skilled labor on exports, while the extensive margin contributes slightly more than half of unskilled labor's impact. The estimates show that the between-firm effect indeed plays a very important role. The results provide evidence that the factor proportions theory alone cannot fully explain the impact of labor supply on exports. The between-firm effect is at least equally, if not more, important as the within-firm effect.

Coefficients on other regressors have the expected signs, with the exception of the coefficient on GDP of importer on the intensive margin, and that of the common border on the extensive margin. Since our trade margins are calculated by importer-year, they represent the relative performance of different exporters in each market, not the absolute volume of trade. The negative coefficient on importer's GDP does not indicate that large countries import less. Instead, it shows that the average market share of exporters is decreasing with the importer's market size. This result is reasonable because large importers tend to import each product (HS6) from more exporters, which makes each exporter's market share smaller. The negative sign of the border coefficient could be explained by the fact that being neighboring countries means it is more likely that the two countries produce similar products, which reduces the range of goods they exchange.

[Insert Table 2 here]

5.2 Interactions with GDP per Worker

The effect of an increase in skilled and unskilled labor on exports can differ by countries' level of development. The literature on product diversification/sophistication (e.g., Imbs and Warcziarg, 2003; Hausmann et al., 2007; Cadot et. al., 2009) shows that product diversification has a bell-shaped relationship with GDP per capita. For low-income countries, the growth of trade is shown as an expansion of product sets, which increases the extensive margin. High-income countries will concentrate on improving the quality of specific products, which is captured by an increase in the intensive margin. Additionally, when a new product is created (usually by a developed country), the product classification system may not change immediately to incorporate the creation of the new product. Trade in this product will increase the intensive margin until a new product classification is built into the system. For developing countries with zero-trade in more existing product lines, an increase in skilled labor will expand the range of products they can export in the classification, thus increasing the extensive margin directly.

The implication of the product diversification literature is that an improvement in labor composition should have a relatively greater impact on the extensive margins for developing countries than for developed countries. To explore this issue, we include interaction terms between country's demeaned GDP per worker and labor:[4]

$$\begin{aligned}\ln \mathrm{trade}_{ijt} &= \beta_0 + \beta_1 \ln \mathrm{Skill}_{it} + \beta_2 \ \ln \mathrm{Unskill}_{it} + \beta_3 \ln \mathrm{GDPPW}_{it} + \\ &\quad +\beta_4 \ln \mathrm{GDP}_{jt} + \beta_5 \mathrm{Language}_{ij} + \beta_6 \mathrm{Colony}_{ij} + \beta_7 \ln \mathrm{Distance}_{ij} \\ &\quad +\beta_8 \mathrm{Border}_{ij} + \beta_9 \mathrm{FTA}_{ijt} + \beta_{10} \ln \mathrm{Skill}_{it} \times \text{demeaned} \ln \mathrm{GDPPW}_{it} \\ &\quad +\beta_{11} \ \ln \mathrm{Unskill}_{it} \times \text{demeaned} \ln \mathrm{GDPPW}_{it} + \mu_t + u_{ijt}\end{aligned} \tag{10}$$

The estimated results are presented in Table 3. Coefficients on skilled and unskilled labor are similar to that of the benchmark case. For a country whose GDP per worker equals the sample average (i.e., demeaned GDPPW equals 0), an increase in both skilled and unskilled labor will improve the overall export performance, along with both the extensive and intensive margins. For each margin, the interaction term of skilled labor has a negative coefficient, while that of unskilled labor has a positive coefficient. The results indicate that the effect of skilled labor is greater for low-income countries, and that of unskilled labor is stronger for high-income countries.

[Insert Table 3 here]

To compare the effect of skilled/unskilled on exports in countries with different GDP per worker, we calculate the elasticity of three countries in the sample: South Africa, Spain, and Belgium, whose GDPPW percentiles are 10%, 50%, and 90% in the year 2000, respectively. The results are reported in Table 4. Column 1 shows that the estimated influence of skilled labor on overall exports is much greater in low-income than in high-income countries, while that of unskilled labor is larger in high-income countries than in low-income countries. The finding is consistent with factor endowment proportions theories. Since rich countries are more abundant in skilled labor, the marginal product of skilled labor is lower, and its impact on exports is weaker. On the other hand, poor countries have relatively more unskilled labor than skilled labor, and thus an increase in skilled labor will improve their exports performance more.

Columns 2 and 3 display that the contribution of the two margins also differs by countries' GDP per worker. The impact of skilled labor on both margins decreases with GDP per worker. In particular, the effect of skilled labor on the extensive margin is actually negative in rich countries. A 10% increase in skilled labor raises the extensive

[4] Demeaned log GDPPW equals each exporter's log GDPPW minus the mean of all exporters' log GDPPW in year t.

margin of South Africa by 1.8%, but it reduces the extensive margin of Belgium by 0.6%. The relative importance of the extensive margin in South Africa is 24%, but it is negative in Belgium. This result matches findings in the literature on product diversification. Developed countries are more focused on quality improvement in specific product lines, and thus the range of products exported decreases with the growth of skilled labor.

