Explaining Export Varieties:
The Unexplored Role of Comparative Advantage

Isao Kamata
Department of Economics
University of Michigan

Na Yang
Department of Economics
Michigan State University

(PRELIMINARY DRAFT)
March 5, 2007

Abstract

In this paper we examine how factor proportions determine the extensive margin of trade. To explain the determinants of the number of export varieties, we develop a multi-sector trade model with heterogeneous firms. A semi-Heckscher-Ohlin prediction for export varieties emerges from the model: countries export more varieties in the industries that more intensively use their abundant resources as input factors. Empirical tests confirm that more varieties are exported in industries in which the exporter has the comparative advantage. The paper provides both a theoretical foundation and empirical evidence for the importance of factor proportions in explaining the pattern of exports of product varieties.

---

1. Introduction

The recent trade literature on export/import variety has grown rapidly. The seminal work by Krugman (1979) first brought product variety into focus through his monopolistic competition model of international trade. Although the increases in product variety have long been known as an important source of gains from trade, empirical studies on the significance of the growth of product varieties, or "extensive margin," in international trade are relatively new. For example, Kehoe and Ruhl (2003) show that the trade of new goods (extensive margin) explains a larger proportion of the growth of trade following trade liberalization than the increase in the volume of previously-traded goods (intensive margin) does. A series of empirical studies by Funke and Ruhwedel (2001a, 2001b, 2005) indicates that the growth of product variety in exports has a significant effect on the economic growth in various countries and regions. Feenstra and Kee (2004) also provide evidence supporting the positive impact of export variety on productivity growth for a large sample of developed and developing countries. Broda and Weinstein (2004) empirically show how much the increase in imported variety mattered for the welfare of United States. Their results suggest that the U.S. welfare has increased by 3% due to the increase in the extensive margin of its import.[1]

Although this previous research has examined the cross-country patterns of product varieties in international trade, few studies have explored the trade patterns of product varieties

---

[1] Another important branch of this recent literature focuses on the quality differentiation of exported goods. Hallak (2006) attemps to identify the effect of product quality on the direction of international trade. The paper empirically investigates whether importers at a higher income level tend to buy more varieties of products from exporters with higher income as well because they tend to produce higher quality products. In a related paper Hallak applies his framework of product quality and uses sectoral level data to provide evidence for the Linder hypothesis according to which international trade is more intensive between countries with similar income levels than those that differ (Hallak, 2005). Choi, Hummels and Xiang (2006) explore the effect of income distribution on varieties in trade, whose key insight is that consumers with higher income will buy goods with higher quality rather than buy greater quantities of goods that vary in the quality dimension.

across industries. In this paper we examine whether the traditional theory of comparative advantage explains the cross-industry patterns of product varieties in the exports of countries. Our approach also considers the modern framework of firm-level heterogeneity. We first construct a theoretical model in which countries vary in factor endowment, industries differ in factor intensity, and firms belonging to the same industry are heterogeneous in productivity. This model is used to derive a prediction that relates product varieties in a country's exports to the degree of relative factor intensity of industries. To empirically test the prediction we employ the data on the U.S. imports in 1990 from Feenstra, Romalis, and Schott (2002), which finely classifies imported commodities according to the 10-digit Harmonization System (HS). We also use the data on input factor use in various industries from the 1992 U.S. Census of Manufactures, as well as the data on factor abundance of a number of countries from Hall and Jones (1999). The empirical tests support our semi-Heckscher-Ohlin prediction for product varieties in trade; that is, countries export more varieties in the industries that more intensively use their abundant resources as input factors.

This paper contributes to the literature by extending the theoretical model of Bernard, Redding and Schott (2007), which integrates a heterogeneous firm model by Melitz (2003) into the 2-country, 2-factor and 2-sector framework, to a multi-industry setting as Dornbusch, Fischer and Samuelson (1980) and Romalis (2004). The paper also goes empirically further than others by explicitly linking the factor endowment and industry-wise factor use to the number of varieties in their exports.

The paper proceeds as follows. Section 2 develops the theoretical model in order to provide an implication for the relationship between factor proportions and export variety. Section 3 proposes an empirical approach to test the theoretical prediction, and Section 4 describes the

data. The results of the empirical tests are presented in Section 4. Section 5 concludes.

2. The Model

This paper adopts the monopolistic competition model in which consumers have an identical "love of variety" preference and firms that are heterogeneous in productivity need to incur fixed costs for market entry and export. The model also features a framework of comparative advantage in which countries differ in endowment and thus the exposure to trade leads to inter-firm and inter-industry reallocations of resources toward more productive firms and industries using favorable factor more intensively.

We consider a world with two countries, Home (*H*) and Foreign (*F*); two factors, skilled labor (*S*) and unskilled labor (*U*); multiple industries; and a continuum of heterogeneous firms. Countries share the same production technology for each industry, but differ in factor endowments. Home is relatively abundant in skilled labor, and Foreign is relatively abundant in unskilled labor; that is, $\dfrac{S^H}{U^H} > \dfrac{S^F}{U^F}$.

Consumption:

The representative consumer derives her utility from the consumption of the output from all $N > 2$ industries. Each industry consists of a large number of differentiated products or "varieties", each of which is uniquely produced by a single firm. In what follows we use i to index industries and ω for firms. The upper-tier utility function from the consumption of a bundle of product varieties of all of N industries takes the following Cobb-Douglas form:

$$U = C_1^{\alpha_1} C_2^{\alpha_2} .... C_N^{\alpha_N}, \quad \sum_{i=1}^{N} \alpha_i = 1 \tag{2.1}$$

3

where C_i represents the consumption index for Industry $i=1,\ldots,N$. The representative consumer consume all the available product varieties in each industry, and the industry-wise consumption index C_i takes the following CES (or Dixit-Stiglitz) forms:

$$C_i = [\int_{\omega \in \Omega_i} q_\omega{}^\rho d\omega]^{\frac{1}{\rho}} \tag{2.2}$$

where Ω_i denotes a set of available varieties in Industry i, and q_ω represents the quantity of each variety produced. Accordingly, the price index P_i over individual varieties of products in Industry i is defined as

$$P_i = [\int_{\omega \in \Omega_i} p_{i,\omega}{}^{1-\sigma} d\omega]^{\frac{1}{1-\sigma}} \tag{2.3}$$

where $\sigma = \dfrac{1}{1-\rho} > 1$ is the constant elasticity of substitution across varieties.

Production:

In each industry there is a continuum of firms, each of which produces a unique variety of products. Following Krugman (1979) and Romalis (2004), we model the total production cost of each variety as a combination of two portions: fixed costs and variable costs. The fixed costs are the same for all firms in the same industry within a country,[2] but the variable costs vary across firms according to the difference in their productivities $\phi \in (0, \infty)$. Hence, the cost function for Firm ω in Industry i in Country λ is:

$$\Gamma_{i,\omega}^\lambda = \left[f_i + \frac{q_{i,\omega}}{\phi_{i,\omega}} \right] \cdot (s^\lambda)^{\beta_i} (w^\lambda)^{1-\beta_i}, \quad 0 < \beta_1 < \beta_2 \ldots < \beta_{N-1} < \beta_N < 1 \tag{2.4}$$

---

[2] As shown in Equation (2.4), since the fixed costs also depend on the prices of two production factors,

4

where s is the wage for skilled labor, w is the wage for unskilled labor, the superscript $\lambda = H$ or F denotes the country (Home or Foreign). The industries are ranked according to the skilled-labor intensity in production (β_i), such that the industry indexed with a large number for i is more skilled-labor intensive. Within the same industry, the intensity of factor use does not differ across countries or across firms.

To maximize its profit, each firm sets the price of its own product variety for domestic sale equal to the constant markup over the marginal cost of production.

$$p_{i,\omega}(\phi_{i,\omega}) = \frac{(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}}{\rho\phi_{i,\omega}} \tag{2.5}$$

With this optimal pricing, the domestic revenue of each firm takes the following form:

$$r_{i,\omega}^\lambda(\phi_{i,\omega}) = \alpha_i Y^\lambda \left(\frac{(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}}{\rho\phi_{i,\omega}P_i^\lambda}\right)^{1-\sigma} \tag{2.6}$$

where Y^λ is the total income of Country $\lambda \in \{H,F\}$. The revenue of each firm increases with productivity $\phi_{i,\omega}$, the aggregate income of the country Y^λ, and the industry price index P_i. The profit of each firm, which equals the revenue minus fixed and variable costs of production, is expressed as follows:

$$\pi_{i,\omega}^\lambda(\phi_{i,\omega}) = \frac{r_{i,\omega}^\lambda(\phi_{i,\omega})}{\sigma} - f_i(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i} \tag{2.7}$$

Entry:

To enter the domestic market, each firm needs to bear a sunk entry cost. Firms discover their own productivity after the entry. The productivity parameter ϕ is randomly drawn from a

---

the fixed cost can be different between the two countries due to the difference in factor prices.

distribution $G(\phi)$. The entry cost also depends on the prices of the two input factors, and takes the following form:

$$f_{ei}(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}, \quad f_{ei} > 0 \tag{2.8}$$

In other words, the industry factor intensity commonly affects the fixed and variable production costs, as well as the sunk entry cost. The market in each industry is monopolistically competitive, and thus in equilibrium all firms that produce and sell their own products earn zero profit. The minimum productivity requirement, or the "productivity cutoff," for domestic production is thus determined by the following zero-profit condition:

$$r_i^\lambda(\phi_i^{*\lambda}) = \sigma f_i(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i} \tag{2.9}$$

In Country λ and Industry i, all the firms whose productivity is higher than or equal to $\phi_i^{*\lambda}$ will continue producing in the domestic market, while the firms with productivity lower than this cutoff level will exit.

The value of each firm is determined as the present discount value of the future profit flows. With $\delta < 1$ of some positive probability of "death" in each period,[3] the value of the firm is expressed as follows:

$$v_{i,\omega}(\phi_{i,\omega}) = \max\{0, \sum_{t=0}^{\infty}(1-\delta)^t \pi_{i,\omega}(\phi_{i,\omega})\} = \max\{0, \frac{\pi_{i,\omega}(\phi_{i,\omega})}{\delta}\} \tag{2.10}$$

In the long run equilibrium, the expected value of entry, $V_{i,\omega}$, will equal the sunk entry cost for each firm in each industry. Since the expected value of entry is the *ex post* expected value of the firm (future profit stream) conditional on the *ex ante* probability of successful entry, we obtain the following free-entry condition:

---

[3] This can be interpreted as a risk that the firm may be hit by a negative and idiosyncratic shock and forced to be closed in business.

$$V_{i,\omega}^{\lambda} = [1 - G(\phi_i^{*\lambda})]\frac{\overline{\pi}_i^{\lambda}(\phi)}{\delta} = f_{ei}(s^{\lambda})^{\beta_i}(w^{\lambda})^{1-\beta_i} \qquad (2.11)$$

where $\overline{\pi}_i^{\lambda}(\phi)$ represents the per-period expected future profit for the firm successfully entering

into the market in Industry i. That is, $\overline{\pi}_i^{\lambda}(\phi) = \pi_i(\overline{\phi}_i^{\lambda})$ where $\overline{\phi}_i^{\lambda}$ is the average productivity

of the successful entrees in the industry.[4]

In the case of closed economy, by combining the zero profit condition (2.9) and the free

entry condition (2.11), we can derive the following equation to determine the cutoff-level

productivity $\phi_i^{*\lambda}$:

$$\frac{f_i}{\delta}\int_{\phi_i^{*\lambda}}^{\infty}[(\frac{\phi}{\phi_i^{*\lambda}})^{\sigma-1} - 1]g(\phi)d\phi = f_{ei} \qquad (2.12)$$

where $g(\cdot)$ is the density function of productivity ϕ.[5] The left-hand side of Equation (2.12)

monotonically decreases as the value of $\phi_i^{*\lambda}$ increases, and thus a unique value of $\phi_i^{*\lambda}$ is

identified as the right-hand side of the equation is constant.

Export:

The firms in each country can also export their products to another country by paying

additional costs. In order for each firm to sell its product variety in the overseas market, the firm

must incur fixed costs for export, which depends upon the domestic factor prices and industry

---

[4] The average productivity of the successfully entering firms is determined by the ex-post distribution of
the productivities defined with the zero-profit cutoff productivity level: i.e.;

$$\overline{\phi}_i^{\lambda} = \overline{\phi}(\phi_i^{*\lambda}) = \left[\frac{1}{1 - G(\phi_i^{*\lambda})}\int_{\phi_i^{*\lambda}}^{\infty}\phi^{\sigma-1}g(\phi)d\phi\right]^{\frac{1}{\sigma-1}}$$

where $g(.) = G'(.)$ is a density function of productivity φ.
[5] See Appendix for the derivation of Equation (2.12).

factor intensity[6] as the domestic production fixed costs and sunk entry cost do. In addition, international trade requires variable cost for shipping in the conventional "iceberg" form; that is, only $1/\tau_i$ ($\tau_i > 1$) of the shipped quantity of products reaches the other country. This variable cost is assumed to be symmetric between the two countries.