The impact of unskilled labor on both margins, on the contrary, rises with the income level of the exporter. While a 10% increase in unskilled labor in South Africa would raise the export share by 4.9%, it would raise the export share of Spain and Belgium by 6.5% and 7.1%, respectively. The contribution of the intensive margin relative to the extensive margin increases with GDP per worker, although the difference across countries is not significant. The evidence is again consistent with the prediction of the product diversification literature.

In summary, the estimated results in this section indicate that: (1) Skilled labor is more important than unskilled labor in improving developing countries' export performance; and (2) An increase in labor supply will improve exports performance of developed countries mainly through the intensive margin. These findings are in line with predictions of factor proportions theories and product diversification literature.

[Insert Table 4 here]

5.3 Estimation by Product Type

Skilled and unskilled labor may have an asymmetric impact on different types of products. Based on the Rauch (1999) classification, we categorize products into two types: homogeneous (including reference priced) and differentiated. We then calculate the trade margins and estimate the model in equation 9 of each product type separately.

The estimates are reported in Table 5. Columns 1-3 show the estimated coefficients of homogeneous products, while Columns 4-6 show that of differentiated products. For both types of products, the coefficients on skilled and unskilled labor are positive in each margin, which is consistent with the benchmark estimation. However, the relative importance of skilled and unskilled labor differs greatly across product type. A 10% increase in skilled labor will increase export share of homogeneous products by 3%, while it will increase that of differentiated products by 7.8%. A 10% increase in unskilled labor, on the other hand, will raise the export share of homogeneous and differentiated products by 6.2% and 3.6%, respectively. The estimates confirm our expectation, that skilled labor is used more intensively in the production of differentiated products, while unskilled labor plays a greater role in that of homogeneous products.

In terms of the relative contribution of the extensive and intensive margins, there is no large difference between the two types of products: the extensive margin contributes 60%-70% of the positive effect of unskilled labor, and the intensive margin contributes more than 80% of the effect of skilled labor. The relative importance of the two margins is similar in both types of products, which is consistent with the outcomes of our benchmark estimation.

[Insert Table 5 here]

5.4 Robustness Checks

The discussion so far shows that the main findings in the benchmark estimation are robust to different countries and products types. In this section, we will run additional robustness checks.

The factor proportions models predict that trade patterns are determined by the relative endowment of factors. As discussed in Section 5.1, we include the levels of both skilled and unskilled labor (instead of the relative labor supply) in the model to estimate the within and between effects of each type of labor distinguishably. As a robustness check, we replace the levels of skilled and unskilled labor with total employment and a relative supply of skilled to unskilled labor (i.e., a skilled-unskilled labor ratio). The estimates in Table A.2 are consistent with the benchmark case: an increase in the relative supply of skilled labor increases the intensive margin more than the extensive margin.

In the benchmark case, we control for the time fixed effect. Similar results are found when we additionally control for the importer fixed effect, and the coefficients are reported in Table A.4. Within an importing country, our results are still valid. The coefficients are less significant when the exporter fixed effects are included, which could be expected since the variation of labor supply mostly comes from the cross-sectional difference across exporters. Once the exporter fixed effect is controlled, the estimation relies on the relatively small variation over time, which reduces the precision of the estimation and makes coefficients on labor less significant.

One possible concern is about our measure of skilled labor. In trade literature, the skilled and unskilled labor have various measures, such as by occupation or education. Instead of the number of scientists, we use the number of R&D personnel as an alternative measure of skilled labor to estimate the model. Table A.3 shows that our results are robust with this alternative measure.

Another concern is that labor supply is influenced by international trade. Specifically, exports in past years may affect the composition of labor supply in later years, which leads to an endogeneity problem when observations of all years are pooled together. To mitigate this concern, we construct a cross-sectional sample for every year, and estimate the model in equation (9) year by year. The estimated coefficients are not reported here to save space, but results similar to the benchmark case are found in estimations of almost all years.

The trade margins in the sample are calculated based on trade in manufacturing sectors, since these sectors are where R&D is likely to occur and data in these sectors are in general more reliable. Alternatively, we calculate the trade margins of all sectors and re-estimate the model. Table A.5 shows that using trade data of all sectors does not change the conclusion.

Finally, we estimate the model with two alternative estimators to account for possible bias due to excluding observations of zero trade: the Poisson pseudo-maximum-likelihood (PPML) estimator (Santos Silva and Tenreyro, 2006) and the two-stage estimation procedure in Helpman, Melitz, and Rubinstein (2008).[5] The estimates are

[5] In the two-stage estimation, exports are measured at the industry level (HS2). As in Helpman et

reported in Table A.6. Since exports are no longer decomposed into the two margins linearly, the exact contribution of each margin cannot be measured as in the benchmark. Instead, we compare the relative importance of each type of labor in the two margins. In the PPML estimation (columns 1-3), the skilled and unskilled labor have a greater effect on the intensive and extensive margin, respectively, which is the same as in the benchmark. In the two-stage estimation (columns 4-5), although the effect of the unskilled labor is now greater than that of the skilled labor in both margins, it is still *relatively* more important in the extensive margin than in the intensive margin. The results are consistent with that in the benchmark.