The optimal price of the product of Firm ω in Industry i in Country λ to be sold in the overseas market, $p_{ix,\omega}^{\lambda}$, is equal to the constant markup over the marginal production cost, but the marginal cost for foreign sales must take into account the variable trade cost. That is;

$$p_{ix,\omega}^{\lambda}(\phi) \equiv \tau_i \cdot p_{i,\omega}^{\lambda}(\phi) = \frac{\tau_i (s^{\lambda})^{\beta_i} (w^{\lambda})^{1-\beta_i}}{\rho \phi_{i,\omega}} \tag{2.13}$$

Firms that successfully enter the domestic market will either produce to serve only the domestic market, or become exporters that serve both domestic and foreign markets, depending on their productivity. Therefore, the total revenue of each firm is now as follows:

$$r_{i,\omega,total}^{\lambda}(\phi) = r_{i,\omega}^{\lambda}(\phi) \qquad \text{if the firm serves only the domestic market;}$$

$$r_{i,\omega,total}^{\lambda}(\phi) = r_{i,\omega}^{\lambda}(\phi) + r_{ix,\omega}^{\lambda}(\phi) \qquad \text{if the firm also exports.}$$

As in the closed economy case, the zero-profit condition and the free-entry condition jointly identified the productivity cuttoff that that divides the firms into domestic producers and exporters. The profit of each firm now consists of two parts:

$$\pi_{i,\omega,total}^{\lambda}(\phi) = \pi_{i,\omega}^{\lambda}(\phi) + \max\{0, \pi_{ix,\omega}^{\lambda}(\phi)\} \tag{2.14}$$

where $\pi_{i,\omega}^{\lambda}(\phi) = \dfrac{r_{i,\omega}^{\lambda}(\phi)}{\sigma} - f_i (s^{\lambda})^{\beta_i} (w^{\lambda})^{1-\beta_i}$;

$$\pi_{ix,\omega}^{\lambda}(\phi) = \frac{r_{ix,\omega}^{\lambda}(\phi)}{\sigma} - f_{ix} (s^{\lambda})^{\beta_i} (w^{\lambda})^{1-\beta_i}.$$

---

[6] Specifically, the fixed costs for exporting takes the form of $f_{ix}(s^{\lambda})^{\beta_i}(w^{\lambda})^{1-\beta_i}, f_{ix} > 0$.

Accordingly, the zero-profit condition is two-fold, which consists of the following two equations:

Zero-profit condition for domestic production, which involves the domestic producer productivity cutoff $\phi_i^{*\lambda}$:

$$r_i^\lambda(\phi_i^{*\lambda}) = \sigma f_i(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i} \tag{2.15}$$

Zero-profit condition for export, which involves the exporter productivity cutoff $\phi_{ix}^{*\lambda}$:

$$r_{ix}^\lambda(\phi_{ix}^{*\lambda}) = \sigma f_{ix}(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i} \tag{2.16}$$

Equations (2.6), (2.15) and (2.16) jointly determine the relationship between the two cutoffs $\phi_i^{*\lambda}$ and $\phi_{ix}^{*\lambda}$ for each country $\lambda \in \{H, F\}$, such as follows:

$$\phi_{ix}^{*H} = \Lambda_i^H \cdot \phi_i^{*H} \tag{2.17}$$

$$\phi_{ix}^{*F} = \Lambda_i^F \cdot \phi_i^{*F} \tag{2.18}$$

where $\Lambda_i^H = \tau_i(\frac{P_i^H}{P_i^F})(\frac{Y^H}{Y^F} \cdot \frac{f_{ix}}{f_i})^{\frac{1}{\sigma-1}}$ and $\Lambda_i^F = \tau_i(\frac{P_i^F}{P_i^H})(\frac{Y^F}{Y^H} \cdot \frac{f_{ix}}{f_i})^{\frac{1}{\sigma-1}}$,[7] and P_i^λ is the industry

price index in each country, which is in general different across countries due to the trade costs.[8] Empirical studies have shown that not all domestically active firms are engaged in export, and also that exporting firms tend to be larger (or more productive) than non-exporters. This is thus relevant to focus our analysis to the case where the productivity cutoff for export is higher than that for domestic production: i.e., $\phi_{ix}^{*\lambda} > \phi_i^{*\lambda}$, or $\Lambda_i^\lambda > 1$. This would be the case when the fixed costs for export is fairly higher than the fixed costs for domestic production ($f_{ix} > f_i$), and/or the variable trade cost (τ_i) is fairly large. In this case, only a portion of firms that successfully enter the domestic market can export. Of all the firms in a country that draw a random productivity for

---

[7] See Appendix for the derivation of Equations (2.17) and (2.19).

the sunk entry cost, a fraction of $G(\phi_i^{*\lambda})$ will exit because their revenues can not cover the fixed

costs for domestic production. A fraction $G(\phi_{ix}^{*\lambda}) - G(\phi_i^{*\lambda})$ of the firms will serve only the

domestic market in Country λ because they will not be able to cover the higher fixed costs for

export. Only the remaining firms (the fraction of $1 - G(\phi_{ix}^{*\lambda})$), which are the most productive,

will be exporters.

The free-entry condition is also modified because now the value of the firm is the sum of

two parts: the *ex post* expected future profit stream from domestic production; and the expected

future profit from the export market multiplied by the probability of being an exporter

conditional on that the firm successfully enters the domestic market. That is;

$$v_{i,\omega}^{\lambda}(\phi) = \max\{0, \frac{\overline{\pi}_i^{\lambda}(\phi)}{\delta}\} + \chi_i^{\lambda} \cdot \max\{0, \frac{\overline{\pi}_{ix}^{\lambda}(\phi)}{\delta}\} \tag{2.19}$$

where $\chi_i^{\lambda} \equiv \dfrac{1 - G(\phi_{ix}^{*\lambda})}{1 - G(\phi_i^{*\lambda})}$, and $\overline{\pi}_i^{\lambda}(\phi) = \pi_i^{\lambda}(\overline{\phi}_i^{\lambda})$ and $\overline{\pi}_{ix}^{\lambda}(\phi) = \pi_{ix}^{\lambda}(\overline{\phi}_{ix}^{\lambda})$ are the average profit of

the firms that domestic produce and the average profit of the exporters in Country $\lambda = H$ or F,

respectively, which are determined by the average productivity levels of those groups of firms

($\overline{\phi}_i^{\lambda}$ and $\overline{\phi}_{ix}^{\lambda}$).[9]

Hence, the zero-profit condition with costly international trade is that the *ex ante* expected

value of entry, which is the value of the firm multiplied by the *ex ante* probability of successful

---

[8] The form of price index under the costly trade is shown later in this section.
[9] The ex-post average productivity level of domestically-producing firms is defined with the cutoff
productivity for domestic producers in each country, such as follows:

$$\overline{\phi}_i^{\lambda}(\phi_i^{*\lambda}) = [\frac{1}{1 - G(\phi_i^{*\lambda})} \int_{\phi_i^{*\lambda}}^{\infty} \phi^{\sigma-1} g(\phi) d\phi]^{\frac{1}{\sigma-1}}$$

Similarly, the average productivity level of exporters is defined with the cutoff productivity for export:

$$\overline{\phi}_{ix}^{\lambda}(\phi_{ix}^{*\lambda}) = [\frac{1}{1 - G(\phi_{ix}^{*\lambda})} \int_{\phi_{ix}^{*\lambda}}^{\infty} \phi^{\sigma-1} g(\phi) d\phi]^{\frac{1}{\sigma-1}}$$

entry, equals the sunk entry cost:

$$V_i^\lambda = \frac{1 - G(\phi_i^{*\lambda})}{\delta}[\bar{\pi}_i^\lambda(\phi) + \chi_i^\lambda \bar{\pi}_{ix}^\lambda(\phi)] = f_{ei}(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i} \qquad (2.20)$$

Combining this free-entry condition with the zero-profit condition (2.15) and (2.16) yields the

following equation[10]:

$$\frac{f_i}{\delta}\int_{\phi_i^{*\lambda}}^{\infty}[(\frac{\phi}{\phi_i^{*\lambda}})^{\sigma-1} - 1]g(\phi)d\phi + \frac{f_{ix}}{\delta}\int_{\phi_{ix}^{*\lambda}}^{\infty}[(\frac{\phi}{\phi_{ix}^{*\lambda}})^{\sigma-1} - 1]g(\phi)d\phi = f_{ei} \qquad (2.21)$$

The first term of the left-hand side of this equation is monotonically decreasing in $\phi_i^{*\lambda}$, and the

second term is monotonically decreasing in $\phi_{ix}^{*\lambda}$. Since $\phi_{ix}^{*\lambda}$ increases as $\phi_i^{*\lambda}$ increases (from

Equations (2.17) and (2.18), $\phi_{ix}^{*\lambda} = \Lambda_i^\lambda \cdot \phi_i^{*\lambda}, \Lambda_i^\lambda > 1$), the whole of the left-hand side of the

equation monotonically decreases as the value of $\phi_i^{*\lambda}$ increases. With the right-hand side being

constant, this Equation (2.21) solves for the unique value of the domestic production cutoff $\phi_i^{*\lambda}$

and accordingly the export cutoff $\phi_{ix}^{*\lambda}$.

Factor Prices:

In our model, unlike the case of free and frictionless trade, the factor prices will not be

equalized between the two countries, due to the fixed and variable costs of trade. Instead, under

costly trade the equilibrium relative prices of the two production factors will fall between the

autarky level and the level under free trade. In autarky, the wage for skilled labor relative to that

for the unskilled is lower in the skill-abundant Home. Opening the country to costly trade will

result in an increase in the reward for the abundant factor in each country (i.e., *s* will rise in the

---

[10] The derivation of Equation (2.21) is similar to the closed-economy version, Equation (2.12), which is
shown in Appendix.

Home and w will rise in the Foreign), which will decrease the difference in the relative factor

price between the two countries, while the factor prices will not become equal. That is;

$$\left(\frac{\frac{s^H}{w^H}}{\frac{s^F}{w^F}} \right)^A < \left(\frac{\frac{s^H}{w^H}}{\frac{s^F}{w^F}} \right)^{CT} < \left(\frac{\frac{s^H}{w^H}}{\frac{s^F}{w^F}} \right)^{FT}$$

where *A, CT,* and *FT* indicate autarky, costly trade, and free trade, respectively.[11] The right-hand

side (the third term) of the inequality above will be equal to one under free trade with factor price

equalization (FPE).

    This difference in equilibrium relative factor reward implies that in this framework of two

countries, two factors, multiple industries and heterogeneous firms, opening from an autarkic

state to costly trade will have different impacts on each of the two countries that are asymmetric

in factor endowment, as well as on each of the industries that are different in factor intensity. The

profit derived from exporting will also vary across countries, across industries, and across

heterogeneous firms.

Mass of Firms:

    Now we examine how many firms in each country will export to the overseas market in

each industry. In our model the number of firms is measured by the size of the "mass" of the

continuum of firms. M_i^{λ} denotes the mass of the firms serving only domestic market, and M_{ix}^{λ}

denotes the mass of the exporting firms, for each country $\lambda \in \{H, F\}$. Only a portion of the

domestically-producing firms will be exporters, and that fraction is determined by the two cutoff

productivity levels: the one for domestic production and that for export, which is shown as

---

[11] See Appendix for more rigorous demonstration for the equilibrium factor prices.

follows:

$$M_{ix}^{\lambda} = \chi_i^{\lambda} \cdot M_i^{\lambda} \tag{2.22}$$

where $\chi_i^{\lambda} \equiv \dfrac{1 - G(\phi_{ix}^{*\lambda})}{1 - G(\phi_i^{*\lambda})} < 1$ is as defined previously. Note that $M_i^{\lambda} = \dfrac{R_i^{\lambda}}{\overline{r}_i^{\lambda}(\phi)}$, where R_i^{λ} is the

total revenue *from domestic sales* in Industry i in Country λ; and $\overline{r}_i^{\lambda}(\phi)$ is the average *domestic*

revenue of the active firms (domestic producers and exporters) in the industry in the country.