6 Conclusion

Trade liberalization has been promoted as an effective way to enhance welfare, yet the gains depend on which component of trade flows flourishes. If export booms because of the extensive margin, more goods will be available for consumption and more types of inputs will be available for production. If the intensive margin increases, buyers can experience cheaper or/and higher quality goods, but it may also worsen the exporter's terms of trade. The literature investigating the source of export growth has been growing, but there is still no consensus on which margin plays a greater role. Our paper contributes to the literature on trade growth by studying how labor composition affects the different margins of exports. Using trade data from 34 countries, we find that skilled labor plays a more important role in explaining the rise in the intensive margin while unskilled labor plays a greater role in explaining the rise in the extensive margin. The results could be explained by the effect of labor skill composition on the number of exporting firms. We also find that the impact of skilled and unskilled labor on trade margins depends on the income level of the exporting country. In particular, the effect of skilled labor is greater in low-income countries, while that of unskilled labor is stronger in high-income countries. Our results suggest that developing countries might be vulnerable to trade shocks as they do not diversify their export portfolio enough, compared to developed countries.

al. (2008), we calculate $\widehat{\overline{\eta}}^*$ (the inverse Mills ratio) and $\widehat{\overline{z}}^* = \Phi^{-1}(\widehat{\rho})$ from the first stage, where $\widehat{\rho}$ is the predicted value in the probit. $\widehat{\overline{\eta}}^*$ and polynomials of $\widehat{\overline{z}}^*$ are included in the second stage estimation to account for firm heterogeneity and sample selection bias. We select common language and colonial history as excluded variables in the second stage (see Bao and Qiu, 2012).

Table 1: Summary Statistics

Variables	Mean	Std. Dev.	Min	Max
export share	0.030	0.064	2.28×10^{-9}	0.836
extensive margin	0.536	0.288	1.34×10^{-6}	1.000
intensive margin	0.040	0.070	1.98×10^{-6}	0.975
skilled labor (researcher)	142,772	279,475	1,076.3	1,592,420
unskilled labor	4.19×10^{7}	1.34×10^{8}	140,694.1	7.79×10^{8}
GDP per employment	0.051	0.020	0.003	0.112
importer GDP	1,074,121	2,106,114	6,214.332	1.44×10^{8}
distance	6,587.971	5,376.665	59.615	19,586
language	0.079	0.270	0	1
border	0.056	0.230	0	1
colony	0.037	0.189	0	1
FTA	0.546	0.498	0	1

Notes: Sources: UN-COMTRADE for bilateral trade flows from 1995 to 2010; CEPII database for distance, common language, colonial history, and common borders; OECD Main Science and Technology Indicators for GDP, Employment, and Skilled Labor; WTO for FTA.

Table 2: Results of the Benchmark Estimation

Variables	(1) export share	(2) ext. margin	(3) int. margin
ln(exporter skilled labor)	0.642***	0.141***	0.501***
	(0.0690)	(0.0392)	(0.0493)
ln(exporter unskilled labor)	0.452***	0.227***	0.225***
	(0.0720)	(0.0454)	(0.0498)
ln(exporter GDPPW)	1.102***	0.551***	0.551***
	(0.0973)	(0.0523)	(0.0593)
ln(importer GDP)	0.124***	0.202***	-0.0784***
	(0.0121)	(0.00866)	(0.00841)
ln(distance)	-0.738***	-0.367***	-0.371***
	(0.0284)	(0.0185)	(0.0205)
common border	0.443***	-0.227***	0.670***
	(0.0514)	(0.0324)	(0.0326)
common language	0.652***	0.292***	0.360***
	(0.0830)	(0.0350)	(0.0601)
colony	0.307***	0.152***	0.155***
	(0.0508)	(0.0245)	(0.0363)
FTA	0.366***	0.0245	0.341***
	(0.0627)	(0.0308)	(0.0482)
Constant	-10.99***	-3.978***	-7.010***
	(0.479)	(0.321)	(0.347)
Time FE	Yes	Yes	Yes
Observations	14,448	14,448	14,448
R-squared	0.717	0.547	0.646

Note: Standard errors in parentheses are clustered by exporter-year.
All the variables, except the dummies, are in log terms.
* indicates significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: Interactions with GDP per Worker

Variables	(1) export share	(2) ext. margin	(3) int. margin
ln(exporter skilled labor)	0.461***	0.0608*	0.400***
	(0.0604)	(0.0324)	(0.0480)
ln(exporter unskilled labor)	0.604***	0.293***	0.310***
	(0.0660)	(0.0381)	(0.0477)
demean ln(exp gdppw) × ln(exp skill)	-0.573***	-0.229***	-0.344***
	(0.107)	(0.0706)	(0.0761)
demean ln(exp gdppw) × ln(exp unskill)	0.207**	0.0726	0.135**
	(0.0852)	(0.0574)	(0.0576)
ln(exporter GDPPW)	4.387***	2.058***	2.328***
	(0.515)	(0.395)	(0.294)
ln(importer GDP)	0.125***	0.203***	-0.0775***
	(0.0121)	(0.00871)	(0.00834)
ln(distance)	-0.733***	-0.366***	-0.367***
	(0.0296)	(0.0187)	(0.0205)
common border	0.451***	-0.224***	0.675***
	(0.0519)	(0.0322)	(0.0331)
common language	0.609***	0.271***	0.338***
	(0.0790)	(0.0350)	(0.0572)
colony	0.382***	0.186***	0.196***
	(0.0487)	(0.0255)	(0.0340)
FTA	0.409***	0.0427	0.366***
	(0.0624)	(0.0311)	(0.0475)
Time FE	Yes	Yes	Yes
Constant	-0.390	0.915	-1.305
	(2.000)	(1.589)	(1.045)
Observations	14,448	14,448	14,448
R-squared	0.735	0.564	0.658