Our concern is with the relative size of the exporter mass between the two countries in each

industry, $\dfrac{M_{ix}^{H}}{M_{ix}^{F}}$, and how it will differ across industries in relation to the factor intensities of the

industries. To examine it, consider the price indexes of Industry i in the two countries in the

costly-trade equilibrium, which are composed of the number and average price of

domestically-produced products, as well as those of imported products from the other country:

$$P_i^{H} = [M_i^{H}(p_i^{H}(\overline{\phi}_i^{H}))^{1-\sigma} + \chi_i^{F} \cdot M_i^{F}(\tau_i \cdot p_i^{F}(\overline{\phi}_{ix}^{F}))^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{2.23}$$

$$P_i^{F} = [M_i^{F}(p_i^{F}(\overline{\phi}_i^{F}))^{1-\sigma} + \chi_i^{H} \cdot M_i^{H}(\tau_i \cdot p_i^{H}(\overline{\phi}_{ix}^{H}))^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{2.24}$$

Dividing Equation (2.23) by (2.24) in both sides yields the following equation:

$$\left(\frac{P_i^{H}}{P_i^{F}}\right)^{1-\sigma} = \frac{M_i^{H}(p_i^{H}(\overline{\phi}_i^{H}))^{1-\sigma} + \chi_i^{F} \cdot M_i^{F} \cdot \tau_i^{1-\sigma}(p_i^{F}(\overline{\phi}_{ix}^{F}))^{1-\sigma}}{M_i^{F}(p_i^{F}(\overline{\phi}_i^{F}))^{1-\sigma} + \chi_i^{H} \cdot M_i^{H} \cdot \tau_i^{1-\sigma}(p_i^{H}(\overline{\phi}_{ix}^{H}))^{1-\sigma}} \tag{2.25}$$

By rearranging this equation, we can derive the following expression for the ratio of the masses

of active firms in the two countries:

$$\frac{M_i^{H}}{M_i^{F}} = \frac{\left(\frac{P_i^{H}}{P_i^{F}}\right)^{1-\sigma}(p_i^{F}(\overline{\phi}_i^{F}))^{1-\sigma} - \chi_i^{F} \cdot \tau_i^{1-\sigma}(p_i^{F}(\overline{\phi}_{ix}^{F}))^{1-\sigma}}{(p_i^{H}(\overline{\phi}_i^{H}))^{1-\sigma} - \left(\frac{P_i^{H}}{P_i^{F}}\right)^{1-\sigma} \cdot \chi_i^{H} \cdot \tau_i^{1-\sigma}(p_i^{H}(\overline{\phi}_{ix}^{H}))^{1-\sigma}} \tag{2.26}$$

Combining Equations (2.22) and (2.26) and rearranging further yields the following expression

13

for the ratio of the exporter masses in the two countries[12]:

$$\frac{M_{ix}^{H}}{M_{ix}^{F}} = \frac{\chi_{i}^{H}}{\chi_{i}^{F}} \cdot \frac{[(\frac{Y^{H}}{Y^{F}})(\frac{f_{i}}{f_{ix}})(\frac{\phi_{ix}^{*F}}{\phi_{i}^{*F}})^{\sigma-1} - \chi_{i}^{F}(\frac{\bar{\phi}_{ix}^{F}}{\bar{\phi}_{i}^{F}})^{\sigma-1}]}{\tau_{i}^{\sigma-1}[1 - \chi_{i}^{H}(\frac{Y^{H}}{Y^{F}})(\frac{f_{ix}}{f_{i}})(\frac{\phi_{i}^{*H}}{\phi_{ix}^{*H}})^{\sigma-1}(\frac{\bar{\phi}_{ix}^{H}}{\bar{\phi}_{i}^{H}})^{\sigma-1}]} \cdot \left(\frac{p_{i}^{H}(\bar{\phi}_{i}^{H})}{p_{i}^{F}(\bar{\phi}_{i}^{F})}\right)^{\sigma-1} \quad (2.27)$$

That is, the relative size of the exporter mass in each industry depends upon the ratio of (or the

"gap" between) the two productivity cutoffs ($\phi_{ix}^{*\lambda} / \phi_{i}^{*\lambda}$) and the ratio of the average productivity

of exporters to that of domestic producers ($\bar{\phi}_{ix}^{\lambda} / \bar{\phi}_{i}^{\lambda}$), as well as the ratio of the average price of

domestically-supplied products between the two countries ($p_{i}^{H}(\bar{\phi}_{i}^{H}) / p_{i}^{F}(\bar{\phi}_{i}^{F})$).

For the purpose of the cross-industry comparison of this relative exporter mass, we

introduce the following assumption:

Assumption 1: $f_{i} = f_{j}, f_{ix} = f_{jx}$, and $\tau_{i} = \tau_{j}$ for $i \neq j$

This assumption implies that both fixed costs for production and fixed costs for export, *adjusted*

for factor price difference, are identical across industries, and also that the "iceberg" shipping

cost (variable cost) for export is the same for all industries.

By examining Equation (2.27) across industries with Assumption 1, we derive the

following proposition regarding the relative size of the masses of exporters between the two

countries.

Proposition 1: The mass of exporters in a country relative to that in the other will

be larger in an industry that uses a factor with which the country is relatively better

endowed more intensively (i.e., comparative advantage industry). That is, for the

relatively skilled-labor abundant Home, $\dfrac{M_{i}^{H}}{M_{i}^{F}} > \dfrac{M_{j}^{H}}{M_{j}^{F}}$ *for more skill-intensive*

---

[12] See Appendix for the derivation of Equation (2.27).

Industry i than j (i.e., $\beta_i > \beta_j$).

Proof: See Appendix.

This proposition may be weaker than how it states since the cross-country comparison of the

relative size of exporter masses in the two countries might leave ambiguity, as mentioned in

Appendix.[13] The intuition of this possible ambiguity is as follows. First, note that in the

framework of our model, international trade has two effects. (i) *Selection effect*: international

trade will expose firms to potential access to overseas market, which is an additional source of

their revenues. The potential of the additional revenue is larger in industries in which the country

has the comparative advantage, and thus in the comparative advantage industries the demand for

production factors will increase. This will raise the price of the factor that is used more

intensively in those industries; i.e., the factor that is more abundant in that country. The rise in

the relative price of the more favorable factor will increase the production cost in the

comparative advantage industries, and as a result firms with relatively low productivity will need

to exit. This will reduce the size of the active firm mass (domestic producers plus exporters) in

the comparative advantage industries relative to that in comparative disadvantage industries. (ii)

Export comparative advantage effect: Once a firm successfully enters the domestic market with

sufficiently high productivity, however, the chance to become an exporter will be larger in the

comparative advantage industries since in those industries firms are more competitive against

foreign producers due to the advantage in production cost. Therefore, the fraction of the exporter

mass out of the mass of active firms (domestic producers) will be larger in the comparative

advantage industries than in the comparative disadvantage industries. These two effects will

influence the size of the mass of exporters oppositely to each other, and the ambiguity in the

---

[13] In order to completely remove this ambiguity, we need to specify the values of all the parameters in the
model and the shape of the distribution of productivities, as well as the exogenous amounts of factor

15

effect of trade on the size of the mass might occur especially when the first effect is very significant. However, we can *unambiguously* predict that the share of exporters in firms that are active (producing) in the domestic market (i.e., $\chi_i^\lambda \equiv M_{ix}^\lambda / M_i^\lambda$) will be larger in comparative advantage industries than in comparative disadvantage industries.

Can we predict the relative size of the mass of exporters under free trade with FPE? It is well-known that with FPE the cross-industry patterns of production and trade are indeterminate when the number of industries (sectors) is greater than the number of input factors (e.g., Melvin (1968)). This indeterminacy will also apply to our model,[14] and under free trade with FPE there exists multiple equilibrium allocations of the two factors across industries. As an overall tendency, however, the production resources will be on average allocated more to industries in which the country has its comparative advantage (for both factors in the country to be fully employed), so that the mass of firms will be on average larger in the comparative advantage industries.[15]

Patterns in Export Varieties:

In our model, each firm produces a unique variety of differentiated product, and thus the mass of exporting firms in a country, which is examined above, represents the number of product varieties exported from the country in that industry. Therefore, Proposition 1 has the following implication for product varieties in export, which is empirically tested in the following sections of this paper:

---

endowments in the two countries.

[14] We can see this indeterminacy in the relative size of the mass of exporters in Equation (2.26). Under free trade with FPE, $\tau_i = 1$, $\chi_i^\lambda = 1$ (since all active firms will be exporters), the price of a product variety will be the same in the two market, and the industry price index will be equal in the two countries. Hence, both numerator and denominator of the right-hand side of the equation is zero, which implies the indeterminacy of M_i^H / M_i^F.

Proposition 2: Between a certain pair of countries, the international trade will

exhibit the following cross-industry pattern: the relatively more skilled-labor

abundant country will export more varieties of products in skill-intensive industries

(i.e., industries with greater β); on the other hand, the relatively more unskilled-

labor abundant country will export more varieties in unskilled labor-intensive

industries (i.e., industries with smaller β).

3. Data

An empirical test of the implication (Proposition 2) of our model requires data for three

variables: the number of product varieties exported from each country in each industry,

production factor endowment in each exporter, and input factor intensity in each industry.

For the product varieties in exports, we use the data on the U.S. imports in 1990 from

Feenstra, Romalis and Schott (2002). The data contain information on the U.S. imports of each

commodity classified according to the very disaggregated 10-digit Harmonized System (HS)

from each exporter country. The data also include product classification codes according to the

4-digit U.S. Standard Industrial Classification (SIC, 1987 version) corresponding to each 10-digit

HS. These two classification levels enable us to count the number of product varieties in each

industry for each country by defining products according to the 10-digit HS and industries

according to the 4-digit SIC (see the following section for the details). Due to the availability of

the data on industry factor intensity, our empirical analysis focuses on trade in manufacturing

industries (the 4-digit SIC 2011 through 3999). Table 1 provides the number of exporters,

number of product varieties, and total import value in the whole U.S. imports in 1990, as well as

---

[15] The proof of the indeterminacy under free trade with FPE is upon request.

the figures in the U.S. manufacturing imports. Manufacturing industries represent 94% of the total U.S. 1990 imports in terms of the number of product varieties, and 83% in terms of value.

The data for the factor endowment of each country are from Hall and Jones (1999). Since our theoretical model is embedded in a two-factor framework with skilled labor (S) and unskilled labor (U), we use the data on the ratio of human capital to labor as the measure of the abundance of skilled labor relative to unskilled labor (S/U). The data on human capital to labor ratio as of 1988 are available for 127 countries. Since we consider the U.S. imports from other countries, we calculate each exporter's skilled-to-unskilled labor ratio relative to the S/U of the United States.

Our theoretical model assumes a common production technology in each industry across countries. For the world common input factor intensities, we employ the data from the 1992 U.S. Census of Manufactures, which covers 458 manufacturing industries classified according to the 4-digit SIC (1987 version; the codes 2011 through 3999). We measure the skilled-labor intensity of each industry using the number of non-production workers as the share of the total number of employees in each 4-digit SIC, and the unskilled-labor intensity using the number of production workers per total employment.

The sample for our empirical analysis includes 115 countries from which the U.S. imported in any one or more manufacturing industry in 1990; the sample also includes 394 manufacturing industries (4-digit SIC) in which the U.S. imported from one or more exporters in 1990. Table 2 lists the 115 countries in the sample. Table 3 provides the summary statistics of the relative factor endowment (the skilled-labor to unskilled-labor ratio: S/U) of the sample countries, as well as the ten most and least skilled labor-abundant countries. Table 4 presents the summary statistics of the intensities of the two factors (S and U) of the 394 sample industries,

and also lists the ten most and least skilled labor-intensive industries. Figure 1 displays the number of countries from which the U.S. imported in each 4-digit industry in 1990. The industries are sorted (from left to right) in order of skilled-labor intensity. Figures 2 and 3 plot the number of exporters and the total number of product varieties in the U.S. imports in each industry, respectively, against industry skilled-labor intensity. These figures indicate that the U.S., the world's second most skilled labor-abundant country, tends to import more varieties of products from more exporters in unskilled labor-intensive industries than in skilled labor-intensive industries.

4. Empirical Tests

As stated as Proposition 2 in Section 2, our model provides one key implication: A country will export more varieties of products in industries in which the country has a comparative advantage in the Heckscher-Ohlin sense than it will in other industries. In this section we empirically test this implication using the data described in Section 3.

Measuring Exported Varieties:

Our model explains the number of product varieties in each industry exported from each country to a common importer—in this case, the U.S.— in terms of two elements: the exporter's relative resource abundance and the industry's relative factor use or intensity. As described in the previous section, we define varieties according to the 10-digit HS commodities and industries according to the 4-digit SIC; we thus measure the number of product varieties in Industry i exported from Country c, or n_{ic}, as follows:

$n_{ic} \equiv$ No. of 10-digit HS commodities in a 4-digit SIC i exported from country c.

Some 4-digit SIC industries may contain by nature more 10-digit HS commodities in their

catalogue than other industries, and thus in the U.S. imports we may observe more product

varieties in those industries than in other industries, regardless of the force of the comparative

advantage. Therefore, for a proper cross-industry comparison we use an adjusted measure of the

number of varieties, which is constructed as follows:[16]

$$n\_share_{ic} = \frac{n_{ic}}{N_i}$$

where N_i is the total number of varieties that the U.S. imports from the world in industry i:

$N_i = \sum_c n_{ic}$. Note that since the theoretical model assumes that each firm produces a unique

variety of products, the imports of the same 10-digit commodities from different countries are

considered as different product varieties.

(1) Regressions for Aggregate North and South:

We first test our two-country, two-factor and multi-industry model with the data for

country aggregates. We divide our 115 sample countries into two groups to construct two

country aggregates, one of which consists of countries that are relatively more skilled-labor

abundant than unskilled (or with relatively high S/U). We refer to this group as the "North."

The other consists of countries that are relatively more unskilled-labor abundant (or with low

S/U), which we call the "South." The North includes 51 countries whose S/U is above the

sample mean; the South includes other 64 sample countries.[17] Table 5 lists the countries

---

[16] This variable is consistent with the idea of the "relative size of firm mass" described in Proposition 1 in
Section 2. Here, due to the limitation of the employed dataset, the number of exported varieties from one
country in one industry is expressed as the relative value to the number of varieties exported from the rest
of the world in that industry, instead of the ratio to the number of varieties exported from the trading
partner (i.e., the U.S.).
[17] We also attempted two other "cutoffs" for S/U to divide the sample countries into the North and

constituting the aggregates North and South. Table 6 compares the within-group averages of relative factor abundance, S/U.

The following equation is estimated using the OLS for the aggregate North and South:[18]

$$log(n\_share_{i,A}) = \alpha + \beta \cdot skill_i + \varepsilon_i \tag{4.1}$$

where $n\_share_{i,A} = \sum_{c \in A} n\_share_{i,A}$ for A = North, South; and $skill_i$ = skill intensity of Industy i.[19]

Our model suggests that the relatively skilled labor-abundant North will export more product varieties in skilled-intensive industries than in unskilled-intensive industries, and the unskilled-abundant South will export more varieties in unskilled-intensive industries. The expected sign of the coefficient β is therefore positive for the North and negative for the South. The results of the estimation are in fact consistent with this prediction, as shown in Table 7.

(2) Pooled Regression for Dependent Parameter Specification:

We next use the pooled data for all the individual exporters to estimate cross-industry patterns of exports in terms of product varieties. We consider the following regression model:

$$log(n\_share_{ic}) = \alpha + \Lambda_c \cdot skill_i + \varepsilon_{ic} \tag{4.2}$$

The slope coefficient for skilled-labor intensity, Λ_c, would differ across exporter countries. The theory predicts that the value of the slope coefficient is higher for countries with greater relative

South: above or below the 75 percentile (29 countries for North, 86 for South), and above or below 0.7 of the value of S/U relative to the U.S. (25 countries for North, 90 for South). These alternative groupings are also indicated in Table 5. The qualitative results of the estimation (the sign and significance of the coefficient estimate) are the same, as shown in Table 7, regardless of the cutoffs.

[18] n_share_{ic} is skewed in distribution, and therefore log-scaled in the regressions to adjust for possible heteroskedasticity. We do not log-scale the factor intensity measure ($skill_i$), but the results are virtually the same even though the log-scaled intensity measure is used.

[19] As described in Section 3, $skill_i$ is measured using the share of non-production workers in the total number of employees. Unskilled-labor intensity, which is measured using the share of production workers

skilled-labor endowment, and lower for exporters with smaller relative skilled-labor endowment

(or greater relative unskilled-labor endowment). This pattern is indeed observed in the result of

the regression (4.2) for each individual exporter. Figure 4 plots the slope coefficient $\hat{\Lambda}_c$

estimated for each country against the relative skilled-labor abundance of the country (relative to

the U.S.). The figure exhibits the tendency that the coefficient Λ_c is greater for more

skill-abundant.[20] To capture this pattern in the pooled regression, we impose the following

structure on the slope coefficient Λ_c:

$$\Lambda_c = \Lambda((S/U)_c) = \beta_1 + \beta_2 \cdot (S/U)_c \tag{4.3}$$

where $(S/U)_c$ is the skilled- to unskilled-labor ratio of exporter country c relative to the

United States. The theoretical prediction is that β_1 will be negative (since Λ_c will be negative

for countries with low skilled-labor abundance) and β_2 will be positive (since Λ_c will increase

to be positive for countries with high skilled-labor abundance). By substituting (4.3) for (4.2), we

derive the following specification for our pooled regression:

$$log(n\_share_{ic}) = \beta_1 \cdot skill_i + \beta_2 \cdot skill_i \cdot (S/U)_c + \mu_c + \varepsilon_{ic} \tag{4.4}$$

We include exporter-specific dummies, μ_c, to capture the effects of all factors other than the

relative skilled-unskilled abundance that differ across countries, such as fixed and variable trade

costs and the size of the exporter.[21]

---

in the total employment, is the same as 1-$skill_i$.

[20] To draw the fitted line in Figure 4, the observations are weighted by the number of observations in each individual country regression (4.2) (i.e., by the number of industries for each country in the sample). Some sub-Saharan African countries such as Angola, Benin, Central African Republic, Rwanda, and Somalia have a large $\hat{\Lambda}_c$ despite their low skilled-labor abundance. However, these countries have exports to the U.S. in very few industries out of 394 4-digit SIC and they are all very unskilled-labor intensive. Hence, the slope coefficients estimated for these "outlier" countries may be vulnerable.

[21] Recall that we develop the theoretical model in the two-country framework. The values of parameters in the model are likely to be different across country pairs.

The result of the estimation of Equation (4.4) using the fixed-effect OLS is shown in Table 8. The estimates of all the coefficients show the signs as expected from the theory, and they are all highly significant. In addition, using these estimates we compute the "threshold" factor abundant $(S/U)^*$ where the slope coefficient for skilled intensity Λ_c turns from negative to positive (i.e., $\Lambda_c((S/U)^*) = 0$). The value of the "threshold" S/U (relative to the U.S.) is 0.66,[22] which is close to the relative factor abundance in Chile and Uruguay (the 35th most skilled-abundant countries out of 115). This factor abundance value could be interpreted as a cutoff to divide countries into the North and South.[23]

These results of the empirical tests suggest that the semi-Heckscher-Ohlin prediction of our economic model on the exported varieties is supported by the U.S. import data.

5. Conclusion

In this paper, we have investigated the relationship between export variety and the exporter's comparative advantage in terms of relative resource abundance. We have generalized the model by Bernard, Redding & Schott (2007) to the case with continuum industries and derived a prediction that relates product varieties in a country's exports in various industries to the "degrees" of relative factor intensity of those industries. To test the prediction we have employed the disaggregated data on the U.S. imports, as well as the data on countries' human capital and labor endowments and the data on the industry-wise uses of skilled- and unskilled-labor in the U.S. manufacturing. The empirical tests support our semi-Heckscher-Ohlin

---

[22] $(S/U)^* = -\dfrac{\hat{\beta}_1}{\hat{\beta}_2} = -\dfrac{-2.72}{4.14} \approx 0.66$

[23] The mean of $(S/U)_c$, which is used as the cutoff of North-South division in the previous subsection, is 0.59, which is a little lower than this value.

prediction, which indicates that exporters that are more unskilled-labor abundant tend to export

more varieties of products in relatively unskilled labor-intensive industries, and more

skilled-abundant exporters tend to export more varieties in relatively skill-intensive industries.

References

[1] Choi, Y. C., D. Hummels, and C. Xiang, 2006, Explaining Import Variety and Quality: the Role of the Income Distribution, Purdue University working paper

[2] Bernard, A. B., S. J. Redding, and P. K. Schott, 2007, Comparative Advantage and Heterogeneous Firms, Review of Economic Studies, Vol. 74, No. 1, pp. 31-66

[3] Broda, C. and D. E. Weinstein, 2004, Variety Growth and World Welfare, American Economic Review, Vol. 94, No. 2, pp. 139-144

[4] Davis, D. R. and D. E. Weinstein, 2003, Market Access, Economic Geography, and Comparative Advantage: An Empirical Assessment, Journal of International Economics, Vol. 59, No. 1, pp. 1-23

[6] Davis, D. R. and D. E. Weinstein, 2001, An Account of Global Factor Trade, American Economic Review, Vol. 91, No. 5, pp. 1423-1453

[7] Dixit, A. K. and V. Norman, 1980, Theory of International Trade, Cambridge University Press, Cambridge, U.K.

[8] Dornbusch, R., S. Fischer, and P. A. Samuelson, 1980, Heckscher-Ohlin Trade Theory with a Continuum of Goods, Quarterly Journal of Economics, Vol. 95, No. 2, pp. 823-839

[9] Falvey, R. E. and H. Kierzkowski, 1987, Product Quality, Intra-industry Trade and imperfect Competition, in Kierzkowski, H. (ed.), Protection and Competition in International Trade: Essays in Honor of W. M. Corden, Basil Blackwell, Oxford and London

[10] Feenstra, R. C. and H. L. Kee, 2004, Export Variety and Country Productivity, World Bank Policy Research Working Paper 3412

[11] Feenstra, R. C., J. Romalis and P. K. Schott, 2002, U.S. Imports, Exports, and Tariff Data, 1989-2001, NBER Working Paper No. 9387

[12] Feenstra, R. C., T. H. Yang, and G. G. Hamilton, 1999, Business groups and product variety in trade: evidence from South Korea, Taiwan and Japan, Journal of International Economics, Vol. 48, No. 1, pp. 71-100

[13] Funke, M. and R. Ruhwedel, 2001(a), Product Variety and Economic Growth: Empirical Evidence for the OECD Countries, IMF Staff Papers, Vol. 48, No. 2

[14] Funke, M. and R. Ruhwedel, 2001(b), Export Variety and Export Performance: Empirical Evidence for East Asia, Journal of Asian Economics, Vol. 12, No. 4, pp. 493-505

[15] Funke, M. and R. Ruhwedel, 2005, Export Variety and Economic Growth in East European Transition Economies, Economics of Transition, Vol. 13, No. 1, pp. 25-50

[16] Hall, R. E. and C. I. Jones, 1999, Why Do Some Countries Produce So Much More Output Per Worker Than Others?, Quarterly Journal of Economics, Vol. 114, No. 1, pp. 83-116

[17] Hallak, J. C., 2006, Product Quality and the Direction of Trade, Journal of International Economics, Vol. 68, No. 1, pp. 238-265

[18] Hallak, J. C., 2005, A Product-Quality View of the Linder Hypothesis, working paper

[19] Helpman, E. and P. R. Krugman, 1985, Market Structure and Foreign Trade, MIT Press, Cambridge, M.A.

[20] Hummels, D. and P. J. Klenow, 2005, The variety and Quality of a Nation's Trade, American Economics Review, Vol. 95, No. 3, pp. 704-723

[21] Hummels, D. and V. Lugovskyy, 2005, Trade in Ideal Varieties: Theory and Evidence, NBER Working Paper No. 11828

[22] Kehoe, T. J. and K. J. Ruhl, 2003, How Important is the New Goods Margin in International Trade?, Federal Reserve Bank of Minneapolis Research Department Staff Report 324

[23] Krugman, P. R., 1979, Increasing Returns, Monopolistic Competition, and International Trade, Journal of International Economics, Vol. 9, No. 4, pp. 469-479

[24] Melitz, M. J., 2003, The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity, Econometrica, Vol. 71, No. 6, pp. 1695-1725

[25] Melvin, J. R., 1968, Production and Trade with Two Factors and Three Goods, American Economic Review, Vol. 58, No. 5, pp. 1249-1268

[26] Romalis, J., 2004, Factor Proportions and the Structure of Commodity Trade, American Economic Review, Vol. 94, No. 1, pp. 67-97

[27] Samuelson, P. A., 1949, International Factor-Price Equalization Once Again, Economic Journal, Vol. 59, No. 234, pp. 181-197

[28] Schott, P. K., 2003, One Size Fits All? Heckscher-Olin Specialization in Global Production, American Economic Review, Vol. 93, No.3, pp. 686-708

[29] Schott, P. K., 2004, Across-Product versus Within-Product Specialization in International Trade, Quarterly Journal of Economics, Vol. 119, No. 2, pp. 647-678

Appendix

1. Deviation of Equation (2.12):

Note, from Equation (2.6), that the ratio of the revenues of two firms with different productivities is expressed with the ratio of those firms' productivities, such as follows:

$$\frac{r_i(\phi')}{r_i(\phi)} = (\frac{\phi'}{\phi})^{\sigma-1} \Leftrightarrow ri(\phi') = (\frac{\phi'}{\phi})^{\sigma-1} r_i(\phi) \tag{A.1}$$

Using this relationship, as well as Equation (2.7) for an individual firm's profit and Equation (2.9) for the revenue of the firm with the cutoff-level productivity, the free-entry condition (2.11) becomes as follows:

$$[1 - G(\phi_i^{*\lambda})]\frac{\bar{\pi}_i^\lambda(\phi)}{\delta} = f_{ei}(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}$$

$$\Leftrightarrow [1 - G(\phi_i^{*\lambda})]\frac{1}{\delta}\{\frac{\bar{r}_i^\lambda(\phi)}{\sigma} - f_i(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}\} = f_{ei}(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}$$

$$\Leftrightarrow [1 - G(\phi_i^{*\lambda})]\frac{1}{\delta}\{\frac{1}{\sigma}(\frac{\bar{\phi}_i}{\phi_i^{*\lambda}})^{\sigma-1} \cdot r_i^\lambda(\phi_i^{*\lambda}) - f_i(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}\} = f_{ei}(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}$$

$$\Leftrightarrow [1 - G(\phi_i^{*\lambda})]\frac{1}{\delta}\{(\frac{\bar{\phi}_i}{\phi_i^{*\lambda}})^{\sigma-1} - 1\}f_i(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i} = f_{ei}(s^\lambda)^{\beta_i}(w^\lambda)^{1-\beta_i}$$

$$\Leftrightarrow [1 - G(\phi_i^{*\lambda})]\frac{f_i}{\delta}\{\frac{1}{1 - G(\phi_i^{*\lambda})}\int_{\phi_i^{*\lambda}}^{\infty}(\frac{\phi}{\phi_i^{*\lambda}})^{\sigma-1}g(\phi)d\phi - 1\} = f_{ei}$$

and thus Equation (2.12) follows.

2. Derivation of Equations (2.17) & (2.18):

WLOG, here we derive Equation (2.17) for Home. Equation (2.18) for Foreign can be derived analogously.