Note: Labor supply are interacted with demeaned GDP per worker in the exporter country. Standard errors in parentheses are clustered by exporter-year. * indicates significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 4: Elasticity of Exports in Different Countries

	(1) exp	(2) ext		(3) int	
Skilled labor					
South Africa	0.765	0.182	24%	0.582	76%
Spain	0.323	0.006	2%	0.317	98%
Belgium	0.163	-0.058	-36%	0.221	136%
Unskilled labor					
South Africa	0.494	0.255	52%	0.239	48%
Spain	0.654	0.311	48%	0.343	52%
Belgium	0.712	0.331	46%	0.381	54%

Table 5: Estimations by Product Type

Product Type	Homogeneous					Differentiated				
	(1)	(2)		(3)		(4)	(5)		(6)	
Variables	export share	ext. margin		int. margin		export share	ext. margin		int. margin	
ln(exporter skilled labor)	0.293***	0.0921**	18%	0.201***	82%	0.775***	0.117***	15%	0.658***	85%
	(0.0840)	(0.0444)		(0.0635)		(0.0693)	(0.0389)		(0.0451)	
ln(exporter unskilled labor)	0.616***	0.403***	65%	0.212***	34%	0.358***	0.249***	69%	0.109**	31%
	(0.0781)	(0.0502)		(0.0616)		(0.0692)	(0.0454)		(0.0463)	
ln(exporter GDPPW)	1.311***	0.756***		0.554***		1.028***	0.575***		0.453***	
	(0.0909)	(0.0547)		(0.0599)		(0.112)	(0.0541)		(0.0718)	
ln(importer GDP)	0.151***	0.266***		-0.114***		0.114***	0.208***		-0.0936***	
	(0.0125)	(0.0103)		(0.00872)		(0.0115)	(0.00845)		(0.00834)	
ln(distance)	-0.756***	-0.590***		-0.165***		-0.756***	-0.362***		-0.394***	
	(0.0301)	(0.0230)		(0.0230)		(0.0306)	(0.0189)		(0.0205)	
common border	0.679***	-0.293***		0.972***		0.381***	-0.263***		0.644***	
	(0.0608)	(0.0416)		(0.0408)		(0.0537)	(0.0329)		(0.0354)	
common language	0.994***	0.555***		0.439***		0.541***	0.257***		0.284***	
	(0.0807)	(0.0512)		(0.0417)		(0.0832)	(0.0338)		(0.0610)	
colony	0.471***	0.264***		0.207***		0.272***	0.155***		0.117***	
	(0.0554)	(0.0325)		(0.0388)		(0.0570)	(0.0244)		(0.0434)	
FTA	0.335***	0.131***		0.204***		0.390***	0.00709		0.383***	
	(0.0710)	(0.0394)		(0.0513)		(0.0665)	(0.0305)		(0.0487)	
Time FE	Yes	Yes		Yes		Yes	Yes		Yes	
Constant	-9.390***	-5.342***		-4.048***		-10.95***	-4.000***		-6.945***	
	(0.545)	(0.361)		(0.420)		(0.481)	(0.316)		(0.370)	
Observations	14,404	14,404		14,404		14,448	14,448		14,448	
R-squared	0.600	0.539		0.362		0.716	0.539		0.650	

Note: Products are divided into homogeneous and differentiated goods, according to the Rauch classification.

Standard errors in parentheses are clustered by exporter-year.

* indicates significance levels: *** p<0.01, ** p<0.05, * p<0.1

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A Appendix

A.1 Proof: The relative wage of skilled labor

In the monopolistic framework, the firms have a constant markup, as shown in the pricing strategy (5). This feature implies that the variable costs (which are the payment to the workers) are proportional to the total revenue in this industry. As a result, the total net profit of the whole industry after paying variable costs ($\Pi^i = M \int_{\widehat{\theta}}^{\infty} \Pi(n, \theta)\, g(\theta)\, d\theta$ with M being the number of entrants) is also proportional to total revenue

$$\Pi^i = (1 - \rho)\, R. \tag{A.1}$$

with $\rho = \frac{\sigma - 1}{\sigma}$.