From Equation (2.13) for the optimal pricing of exported product, the revenue of an individual firm earned from the overseas market (export) is as follows:

$$r_{ix,\omega}^{H}(\phi) = \alpha_i Y^F \left(\frac{\rho P_i^F \phi}{\tau_i (s^H)^{\beta_i} (w^H)^{1-\beta_i}} \right) \tag{A.2}$$

From this and Equation (2.6), the ratio of the revenue earned by an exporter and that earned by a domestic producer in Home country is expressed as follows:

$$\frac{r_{ix}^{H}(\phi)}{r_i^{H}(\phi)} = \tau_i^{1-\sigma} \left(\frac{P_i^F}{P_i^H} \right)^{\sigma-1} \left(\frac{Y^F}{Y^H} \right) \tag{A.3}$$

Equation (A.1) can be modified to the following equation, which implies that the ratio of two firms' productivities is a function of the ratio of the revenues that two firms earn *in the same (domestic) market*:

$$\frac{\phi'}{\phi} = \left(\frac{r_i(\phi')}{r_i(\phi)} \right)^{\frac{1}{\sigma-1}} \tag{A.4}$$

Using Equations (A.3) and (A.4), we can express the ratio of the productivity cutoff for exporting to the cutoff for domestic production in Home as follows:

$$\frac{\phi_{ix}^{*H}}{\phi_i^{*H}} = \left(\frac{r_i^{H}(\phi_{ix}^{*H})}{r_i^{H}(\phi_i^{*H})} \right)^{\frac{1}{\sigma-1}}$$

$$= \left(\frac{r_{ix}^{H}(\phi_{ix}^{*H}) \cdot \tau_i^{\sigma-1} \left(\frac{P_i^H}{P_i^F} \right)^{\sigma-1} \left(\frac{Y^H}{Y^F} \right)}{r_i^{H}(\phi_i^{*H})} \right)^{\frac{1}{\sigma-1}}$$

$$= \left(\frac{r_{ix}^{H}(\phi_{ix}^{*H})}{r_i^{H}(\phi_i^{*H})} \right)^{\frac{1}{\sigma-1}} \cdot \left(\frac{P_i^H}{P_i^F} \right) \left(\frac{Y^H}{Y^F} \right)^{\frac{1}{\sigma-1}}$$

$$= \tau_i \left(\frac{f_{ix}}{f_i} \right)^{\frac{1}{\sigma-1}} \left(\frac{P_i^H}{P_i^F} \right) \left(\frac{Y^H}{Y^F} \right)^{\frac{1}{\sigma-1}}$$

The last equality is from the zero-profit condition in the domestic market (2.6) and the zero-profit condition in the export market (2.15). Equation (2.17) thus follows by defining the right-hand side of the last line of the equation above as Λ_i^H.

3. Relative Factor Prices under Costly Trade:

Here we demonstrate that in equilibrium the relative prices of the two production factors (S and

U) is not equalized in our framework of costly trade. The wage for skilled labor relative to the

that for unskilled labor will be lower in Home, where skilled labor is relatively more abundant,

than in Foreign; i.e., $\dfrac{s^H}{w^H} < \dfrac{s^F}{w^F}$.

First, note that autarky and free trade are the two extreme cases, or limits, of the costly trade.

That is, the former is the limit with infinitely large trade costs ($f_{ix} \to \infty, \tau_i \to \infty$), and the latter

is the limit with no additional costs for trade ($f_{ix} \to f_i, \tau_i \to 0$). The equilibrium relative factor

price under costly trade will fall in the range between those in these two limit cases (i.e.,

$\dfrac{s^H}{w^H} < \dfrac{s^F}{w^F}$). We will thus show how the relative factor prices in the two countries will be in

these two limit cases.

(1) Autarky

Since the production function (2.4) has a Cobb-Douglas form with the common factor intensities,

the optimal allocation of the two factors in each industry is such that the total payment to each

factor is proportional to the total revenue, which equals the total expenditure, in the industry.

That is, in Country $\lambda \in \{H, F\}$;

$$S_i^\lambda = (\frac{\beta_i}{s^\lambda})R_i^\lambda = (\frac{\beta_i}{s^\lambda})\alpha_i Y^\lambda \tag{A.5}$$

$$L_i^\lambda = (\frac{1-\beta_i}{w^\lambda})R_i^\lambda = (\frac{1-\beta_i}{w^\lambda})\alpha_i Y^\lambda \tag{A.6}$$

where R_i^λ is the total revenue in Industry i in each country, which is equal to the total industry

expenditure in equilibrium. The industry expenditure is proportional to the national income due

to the Cobb-Douglas utility function (2.1) (i.e., $R_i^\lambda = \alpha_i Y^\lambda$).

Inelastic supply of the each factor equals the sum of that factor allocated to each industry, that is;

$$\overline{S}^\lambda = \sum_i S_i^\lambda = \frac{Y^\lambda}{s^\lambda} \sum_i \alpha_i \beta_i \Leftrightarrow s^\lambda \overline{S}^\lambda = Y^\lambda \sum_i \alpha_i \beta_i \tag{A.7}$$

$$\overline{U}^\lambda = \sum_i U_i^\lambda = \frac{Y^\lambda}{w^\lambda} \sum_i \alpha_i (1-\beta_i) \Leftrightarrow w^\lambda \overline{U}^\lambda = Y^\lambda \sum_i \alpha_i (1-\beta_i) \tag{A.8}$$

Dividing (A.7) by (A.8) in both sides yields the following equation:

$$\frac{s^\lambda \overline{S}^\lambda}{w^\lambda \overline{U}^\lambda} = \frac{\sum_i \alpha_i \beta_i}{\sum_i \alpha_i (1-\beta_i)}$$

$$\Leftrightarrow \frac{s^\lambda}{w^\lambda} = \left(\frac{\sum_i \alpha_i \beta_i}{\sum_i \alpha_i (1-\beta_i)} \right) \cdot \left(\frac{\overline{U}^\lambda}{\overline{S}^\lambda} \right) \tag{A.9}$$

Since consumers share the identical preference and the production technology is common across

countries in each industry (i.e., the parameters α_i and β_i are common across countries), the first

term of the product in the right-hand side of Equation (A.9) is the same for both countries. Hence,

the relative factor price $\dfrac{s^\lambda}{w^\lambda}$ in each country is determined by the ratio of the two factors that the

country is endowed with, $\dfrac{\overline{S}^\lambda}{\overline{U}^\lambda}$. Since $\dfrac{\overline{S}^H}{\overline{U}^H} > \dfrac{\overline{S}^F}{\overline{U}^F}$ by assumption, (A.9) implies that $\dfrac{s^H}{w^H} < \dfrac{s^F}{w^F}$

in the autarky equilibrium.

(2) Free Trade

Here we focus on the case with FPE. We can identify the equilibrium relative factor price with

FPE by solving for the problem of the integrated world economy, which is characterized by

Equations (A.5) through (A.9) in the autarky case described above, but ignoring the country

script λ. The common relative factor price $\dfrac{s}{w}$ is determined by the world relative factor supply

$\dfrac{\bar{S}}{\bar{U}}$. Hence, in the free-trade equilibrium with FPE, $\dfrac{s^H}{w^H} = \dfrac{s^F}{w^F}$. [24]

4. Derivation of Equations (2.27):

From Equations (2.17) and (2.18) and the definition of Λ_i^{λ} for $\lambda \in \{H, F\}$, the ratio of the

industry price index in the two countries can be expressed as follows:

$$\frac{P_i^H}{P_i^F} = \tau_i^{-1} \left(\frac{\phi_{ix}^{*H}}{\phi_i^{*H}}\right)\left(\frac{Y^F}{Y^H}\right)^{\frac{1}{\sigma-1}}\left(\frac{f_i}{f_{ix}}\right)^{\frac{1}{\sigma-1}} = \tau_i \left(\frac{\phi_i^{*F}}{\phi_{ix}^{*F}}\right)\left(\frac{Y^F}{Y^H}\right)^{\frac{1}{\sigma-1}}\left(\frac{f_{ix}}{f_i}\right)^{\frac{1}{\sigma-1}} \tag{A.10}$$

Substituting this Equation (A.10) to Equation (2.26) (with the second equality for the numerator

and the first for the denominator of the right-hand side of (2.26)) and re-arranging yields the

following:

$$\frac{M_i^H}{M_i^F} = \frac{\tau_i^{1-\sigma}\left[\left(\frac{Y^H}{Y^F}\right)\left(\frac{f_i}{f_{ix}}\right)\left(\frac{\phi_i^{*F}}{\phi_{ix}^{*F}}\right)^{1-\sigma}(p_i^F(\bar{\phi}_i^F))^{1-\sigma} - \chi_i^F(p_i^F(\bar{\phi}_{ix}^F))^{1-\sigma}\right]}{(p_i^H(\bar{\phi}_i^H))^{1-\sigma} - \chi_i^H\left(\frac{Y^H}{Y^F}\right)\left(\frac{f_{ix}}{f_i}\right)\left(\frac{\phi_{ix}^{*H}}{\phi_i^{*H}}\right)^{1-\sigma}(p_i^H(\bar{\phi}_{ix}^H))^{1-\sigma}} \tag{A.11}$$

The optimal pricing Equation (2.5) implies that the ratio of the prices charged by two firms with

different productivity *in the same market* can be expressed as the ratio of the two productivities,

i.e.;

$$p_i^{\lambda}(\phi') = \left(\frac{\phi}{\phi'}\right) \cdot p_i^{\lambda}(\phi) \tag{A.12}$$

Using this, the price charged by a firm with the average exporter productivity *in the domestic*

market is expressed, using the average price of domestic producers, as follows:

$$p_i^H(\overline{\phi}_{ix}^H) = \left(\frac{\overline{\phi}_i^H}{\overline{\phi}_{ix}^H}\right) \cdot p_i^H(\overline{\phi}_i^H) \tag{A.13}$$

$$p_i^F(\overline{\phi}_{ix}^F) = \left(\frac{\overline{\phi}_i^F}{\overline{\phi}_{ix}^F}\right) \cdot p_i^F(\overline{\phi}_i^F) \tag{A.14}$$

Substituting these equations into Equation (A.11) (applying (A.14) to the numerator and (A.13) to the denominator of the right-hand side) and re-arranging the terms yields the following expression for the relative size of the masses of domestically-producing firms:

$$\frac{M_i^H}{M_i^F} = \frac{[(\frac{Y^H}{Y^F})(\frac{f_i}{f_{ix}})(\frac{\phi_{ix}^{*F}}{\phi_i^{*F}})^{\sigma-1} - \chi_i^F(\frac{\overline{\phi}_{ix}^F}{\overline{\phi}_i^F})^{\sigma-1}]}{\tau_i^{\sigma-1}[1 - \chi_i^H(\frac{Y^H}{Y^F})(\frac{f_{ix}}{f_i})(\frac{\phi_i^{*H}}{\phi_{ix}^{*H}})^{\sigma-1}(\frac{\overline{\phi}_{ix}^H}{\overline{\phi}_i^H})^{\sigma-1}]} \cdot \left(\frac{p_i^H(\overline{\phi}_i^H)}{p_i^F(\overline{\phi}_i^F)}\right)^{\sigma-1} \tag{A.15}$$

Equation (2.27) is derived from this (A.15) and Equation (2.22).

5. Proof of Proposition 1:

Equation (2.27) indicates that the relative size of the mass of exporters in the two countries depends upon the following factors:

- The ratio of the productivity cutoff for export to the cutoff for domestic production in each country: $\dfrac{\phi_{ix}^{*H}}{\phi_i^{*H}}$, $\dfrac{\phi_{ix}^{*F}}{\phi_i^{*F}}$

- The ratio of the *ex post* average productivity of exporters to that of domestic producers in each country: $\dfrac{\overline{\phi}_{ix}^H}{\overline{\phi}_i^H}$, $\dfrac{\overline{\phi}_{ix}^F}{\overline{\phi}_i^F}$

  (This ratio is indeed determined by the ratio of the productivity cutoffs.)

- The levels of the average productivities of domestic producers in the two countries:

---

proof upon request.

$$\bar{\phi}_i^{\,H}, \ \bar{\phi}_i^{\,F}$$

- Equilibrium relative factor rewards in the two countries: $\dfrac{s^H}{w^H}, \ \dfrac{s^F}{w^F}$

The proof strategy is as follows:

(i) We first show that the relative industry price index (Home to Foreign) is smaller for an industry in which the skill-abundant Home has the comparative advantage (i.e.,

$$\frac{P_i^H}{P_i^F} < \frac{P_j^H}{P_j^F} \quad \text{for } i \neq j \text{ such that } \beta_i > \beta_j);$$

(ii) We next demonstrate that (i) implies that the "distance" of the two productivity cutoffs is closer in an industry in which the country has the comparative advantage (i.e.,

$$\frac{\phi_{ix}^{*H}}{\phi_i^{*H}} < \frac{\phi_{jx}^{*H}}{\phi_j^{*H}} \quad \text{and} \quad \frac{\phi_{ix}^{*F}}{\phi_i^{*F}} > \frac{\phi_{jx}^{*F}}{\phi_j^{*F}} \quad \text{for } i \neq j \text{ such that } \beta_i > \beta_j). \text{ This also implies that the}$$

"distance" of the average productivities of exporters and that of domestic producers is

in the same relationship (i.e., $\dfrac{\bar{\phi}_{ix}^{\,H}}{\bar{\phi}_i^{\,H}} < \dfrac{\bar{\phi}_{jx}^{\,H}}{\bar{\phi}_j^{\,H}}$ and $\dfrac{\bar{\phi}_{ix}^{\,F}}{\bar{\phi}_i^{\,F}} > \dfrac{\bar{\phi}_{jx}^{\,F}}{\bar{\phi}_j^{\,F}}$ for $i \neq j$ such that $\beta_i > \beta_j$);

(iii) We then use the results in (ii) and the relationship between the relative factor prices in the two countries in equilibrium, which has been derived in 3. above in this Appendix, to compare across industries the relative sizes of exporter masses in the two countries,

$$\frac{M_{ix}^H}{M_{ix}^F} \quad \text{and} \quad \frac{M_{jx}^H}{M_{jx}^F} \, .$$

In what follows, we impose Assumption 1.

(i) Relative industry price index in two countries:

33

To demonstrate that $\dfrac{P_i^H}{P_i^F} < \dfrac{P_j^H}{P_j^F}$ for $i \neq j$ such that $\beta_i > \beta_j$, here we apply a similar logic to the

one that we have used in 3. above to show the relative factor prices in the costly-trade

equilibrium ($\dfrac{s^H}{w^H} < \dfrac{s^F}{w^F}$). Recall Equation (2.25) for the relative industry price index in the

costly-trade equilibrium, with a slight modification:

$$\frac{P_i^H}{P_i^F} = \frac{[M_i^H (p_i^H (\overline{\phi}_i^H))^{1-\sigma} + \chi_i^F \cdot M_i^F \cdot \tau_i^{1-\sigma} (p_i^F (\overline{\phi}_{ix}^F))^{1-\sigma}]^{\frac{1}{1-\sigma}}}{[M_i^F (p_i^F (\overline{\phi}_i^F))^{1-\sigma} + \chi_i^H \cdot M_i^H \cdot \tau_i^{1-\sigma} (p_i^H (\overline{\phi}_{ix}^H))^{1-\sigma}]^{\frac{1}{1-\sigma}}} \qquad (A.16)$$

Since the autarky and the free-trade FPE equilibria is the two extreme or limit cases, the relative

price index in the costly trade equilibrium falls between the one in the autarky equilibrium and

the one in the free-trade FPE equilibrium.

In autarky, which is characterized by $\tau_i = \infty$ and $f_{ix} = \infty$, no firms will be exporters ($\chi_i^\lambda = 0$ in each

country λ). Therefore, Equation (A.16) is now as follows:

$$\frac{P_i^H}{P_i^F} = \frac{(M_i^H)^{\frac{1}{1-\sigma}} \cdot p_i^H (\overline{\phi}_i^H)}{(M_i^F)^{\frac{1}{1-\sigma}} \cdot p_i^F (\overline{\phi}_i^F)} = (\frac{M_i^H}{M_i^F})^{\frac{1}{1-\sigma}} (\frac{p_i^H (\overline{\phi}_i^H)}{p_i^F (\overline{\phi}_i^F)}) \qquad (A.17)$$

Since $M_i^\lambda = R_i^\lambda / r_i^\lambda (\overline{\phi}_i^\lambda)$ and $R_i^\lambda = \alpha_i Y^\lambda$ for each country $\lambda \in \{H, F\}$ in the autarky

equilibrium, Equation (A.17) yields the following equation;

$$\frac{P_i^H}{P_i^F} = (\frac{Y^H}{Y^F})^{\frac{1}{1-\sigma}} (\frac{r_i^F (\overline{\phi}_i^F)}{r_i^H (\overline{\phi}_i^H)})^{\frac{1}{1-\sigma}} (\frac{p_i^H (\overline{\phi}_i^H)}{p_i^F (\overline{\phi}_i^F)}) \qquad (A.18)$$

Using Equations (A.1) and (A.12), as well as the optima pricing (2.5) and the zero-profit

condition (2.9), Equation (A.18) can be expressed as follows:

$$\frac{P_i^H}{P_i^F} = (\frac{Y^H}{Y^F})^{\frac{1}{1-\sigma}} \left(\frac{(\frac{\overline{\phi}_i^F}{\phi_i^{*F}})^{\sigma-1}(s^F)^{\beta_i}(w^F)^{1-\beta_i}}{(\frac{\overline{\phi}_i^H}{\phi_i^{*H}})^{\sigma-1}(s^H)^{\beta_i}(w^H)^{1-\beta_i}} \right)^{\frac{1}{1-\sigma}} \left(\frac{(\frac{\overline{\phi}_i^H}{\phi_i^{*H}})^{\sigma-1}\frac{(s^H)^{\beta_i}(w^H)^{1-\beta_i}}{\phi_i^{*H}}}{(\frac{\overline{\phi}_i^F}{\phi_i^{*F}})^{\sigma-1}\frac{(s^F)^{\beta_i}(w^F)^{1-\beta_i}}{\phi_i^{*F}}} \right) \quad \text{(A.19)}$$

Note that the productivity cutoff for each country, $\phi_i^{*\lambda}$, is determined by the free-entry condition

(2.12), which is common for the two countries. Therefore, $\phi_i^{*H} = \phi_i^{*F}$, and accordingly,

$\overline{\phi}_i^H = \overline{\phi}_i^F$ since the productivity distribution is common across countries. These imply that

$\frac{\overline{\phi}_i^H}{\phi_i^{*H}} = \frac{\overline{\phi}_i^F}{\phi_i^{*F}}$. Hence, from Equation (A.19) we obtain the following:

$$\frac{P_i^H}{P_i^F} = (\frac{Y^H}{Y^F})^{\frac{1}{1-\sigma}} \cdot \left\{ \left(\frac{s^F}{s^H} \right)^{\beta_i} \left(\frac{w^F}{w^H} \right)^{1-\beta_i} \right\}^{\frac{1}{1-\sigma}}$$

$$\Leftrightarrow \frac{P_i^H}{P_i^F} = (\frac{Y^H}{Y^F})^{\frac{1}{1-\sigma}} \cdot \left\{ \left(\frac{s^H / w^H}{s^F / w^F} \right)^{\beta_i} \left(\frac{w^H}{w^F} \right) \right\}^{\frac{\sigma}{\sigma-1}} \quad \text{(A.20)}$$

Analogously;

$$\frac{P_j^H}{P_j^F} = (\frac{Y^H}{Y^F})^{\frac{1}{1-\sigma}} \cdot \left\{ \left(\frac{s^H / w^H}{s^F / w^F} \right)^{\beta_j} \left(\frac{w^H}{w^F} \right) \right\}^{\frac{\sigma}{\sigma-1}} \quad \text{(A.21)}$$

It has been shown in 3.(1) above that $\frac{s^H}{w^H} < \frac{s^F}{w^F}$ in autarky. Therefore, since $\beta_i > \beta_j$, it follows

that $\frac{P_i^H}{P_i^F} < \frac{P_j^H}{P_j^F}$ in the autarky equilibrium.

Next, consider the free-trade equilibrium, which is characterized by $\tau_i = 1$ and $f_{ix} = f_i$. Since all

domestically active firms will export, $\chi_i^\lambda = 1$ in each country λ. Furthermore, with FPE, firms in

the two countries will charge the same price for both domestic sales and export if their

productivities are the same, $p_i^H(\bar{\phi}_i^H) = p_{ix}^H(\bar{\phi}_{ix}^H) = p_i^F(\bar{\phi}_i^F) = p_{ix}^F(\bar{\phi}_{ix}^F)$ (the average productivity

is the same across countries since it is determined by the common free-entry condition (2.12)).

Hence, Equation (A.16) yields:

$$\frac{P_i^H}{P_i^F} = \frac{(M_i^H + M_i^F)^{\frac{1}{1-\sigma}}}{(M_i^H + M_i^F)^{\frac{1}{1-\sigma}}} = 1$$

Therefore, under costly trade, which is the intermediate case of the two extremes shown above,

$$\frac{P_i^H}{P_i^F} < \frac{P_j^H}{P_j^F} \quad \text{for } i \neq j \text{ such that } \beta_i > \beta_j \text{ in equilibrium.}$$

(ii) "Distance" between export productivity cutoff and domestic production cutoff:

From Equations (2.17) and (2.18);

$$\frac{\phi_{ix}^{*H}}{\phi_i^{*H}} = \Lambda_i^H = \tau_i (\frac{P_i^H}{P_i^F})(\frac{Y^H}{Y^F} \cdot \frac{f_{ix}}{f_i})^{\frac{1}{\sigma-1}}$$

$$\frac{\phi_{jx}^{*H}}{\phi_j^{*H}} = \Lambda_j^H = \tau_j (\frac{P_j^H}{P_j^F})(\frac{Y^H}{Y^F} \cdot \frac{f_{jx}}{f_j})^{\frac{1}{\sigma-1}}$$

$$\frac{\phi_{ix}^{*F}}{\phi_i^{*F}} = \Lambda_i^F = \tau_i (\frac{P_i^F}{P_i^H})(\frac{Y^F}{Y^H} \cdot \frac{f_{ix}}{f_i})^{\frac{1}{\sigma-1}}$$

$$\frac{\phi_{jx}^{*F}}{\phi_j^{*F}} = \Lambda_j^F = \tau_j (\frac{P_j^F}{P_j^H})(\frac{Y^F}{Y^H} \cdot \frac{f_{jx}}{f_j})^{\frac{1}{\sigma-1}}$$

With Assumption 1 (i.e., $\tau_i = \tau_j$, $f_i = f_j$, and $f_{ix} = f_{jx}$), and also from the result in *(i)* above, the first

two equations imply:

$$(1 <)\Lambda_i^H < \Lambda_j^H \Leftrightarrow (1 <)\frac{\phi_{ix}^{*H}}{\phi_i^{*H}} < \frac{\phi_{jx}^{*H}}{\phi_j^{*H}} \Leftrightarrow (1 <)\frac{\bar{\phi}_{ix}^H}{\bar{\phi}_i^H} < \frac{\bar{\phi}_{jx}^H}{\bar{\phi}_j^H} \qquad (A.22)$$

and the last two equations imply:

$$\Lambda_i^F > \Lambda_j^F (>1) \Leftrightarrow \frac{\phi_{ix}^{*F}}{\phi_i^{*F}} > \frac{\phi_{jx}^{*F}}{\phi_j^{*F}} (>1) \Leftrightarrow \frac{\overline{\phi}_{ix}^F}{\overline{\phi}_i^F} > \frac{\overline{\phi}_{jx}^F}{\overline{\phi}_j^F} (>1) \qquad (A.23)$$

Now recall the free-entry condition (2.21) for costly trade (with Assumption 1):

$$\frac{f}{\delta} \int_{\phi^{*\lambda}}^{\infty} [(\frac{\phi}{\phi^{*\lambda}})^{\sigma-1} - 1]g(\phi)d\phi + \frac{f_x}{\delta} \int_{\phi_x^{*\lambda}}^{\infty} [(\frac{\phi}{\phi_x^{*\lambda}})^{\sigma-1} - 1]g(\phi)d\phi = f_e$$

The first term of the right-hand side of the free-entry condition is monotonically decreasing in

$\phi_i^{*\lambda}$, and the second term is monotonically decreasing in $\phi_{ix}^{*\lambda}$. Since $\phi_{ix}^{*\lambda} = \Lambda_i^{\lambda}\phi_i^{*\lambda}$ for $\Lambda_j^{\lambda} > 1$,

the whole of the right-hand side is monotonically decreasing, which identifies the unique

solutions for $\phi_i^{*\lambda}$ and $\phi_{ix}^{*\lambda}$. Note that the right-hand side of the free-entry condition decreases

more rapidly as the two cutoffs $\phi_i^{*\lambda}$ and $\phi_{ix}^{*\lambda}$ are more distant from each other, so that the

equilibrium value of $\phi_i^{*\lambda}$ is smaller. Therefore, (A.22) indicates that $\phi_i^{*H} > \phi_j^{*H}$, and (A.23)

implies that $\phi_i^{*F} < \phi_j^{*F}$. These results imply the "selection effect" of international trade that is

intuitively described in Section 2: i.e., through the costly international trade the cutoff-level

productivity for successful entry, and the average productivity of active firms accordingly, will

be higher in industries in which each country has its comparative advantage, due to a keener

competition.

Although we can rank the productivity cutoff (and accordingly the average productivity of active

firms) according to the factor intensities of industries for each country, we cannot specify in

which country the cutoff productivity (and accordingly the average productivity) in the same

industry will be greater (i.e., $\phi_i^{*H} > \phi_i^{*F}$ or $\phi_i^{*H} < \phi_i^{*F}$). It is because the level of productivities

in the two countries also depend upon the total incomes of the two countries, which are

somewhat (but not completely) exogenously determined by the factor endowments of the

countries.

(iii) Relative size of exporter masses in two countries:

Now we demonstrate the cross-industry difference of the size of the masses of exporters in the

two countries, Home and Foreign. WLOG, Industry i is more skill intensive than Industry j ($\beta_i >$

β_j). First, the following are derived from (A.22) and (A.23) above:

$$\chi_i^H > \chi_j^H \tag{A.24}$$

$$\chi_i^F < \chi_j^F \tag{A.25}$$

$$\Leftrightarrow \frac{\chi_i^H}{\chi_i^F} > \frac{\chi_j^H}{\chi_j^F} \tag{A.26}$$

Now recall Equation (2.27) for the relative exporter mass:

$$\frac{M_{ix}^H}{M_{ix}^F} = \frac{\chi_i^H}{\chi_i^F} \cdot \frac{[(\frac{Y^H}{Y^F})(\frac{f_i}{f_{ix}})(\frac{\phi_{ix}^{*F}}{\phi_i^{*F}})^{\sigma-1} - \chi_i^F(\frac{\overline{\phi}_{ix}^F}{\overline{\phi}_i^F})^{\sigma-1}]}{\tau_i^{\sigma-1}[1 - \chi_i^H(\frac{Y^H}{Y^F})(\frac{f_{ix}}{f_i})(\frac{\phi_i^{*H}}{\phi_{ix}^{*H}})^{\sigma-1}(\frac{\overline{\phi}_{ix}^H}{\overline{\phi}_i^H})^{\sigma-1}]} \cdot \left(\frac{p_i^H(\overline{\phi}_i^H)}{p_i^F(\overline{\phi}_i^F)}\right)^{\sigma-1}$$

Let us rewrite this as follows:

$$\frac{M_{ix}^H}{M_{ix}^F} = (\frac{\chi_i^H}{\chi_i^F}) \cdot \frac{A_i}{\tau_i^{\sigma-1} \cdot B_i} \cdot \left(\frac{p_i^H(\overline{\phi}_i^H)}{p_i^F(\overline{\phi}_i^F)}\right)^{\sigma-1}$$

where $A_i \equiv (\frac{Y^H}{Y^F})(\frac{f_i}{f_{ix}})(\frac{\phi_{ix}^{*F}}{\phi_i^{*F}})^{\sigma-1} - \chi_i^F(\frac{\overline{\phi}_{ix}^F}{\overline{\phi}_i^F})^{\sigma-1}$ and $B_i \equiv 1 - \chi_i^H(\frac{Y^H}{Y^F})(\frac{f_{ix}}{f_i})(\frac{\phi_i^{*H}}{\phi_{ix}^{*H}})^{\sigma-1}(\frac{\overline{\phi}_{ix}^H}{\overline{\phi}_i^H})^{\sigma-1}$.