The management cost can be calculated by replacing the number of products per firm by (8) in the talent market clearing condition, which can be written as:

$$\begin{aligned} S &= M \int_{\widehat{\theta}}^{\infty} n^m(\theta)\, g(\theta)\, d\theta \\ &= M \int_{\widehat{\theta}}^{\infty} \frac{\pi(\theta)}{mw} n(\theta)\, g(\theta)\, d\theta \\ &= M \int_{\widehat{\theta}}^{\infty} \frac{\Pi(n, \theta)}{mw} g(\theta)\, d\theta \\ &= \frac{\Pi^i}{mw}. \end{aligned}$$

or:

$$wS = \frac{\Pi^i}{m}. \tag{A.2}$$

Since labor (skilled and unskilled) are the only factors in the economy, with the equations A.1 and A.2, we have:

$$\begin{aligned} R &= wS + L \\ &= \frac{\Pi^i}{m} + L \\ &= \frac{(1-\rho)\,R}{m} + L \end{aligned}$$

or

$$R = \frac{L}{1 - \frac{1-\rho}{m}}. \tag{A.3}$$

Then from (A.2) and (A.3) I calculate the wage of the managers (skilled labor):

$$w = \frac{(1-\rho)\,R}{mS} = \frac{(1-\rho)\,L}{(m-1+\rho)\,S}. \tag{A.4}$$

A.2 Proof: The cut-off rises with the relative skilled labor endowment

From (7) we have:

$$\begin{aligned} P^{-\frac{\rho}{1-\rho}} &= \int_{\widehat{\theta}} M_1 p^{-\frac{\rho}{1-\rho}}(\theta)\, n(\theta)\, g(\theta)\, d\theta \\ &= \int_{\widehat{\theta}} M_1 p^{-\frac{\rho}{1-\rho}}(\theta) \left(\frac{\pi(\theta)}{wm}\right)^{\frac{1}{m-1}} \gamma e^{-\gamma\theta} d\theta \\ &= \rho^{\frac{\rho m}{(1-\rho)(m-1)}} (1-\rho)^{\frac{1}{m-1}} R^{\frac{1}{m-1}} (mw)^{-\frac{1}{m-1}} P^{\frac{\rho}{(1-\rho)(m-1)}} M_1 \int_{\widehat{\theta}} \gamma e^{\left(\frac{\rho m}{(1-\rho)(m-1)} - \gamma\right)\theta} d\theta \\ &= \frac{\rho^{\frac{\rho m}{(1-\rho)(m-1)}} (1-\rho)^{\frac{1}{m-1}} R^{\frac{1}{m-1}} P^{\frac{\rho}{(1-\rho)(m-1)}} M_1}{(mw)^{\frac{1}{m-1}} \left(1 - \frac{\rho m}{\gamma(1-\rho)(m-1)}\right)} e^{\left(\frac{\rho m}{(1-\rho)(m-1)} - \gamma\right)\widehat{\theta}}, \end{aligned}$$

or

$$P = \frac{(mw)^{\frac{1-\rho}{\rho m}} \left(1 - \frac{\rho m}{\gamma(1-\rho)(m-1)}\right)^{\frac{(1-\rho)(m-1)}{\rho m}}}{\rho\,(1-\rho)^{\frac{1-\rho}{\rho m}} R^{\frac{1-\rho}{\rho m}} M_1^{\frac{(1-\rho)(m-1)}{\rho m}}} e^{\left(\frac{\gamma(1-\rho)(m-1)}{\rho m} - 1\right)\widehat{\theta}}. \tag{A.5}$$

The marginal firm is defined as a firm that produces one product $\left(n\left(\widehat{\theta}\right)=1\right)$ and whose net profit after management costs is just enough to cover the fixed cost F. Therefore the zero-profit cutoff condition is

$$\frac{m-1}{m}\pi_1(\widehat{\theta})=F. \tag{A.6}$$

$$\begin{aligned} F &= \frac{m-1}{m}\pi_1(\widehat{\theta})=\frac{m-1}{m}(1-\rho)P^{\frac{\rho}{1-\rho}}Rc(\widehat{\theta})^{-\frac{\rho}{1-\rho}} \\ &= \frac{m-1}{m}\frac{(1-\rho)\rho^{\frac{\rho}{1-\rho}}(mw)^{\frac{1}{m}}\left(1-\frac{\rho m}{\gamma(1-\rho)(m-1)}\right)^{\frac{m-1}{m}}R}{\rho(1-\rho)^{\frac{1}{m}}R^{\frac{1}{m}}M_1^{\frac{m-1}{m}}}e^{\frac{\gamma(m-1)}{m}\widehat{\theta}}. \end{aligned} \tag{A.7}$$

Finally the free-entry condition ensures that the entry cost equals to the expected profit of the firm:

$$f_e=\frac{\Pi_1-wS-M_2F}{M_1}=\frac{(1-\rho)\left(1-\frac{1}{m}\right)R-e^{-\gamma\widehat{\theta}}M_1F}{M_1},$$

with M_1 and M_2 being the firms that decide to enter the market and the firms that pay the fixed cost of production, respectively. Then we have:

$$M_1=\frac{(1-\rho)\left(1-\frac{1}{m}\right)R}{f_e+Fe^{-\gamma\widehat{\theta}}}. \tag{A.8}$$

Substituting $M_1$by (A.8) into (A.7) we have

$$\begin{aligned} F &\propto w^{\frac{1}{m}}e^{\frac{\gamma(m-1)}{m}\widehat{\theta}}\left(f_e+Fe^{-\gamma\widehat{\theta}}\right)^{\frac{m-1}{m}} \\ &\propto w^{\frac{1}{m}}\left(f_ee^{\gamma\widehat{\theta}}+F\right)^{\frac{m-1}{m}}, \end{aligned} \tag{A.9}$$

The formula above shows that when the wage of managers w is lower (due to an increase in the talent endowment), the cut-off $\widehat{\theta}$ is higher.