The relative exporter mass thus depends upon the ratio of the fractions of exporters among active

firms in the two countries (χ_i^H / χ_i^F), the terms A_i and B_i, and the relative average price of

domestic products in the two countries ($p_i^H(\overline{\phi}_i^H)/ p_i^F(\overline{\phi}_i^F)$). Let us examine these four factors in

order.

- $\dfrac{\chi_i^H}{\chi_i^F}$ vs $\dfrac{\chi_j^H}{\chi_j^F}$: As already shown in (A.26), $\dfrac{\chi_i^H}{\chi_i^F} > \dfrac{\chi_j^H}{\chi_j^F}$.

- A_i vs A_j: With other things being equal, the first term is larger in A_i from (A.23), but the second term for subtraction is mixed due to (A.23) (smaller in A_i) and (A.25) (greater in A_i). The comparison is thus not completely clear without specifying all the parameter values and the function of productivity distribution, but it is more likely that $A_i > A_j$.

- B_i vs B_j: With other things being equal, the first variable in the second term for subtraction is greater in B_i from (A.24) but the last two variables are mixed due to (A.22). The comparison is thus not completely clear without specifying all the parameter values and the function of productivity distribution, but it is more likely that $B_i < B_j$.

- $\dfrac{\overline{p}_i^H}{\overline{p}_i^F}$ vs $\dfrac{\overline{p}_j^H}{\overline{p}_j^F}$: From the optimal pricing Equation (2.5), the relative average price depend on two factors: the ratio of the average productivity of active firms in the two countries, and the relative factor prices. The relative average price takes the following form:

$$\frac{\overline{p}_i^H}{\overline{p}_i^F} = (\frac{\overline{\phi}_i^F}{\overline{\phi}_i^H})\left\{\left(\frac{s^H / w^H}{s^F / w^F}\right)^{\beta_i}\left(\frac{w^H}{w^F}\right)\right\} \tag{A.27}$$

Although the second term of the right-hand side of (A.27) issmaller for Industry i since $\dfrac{s^H}{w^H} < \dfrac{s^F}{w^F}$ and $\beta_i > \beta_j$, we cannot be assured of the first term without specifying all the parameter values and the function of productivity distribution. However, let us focus our attention on the case in which the relative price follows the comparative advantages

of the countries; i.e., $\dfrac{\bar{p}_i^H}{\bar{p}_i^F} < \dfrac{\bar{p}_i^H}{\bar{p}_i^F}$.

Considering from these examinations of the four elements, ambiguity remains depending on the parameter values, the shape of the productivity distribution, and the exogeneous size of total income of each country. It is, however, likely to be more generally the case that $\dfrac{M_{ix}^H}{M_{ix}^F} > \dfrac{M_{jx}^H}{M_{jx}^F}$, which means that each country will have a larger mass of exporters in its comparative advantage industries relative to the other country.

Table 1: U.S. Import and Varieties in 1990

	Total Import	Manufacturing Import
Number of Exporters	153	153
Number of Varieties	182,230	171,322
Total Import Value (in million $)	495,260	409,953

Notes:
1. The data are from Feenstra, Romalis, and Schott (2002).
2. Manufacturing import is the import in the industries classified as the 4-digit U.S. SIC (1987 version) 2011 through 3999.
3. Exporters in this table include overseas territories of countries.
4. The number of varieties is defined as the number of commodities classified by the 10-digit Harmonization System (HS) that the U.S. imports *from each exporter*. (I.e., the same 10-digit HS commodities imported from different exporters are counted as different varieties.)
5. Import value is the customs value of general imports. General Imports measure the total physical arrivals of merchandise from foreign countries, whether such merchandise enters consumption channels immediately or is entered into bonded warehouses or Foreign Trade Zones under Customs custody.

Table 2: Country List (as of 1990, 115 countries)

Algeria	Guinea-Bissau	Poland
Angola	Guyana	Portugal
Argentina	Haiti	Reunion
Australia	Honduras	Rwanda
Austria	Hong Kong	Saudi Arabia
Bangladesh	Hungary	Senegal
Barbados	Iceland	Seychelles
Belgium	India	Sierra Leone
Benin	Indonesia	Singapore
Bolivia	Iran	Somalia
Brazil	Ireland	South Africa
Burkina Faso	Israel	South Korea
Burundi	Italy	Spain
Cameroon	Jamaica	Sri Lanka
Canada	Japan	Sudan
Central African Republic	Jordan	Suriname
Chad	Kenya	Sweden
Chile	Madagascar	Switzerland
China	Malawi	Syria
Colombia	Malaysia	Taiwan
Congo	Mali	Tanzania
Costa Rica	Malta	Thailand
Cote d'Ivoire	Mauritania	Togo
Cyprus	Mauritius	Trinidad and Tobago
Czechoslovakia	Mexico	Tunisia
Denmark	Morocco	Turkey
Dominican Republic	Mozambique	U.S.S.R.
Ecuador	Netherlands	Uganda
Egypt	New Zealand	United Kingdom
El Salvador	Nicaragua	Uruguay
Fiji	Niger	Venezuela
Finland	Nigeria	Yugoslavia
France	Norway	Zaire
Gabon	Oman	Zambia
Gambia	Pakistan	Zimbabwe
Germany	Panama	
Ghana	Papua New Guinea	
Greece	Paraguay	
Guatemala	Peru	
Guinea	Philippines	

Table 3: Factor Abundance of Countries: Skilled Labor (*S*) to Unskilled Labor (*U*) Ratio

Summary Statistics:

Variables	Mean	Std. Dev.	Min.	Max.
S/U ratio	1.879	0.553	1.075	3.369
S/U ratio Relative to U.S.A.	0.567	0.167	0.325	1.017

Number of countries: 115

10 most skilled labor-abundant countries:

Country	*S/U* ratio	*S/U* relative to U.SA
New Zealand	3.369	1.017
Hungary	3.086	0.932
Norway	3.010	0.909
Canada	3.008	0.908
Denmark	2.999	0.905
Australia	2.981	0.900
Finland	2.833	0.855
Sweden	2.825	0.853
Israel	2.818	0.851
Belgium	2.768	0.836

10 most unskilled labor-abundant countries:

Country Name	*S/U* ratio	*S/U* relative to U.S.A
Niger	1.075	0.325
Guinea-Bissau	1.078	0.325
Benin	1.098	0.332
Mali	1.116	0.337
Rwanda	1.119	0.338
Gambia	1.119	0.338
Sudan	1.130	0.341
Mozambique	1.156	0.349
Central African Republic	1.184	0.357
Nigeria	1.217	0.367

Note: The relative skilled-labor abundance to unskilled labor (*S/U*) is measured by the human capital-to-labor ratio provided by Hall and Jones (1999).

Table 4: Input Factor Intensity of Industries:
      Skilled-labor (*S*) to Unskilled-labor (*U*) Ratio

Summary Statistics:

Variables	Mean	Std. Dev.	Min.	Max.
S-intensity	0.296	0.124	0.078	0.827
U-intensity	0.704	0.124	0.173	0.922

Number of industries: 394

10 Most Skilled-labor intensive industries

SIC	Industry Description	*S*-intensity	*U*-intensity
2721	Periodicals	0.827	0.173
2731	Book Publishing	0.766	0.234
3571	Electronic Computers	0.718	0.282
3761	Guided Missiles & Space Vehicles	0.685	0.315
2711	Newspapers	0.676	0.324
2741	Miscellaneous Publishing	0.638	0.362
2835	Diagnostic Substances	0.633	0.367
3572	Computer Storage Devices	0.627	0.373
3826	Analytical Instruments	0.617	0.383
2086	Bottled and Canned Soft Drinks	0.604	0.396

10 Most Unskilled-labor intensive industries

SIC	Industry Description	*S*-intensity	*U*-intensity
2322	Men's & Boys' Underwear & Nightwear	0.078	0.922
2281	Yarn Spinning Mills	0.089	0.911
2284	Thread Mills	0.097	0.903
2211	Weaving Mills, Cotton	0.102	0.898
2436	Softwood Veneer and Plywood	0.105	0.895
2015	Poultry and Egg Processing	0.108	0.892
3263	Fine Earthenware Food Utensils	0.111	0.889
2325	Men's & Boys' Trousers & Slacks	0.116	0.884
2321	Shirts, Men's and Boys'	0.120	0.880
3144	Women's Footwear, Except Athletic	0.120	0.880

Notes:
1. The source of the data for factor intensity is 1992 U.S. Census of Manufactures.
2. Industries are classified according to the 4-digit U.S. Standard Industrial Classification (SIC; 1987 version).
3. Skilled-labor (*S*) intensity is defined as the share of non-production workers in the total number of employees; and unskilled-worker (*U*) intensity is defined as the share of production workers. The sum of S-intensity and U-intensity is thus one for each industry.

Table 5: List of Countries in Aggregate North and South

North (51 countries)		South (64 Countries)	
Argentina[#, ##]	Sri Lanka[#, ##]	Algeria	Oman
Australia	Sweden	Angola	Pakistan
Austria[#, ##]	Switzerland	Bangladesh	Papua New Guinea
Barbados	Taiwan[##]	Benin	Paraguay
Belgium	Thailand[#, ##]	Bolivia	Portugal
Canada	Trinidad and Tobago[#, ##]	Brazil	Reunion
Chile[#, ##]	United Kingdom	Burkina Faso	Rwanda
China[#, ##]	Uruguay[#, ##]	Burundi	Saudi Arabia
Costa Rica[#, ##]	U.S.S.R.	Cote d'Ivoire	Senegal
Cyprus	Venezuela[#, ##]	Cameroon	Seychelles
Czechoslovakia	Yugoslavia	Central African Republic	Sierra Leone
Denmark		Chad	Singapore
Ecuador[#, ##]		Colombia	Somalia
Egypt[#, ##]		Congo	Sudan
Fiji[##]		Dominican Republic	Suriname
Finland		El Salvador	Syria
France[#, ##]		Gabon	Togo
Germany		Gambia	Tunisia
Greece[##]		Ghana	Turkey
Guyana[#, ##]		Guatemala	Uganda
Hong Kong		Guinea	Tanzania
Hungary		Guinea-Bissau	Zaire
Iceland		Haiti	Zambia
Ireland		Honduras	Zimbabwe
Israel		India	
Italy[#, ##]		Indonesia	
Japan		Iran	
Malaysia[#, ##]		Jamaica	
Malta[##]		Jordan	
Morocco[#, ##]		Kenya	
Netherlands		Madagascar	
New Zealand		Malawi	
Norway		Mali	
Panama[#, ##]		Mauritania	
Peru[#, ##]		Mauritius	
Philippines[#, ##]		Mexico	
Poland		Mozambique	
South Korea		Nicaragua	
South Africa[#, ##]		Niger	
Spain[#, ##]		Nigeria	

Notes:
Countries in North are those with the skilled-to-unskilled labor ratio (S/U) above the sample mean.
# indicates the countries grouped into South if the cutoff of 75 percentile value of S/U is applied (22 countries); and ## indicates those grouped into South if the cutoff of 0.7 of S/U relative to the U.S. is applied (26 countries).

Table 6: Skilled-to-Unskilled Labor Ratios (S/U) of North and South

	S/U (group average)	S/U relative to U.S. (group average)
North	2.40	0.72
South	1.47	0.44

Note: The relative factor abundance (*S/U*) is measured by the human capital to labor ratio in Hall & Jones (1999).

Table 7: Regressions for Aggregate North and South

Dependent Variable: Log of aggregate no. of varieties as the share in the total no. of varieties imported by the U.S. ($n\_share_{i,A}$)

	North	South
skill	0.256***	-1.21***
	(0.041)	(0.208)
constant	-0.256***	-1.54***
	(0.014)	(0.063)
Observations	394	385
R^2	0.10	0.12

Notes:
1. Regression equation is (4.1).
2. *skill* is skilled-labor intensity of each industry.
3. Robust standard errors are in parentheses.
4. *, **, and *** indicate that the coefficient estimate is significant at the 1%-level, 5%-level, and 10%-level, respectively.