A.3 Proof: The price index falls as the relative skilled labor endowment rises

First I will prove that the price index falls when there is more talent. From (A.7), we have:

$$F\propto w^{\frac{1}{m}}e^{\frac{\gamma(m-1)}{m}\widehat{\theta}}\left(\frac{R}{M_1}\right)^{\frac{m-1}{m}}.$$

Using (A.5) we have:

$$
\begin{aligned}
F^{\frac{1-\rho}{\rho}} &\propto w^{\frac{1-\rho}{\rho m}} e^{\frac{\gamma(1-\rho)(m-1)}{\rho m}\widehat{\theta}} \left(\frac{R}{M_1}\right)^{\frac{(m-1)(1-\rho)}{m\rho}} \\
&\propto R^{\frac{1-\rho}{\rho}} P e^{\widehat{\theta}}.
\end{aligned}
$$

From (A.3), (A.9) and (A.4) we have:

$$
P \propto L^{-\frac{1-\rho}{\rho}} \left[\left(\frac{L}{S}\right)^{-\frac{1}{m-1}} - B\right]^{-\frac{1}{\gamma}} \tag{A.10}
$$

B here is a constant. This formula shows an increase in the talent endowment S reduces the price index. Therefore, the unskilled workers are the clear winner. Skilled labor, however, may be worse-off because their salaries are lower. Indeed, from (A.4) and (A.10) the real salaries of the managers are proportional to $L^{\frac{1-\rho}{\rho}} \left[\left(\frac{L}{S}\right)^{\gamma-\frac{1}{m-1}} - B\left(\frac{L}{S}\right)^{\gamma}\right]^{\frac{1}{\gamma}}$. Since $\gamma - \frac{1}{m-1} < \gamma$, this real salary increases with S (or decreases with $\frac{L}{S}$) when S is small enough (or $\frac{L}{S}$ big enough).

Table A.1: Summary Statistics by Country

Country	Ext. mar.	Int. mar.	Employment.	Skill workers	Country	Ext. mar.	Int. mar.	Employment	Skill workers
Argentina	0.250	0.016	12,169	28.80	Mexico	0.360	0.016	39,278	29.49
	(0.045)	(0.011)	(1,135)	(4.54)		(0.067)	(0.002)	(3,464)	(9.65)
Australia	0.416	0.027	9,603	74.83	Netherlands	0.770	0.047	8,101	44.18
	(0.043)	(0.005)	(995)	(12.35)		(0.048)	(0.003)	(475)	(5.67)
Austria	0.700	0.028	3,839	28.41	New Zealand	0.284	0.005	1,525	12.63
	(0.051)	(0.003)	(160)	(5.42)		(0.053)	(0.003)	(162)	(5.46)
Belgium	0.792	0.046	4,261	33.66	Norway	0.494	0.024	2,367	21.59
	(0.036)	(0.002)	(148)	(3.09)		(0.038)	(0.003)	(154)	(3.52)
Canada	0.557	0.023	1,313	116.64	Poland	0.437	0.036	14,639	57.65
	(0.094)	(0.003)	(13,610)	(21.98)		(0.211)	(0.013)	(685)	(3.54)
Chile	0.158	0.042	5,682	5.76	Rep. of Korea	0.568	0.047	21,911	151
	(0.030)	(0.028)	(530)	(0.289)		(0.061)	(0.006)	(1,251)	(53.36)
China	0.641	0.083	734,692	881.50	Romania	0.312	0.012	10,114	22.78
	(0.136)	(0.035)	(32125)	(349.80)		(0.098)	(0.003)	(817)	(4.48)
Czech Rep.	0.589	0.023	5,086	18.10	Singapore	0.446	0.026	2,268	18.52
	(0.087)	(0.003)	(127)	(7.07)		(0.042)	(0.003)	(365)	(7.39)
Denmark	0.618	0.023	2,771	25.67	Slovakia	0.380	0.013	2,109	10.89
	(0.047)	(0.002)	(85)	(7.15)		(0.088)	(0.003)	(61)	(1.70)
Estonia	0.215	0.007	606	3.36	Slovenia	0.370	0.006	924	5.18
	(0.061)	(0.003)	(29)	(0.53)		(0.085)	(0.001)	(31)	(1.28)
Finland	0.564	0.031	2,320	36.11	South Africa	0.424	0.012	12,385	17.26
	(0.044)	(0.008)	(142)	(6.99)		(0.028)	(0.002)	(904)	(2.24)
France	0.841	0.071	24,530	187.09	Spain	0.718	0.030	17,261	88.08
	(0.020)	(0.008)	(1116)	(28.83)		(0.066)	(0.003)	(2,432)	(29.76)
Germany	0.906	0.201	38,919	269.17	Sweden	0.720	0.045	4,326	46.36
	(0.012)	(0.010)	(971)	(29.28)		(0.035)	(0.004)	(165)	(6.68)
Hungary	0.453	0.017	4,132	15.08	Switzerland	0.725	0.026	4,191	24.69
	(0.070)	(0.004)	(90)	(3.31)		(0.037)	(0.004)	(206)	(1.77)
Iceland	0.091	0.006	158	1.92	Turkey	0.446	0.016	19,954	33.41
	(0.047)	(0.006)	(12)	(.53)		(0.126)	(0.002)	(1,046)	(15.83)
Italy	0.849	0.076	23,646	77.74	USA	0.829	0.161	139,194	1311.87
	(0.022)	(0.011)	(1230)	(13.61)		(0.023)	(0.020)	(6,250)	(121.32)
Japan	0.642	0.087	64,823	654.65	United Kingdom	0.839	0.064	30,064	203.53
	(0.023)	(0.014)	(1,405)	(20.96)		(0.023)	(0.012)	(1,211)	(41.02)

Notes: Skilled labor is the number of scientists in thousands (in full time equivalent). Emplolyment is also in thousands. Means and standard deviations are calculated over the period 1995-2010.

Table A.2: Skilled-Unskilled Labor Ratio

Variables	(1) export share	(2) ext. margin	(3) int. margin
ln(exporter skilled-unskilled ratio)	0.636***	0.139***	0.497***
	(0.0691)	(0.0392)	(0.0493)
ln(exporter employment)	1.094***	0.368***	0.725***
	(0.0254)	(0.0190)	(0.0158)
ln(exporter GDPPW)	1.103***	0.551***	0.552***
	(0.0973)	(0.0523)	(0.0593)
ln(importer GDP)	0.124***	0.202***	-0.0784***
	(0.0121)	(0.00866)	(0.00841)
ln(distance)	-0.738***	-0.368***	-0.371***
	(0.0284)	(0.0185)	(0.0205)
common border	0.443***	-0.227***	0.670***
	(0.0514)	(0.0324)	(0.0325)
common language	0.651***	0.292***	0.360***
	(0.0830)	(0.0350)	(0.0601)
colony	0.308***	0.152***	0.155***
	(0.0508)	(0.0245)	(0.0363)
FTA	0.365***	0.0244	0.341***
	(0.0627)	(0.0308)	(0.0482)
Time FE	Yes	Yes	Yes
Constant	-11.02***	-3.987***	-7.029***
	(0.479)	(0.322)	(0.347)
Observations	14,448	14,448	14,448
R-squared	0.717	0.547	0.646

Note: Lobor composition is captured by the skilled labor-unskilled labor ratio, and labor scale is measured by total employment.
Standard errors, clustered by exporter-year, in parentheses
* indicates significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.3: Alternative Measure of Skilled Labor

Variables	(1) export share	(2) ext. margin	(3) int. margin
ln(exporter skilled labor)	0.713***	0.193***	0.520***
	(0.0708)	(0.0384)	(0.0481)
ln(exporter unskilled labor)	0.425***	0.204***	0.222***
	(0.0714)	(0.0452)	(0.0463)
ln(exporter GDPPW)	1.106***	0.553***	0.553***
	(0.102)	(0.0546)	(0.0619)
ln(importer GDP)	0.114***	0.204***	-0.0900***
	(0.0123)	(0.00884)	(0.00841)
ln(distance)	-0.750***	-0.369***	-0.381***
	(0.0295)	(0.0192)	(0.0206)
common border	0.399***	-0.230***	0.629***
	(0.0558)	(0.0356)	(0.0333)
common language	0.652***	0.309***	0.343***
	(0.0926)	(0.0382)	(0.0666)
colony	0.393***	0.183***	0.210***
	(0.0542)	(0.0271)	(0.0385)
FTA	0.254***	-7.36e-05	0.254***
	(0.0655)	(0.0328)	(0.0499)
Time FE	Yes	Yes	Yes
Constant	-11.37***	-4.231***	-7.143***
	(0.479)	(0.312)	(0.345)
Observations	14,215	14,215	14,215
R-squared	0.717	0.551	0.638

Note: We use the personnel in research and development as an alternative measure forskilled labor. Standard errors clustered by exporter-year are in parentheses.
* indicates significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.4: Country Fixed Effects

Variables	(1) export	(2) ext. margin	(3) int. margin
ln(exporter skilled labor)	0.629***	0.142***	0.486***
	(0.0675)	(0.0382)	(0.0502)
ln(exporter unskilled labor)	0.499***	0.237***	0.262***
	(0.0679)	(0.0447)	(0.0487)
ln(exporter GDPPW)	1.111***	0.562***	0.549***
	(0.0973)	(0.0529)	(0.0587)
ln(importer GDP)	0.410***	0.825***	-0.415***
	(0.111)	(0.0934)	(0.0774)
ln(distance)	-1.043***	-0.433***	-0.610***
	(0.0364)	(0.0247)	(0.0310)
common border	0.290***	-0.285***	0.575***
	(0.0570)	(0.0394)	(0.0350)
common language	0.501***	0.145***	0.357***
	(0.0803)	(0.0344)	(0.0576)
colony	0.292***	0.175***	0.116***
	(0.0453)	(0.0245)	(0.0319)
FTA	0.308***	0.0413	0.266***
	(0.0591)	(0.0354)	(0.0532)
Time FE	Yes	Yes	Yes
Constant	-11.33***	-11.24***	-0.0847
	(1.415)	(1.290)	(0.980)
Observations	14,448	14,448	14,448
R-squared	0.771	0.585	0.730

Note: Importer country fixed effects are controlled.
Standard errors, clustered by exporter-year, are in parentheses
* indicates significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table A.5: All Sectors

Variables	(1) export share	(2) ext. margin	(3) int. margin
ln(exporter skilled labor)	0.577***	0.122***	0.455***
	(0.0637)	(0.0363)	(0.0523)
ln(exporter unskilled labor)	0.454***	0.234***	0.220***
	(0.0622)	(0.0420)	(0.0527)
ln(exporter GDPPW)	1.127***	0.559***	0.568***
	(0.0961)	(0.0510)	(0.0615)
ln(importer GDP)	0.114***	0.191***	-0.0768***
	(0.0106)	(0.00785)	(0.00796)
ln(distance)	-0.692***	-0.359***	-0.332***
	(0.0263)	(0.0174)	(0.0219)
common border	0.501***	-0.208***	0.710***
	(0.0493)	(0.0311)	(0.0335)
common language	0.658***	0.289***	0.369***
	(0.0778)	(0.0340)	(0.0551)
colony	0.345***	0.155***	0.190***
	(0.0493)	(0.0240)	(0.0352)
FTA	0.335***	0.0252	0.309***
	(0.0577)	(0.0290)	(0.0503)
Time FE	Yes	Yes	Yes
Constant	-10.41***	-3.810***	-6.595***
	(0.455)	(0.311)	(0.391)
Observations	14,452	14,452	14,452
R-squared	0.723	0.564	0.632

Note: Standard errors in parentheses are clustered by exporter-year.
* indicates significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.6: PPML and Two-Stage Estimators

	PPML			Two Stage	
	(1)	(2)	(3)	(4)	(5)
				1-stage Probit	2-stage OLS
Variables	export	ext. margin	int. margin	exp. dummy	exp. value
ln(exp skilled labor)	0.560***	0.104***	0.510***	0.0403***	0.238***
	(0.0541)	(0.0238)	(0.0413)	(0.000866)	(0.00821)
ln(exp unskilled labor)	0.209***	0.117***	0.119***	0.0585***	0.328***
	(0.0571)	(0.0246)	(0.0425)	(0.000841)	(0.00922)
ln(exporter GDPPW)	0.431***	0.305***	0.253***	0.122***	0.313***
	(0.0670)	(0.0346)	(0.0468)	(0.00112)	(0.0150)
ln(importer GDP)	0.0314***	0.112***	-0.0481***	0.0629***	0.444***
	(0.0106)	(0.00382)	(0.0104)	(0.000289)	(0.00647)
ln(distance)	-0.352***	-0.199***	-0.235***	-0.100***	-0.412***
	(0.0251)	(0.00879)	(0.0217)	(0.000574)	(0.0104)
common border	0.534***	-0.0706***	0.618***	-0.0244***	0.966***
	(0.0466)	(0.0185)	(0.0439)	(0.00267)	(0.0141)
common language	0.107***	0.0933***	0.108***	0.0331***	
	(0.0342)	(0.0225)	(0.0336)	(0.00180)	
colony	0.347***	0.167***	0.229***	0.115***	
	(0.0377)	(0.0164)	(0.0375)	(0.00190)	
FTA	0.688***	0.102***	0.540***	0.0185***	0.179***
	(0.0685)	(0.0158)	(0.0606)	(0.00126)	(0.0103)
$\widehat{\eta}^*$					6.421***
					(0.622)
$\widehat{z}^*$					5.059***
					(0.395)
$(\widehat{z}^*)^2$					-0.278***
					(0.0841)
$(\widehat{z}^*)^3$					-0.156***
					(0.00474)
Time FE	Yes	Yes	Yes	Yes	Yes
Constant	-9.885***	-2.697***	-7.810***	0.7869	-1.517***
	(0.422)	(0.177)	(0.361)		(0.500)
Observations	15,062	15,062	15,062	1,114,588	824,553

Note: Result in columns (1) - (3) is estimated by PPML estimator, and that in columns (4) - (5) is estimated the two-stage estimation procedure in Helpman et al. (2008). $\widehat{\eta}^*$ is the invese Mills ratio and $\widehat{z}^* = \Phi^{-1}(\widehat{\rho})$, defined as in Helpman et al. (2008). Coefficients of the first-stage estimation are the marginal effects of explanatory variables at their means. The excluded variables in the second stage are common language and colonial history. Standard errors clustered by exporter-year are in parentheses. * indicates significance levels: *** p<0.01, ** p<0.05, * p<0.1