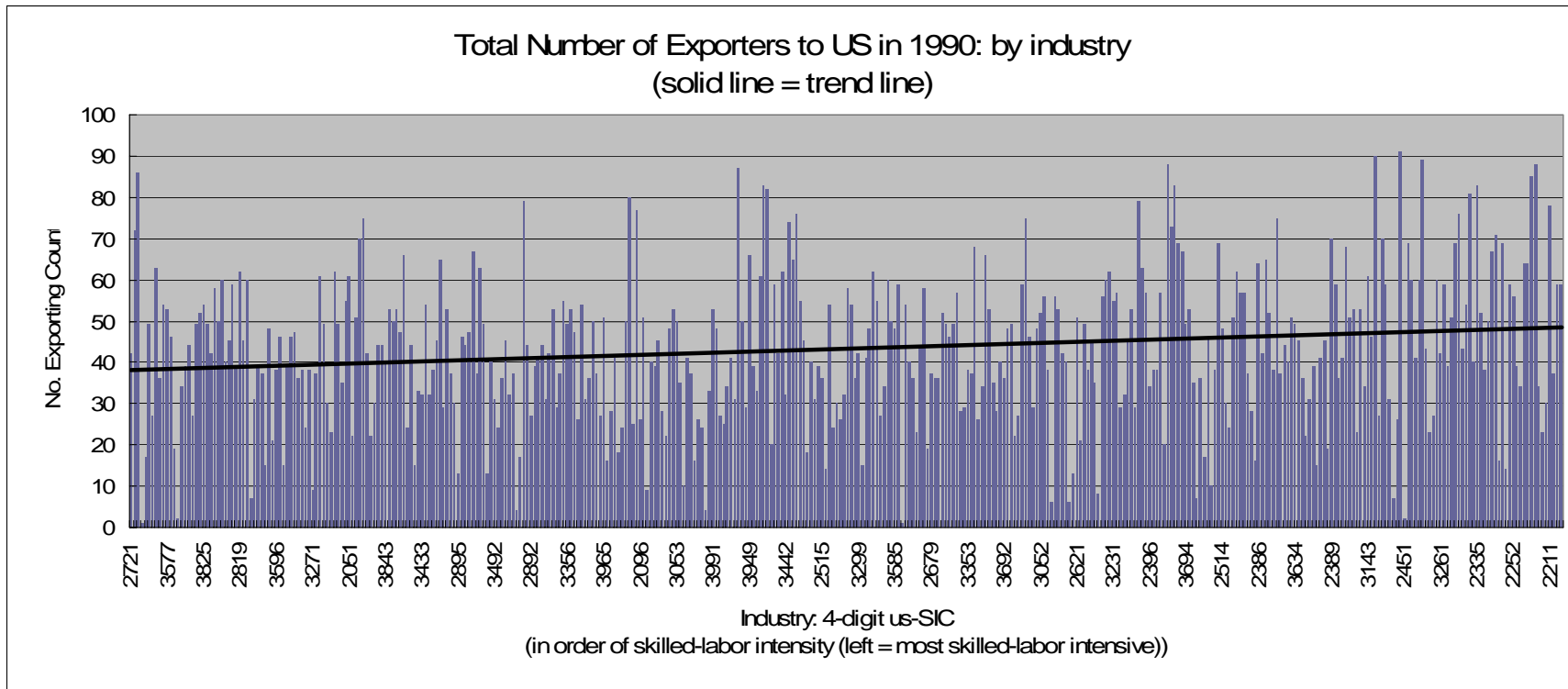## Table 8: Pooled Regression for Individual Exporters

Dependent Variable: Log of no. of exported varieties in each industry as the share in the total no. of varieties imported by the U.S. (n_share_{ic})

skill_i	-2.72***
	(0.566)
skill_i * (*S/U*)_*c*	4.14***
	(0.802)
Observations	17,050
R^2	0.13

Notes:
1. Regression equation is (4.4). Country-specific dummies are included.
2. *skill_i* is skilled-labor intensity of each industry; and (*S/U*)_*c* is skilled-to-unskilled labor endowment ratio in each exporter, relative to the U.S.
3. Standard errors in parentheses are clustered by country.
4. *, **, and *** indicate that the coefficient estimate is significant at the 1%-level, 5%-level, and 10%-level, respectively.

Figure 1: Number of Exporters to the U.S. in each manufacturing industry; in 1990

Total Number of Exporters to US in 1990: by industry
(solid line = trend line)

No. Exporting Count

Industry: 4-digit us-SIC
(in order of skilled-labor intensity (left = most skilled-labor intensive))
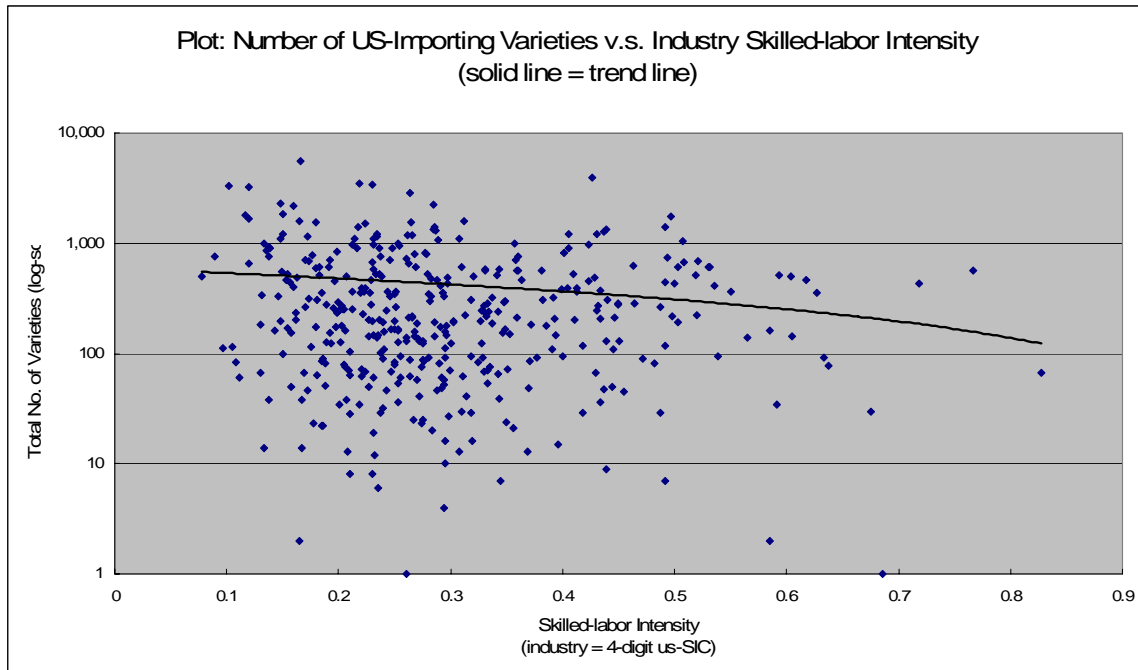
Notes:
1. Industries are listed in order of skilled-labor intensity. The left is the most skilled-labor intensive, and the right is the least.
2. Skilled-labor intensity is defined as the share of non-production workers in the total number of employees.

Figure 2: Scatterplot of Number of Exporters v.s. Industry Skilled-labor Intensity (U.S. Manufacturing Imports in 1990)

Plot: Number of Exporter v.s. Industry Skilled-labor Intensity
(solid line = trend line)
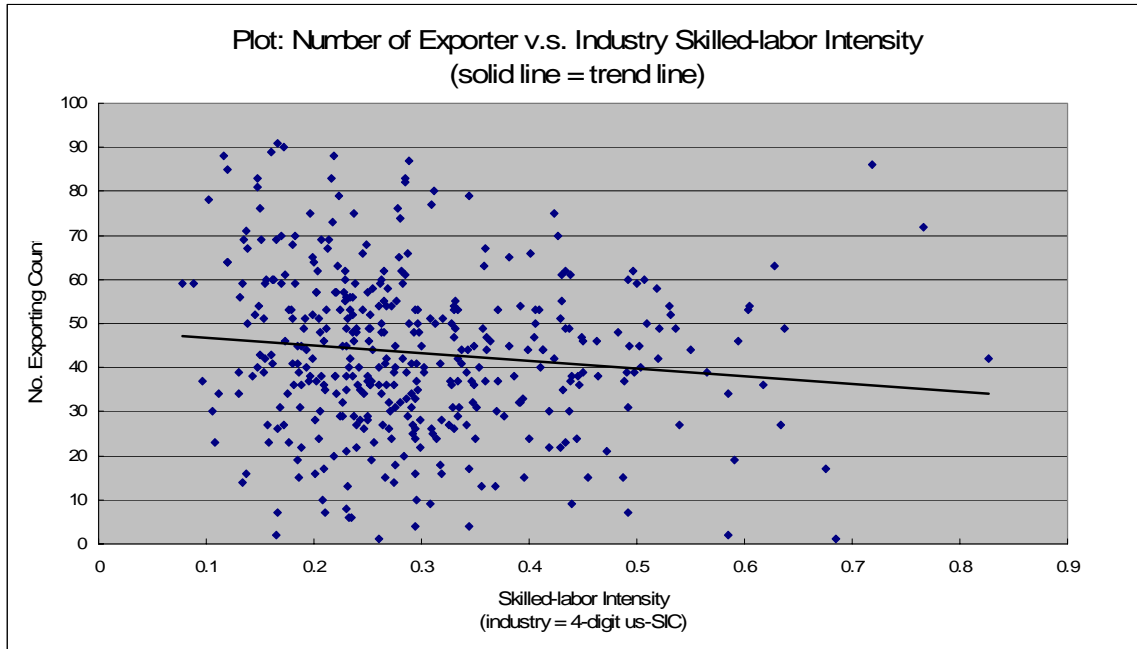
Note: Skilled-labor intensity is defined as the share of non-production workers in the total number of employees in each industry.

Figure 3: Scatterplot of Number of Varieties v.s. Industry Skilled-labor Intensity (U.S. Manufacturing Imports in 1990)

Plot: Number of US-Importing Varieties v.s. Industry Skilled-labor Intensity
(solid line = trend line)

Notes:

1. The number of varieties in each industry is defined as the number of 10-digit HS commodities that the U.S. imports *from each exporter* in each 4-digit SIC industry (i.e., the same HS commodity imported from different countries are counted as different varieties). The mapping between the 10-digit HTS and the 4-digit SIC is according to Feenstra, Romalis, and Schott (2002).

2. Skilled-labor intensity is defined as the share of non-production workers in the total number of employees in each industry.

Figure 4: Individual Exporter Regression:
Scatterplot of Slope Coefficient v.s. Skill Abundance of the Country
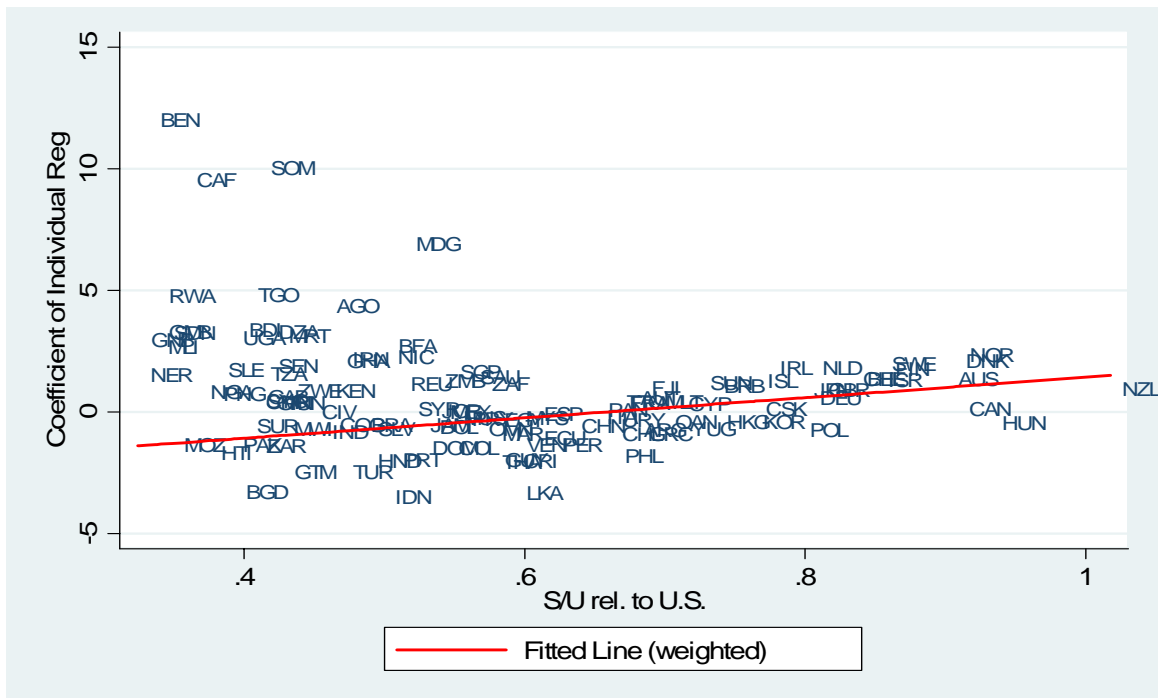
Notes:

1. The individual regression specification is $\log(n\_share_{i,c}) = \alpha_c + \Lambda_c skill_i + \varepsilon_{i,c}$ where i indexes 4-digit SIC industries and c indexes exporter countries. The regression is performed for each country to obtain the country-specific slope coefficient $\hat{\Lambda}_c$.

2. The figure plots $\hat{\Lambda}_c$ for each country (marked by the ISO country code) against the skilled-labor to unskilled-labor ratio of the country $((S/U)_c)$ relative to the U.S.

3. The fitted line is based on the weighted regression of $\hat{\Lambda}_c$ on $(S/U)_c$ with the observations weighted by the number of 4-digit industries for each country in the sample. (That is, the weight is the number of observation used for each individual country regression.)

Figure 5-1: Exporter's Relative Factor Abundance, Industry Factor Intensity, and Number of Varieties in U.S. Manufacturing Imports in 1990 (1): Selected Skilled Labor-abundant Countries (relative to unskilled: *S/U*)
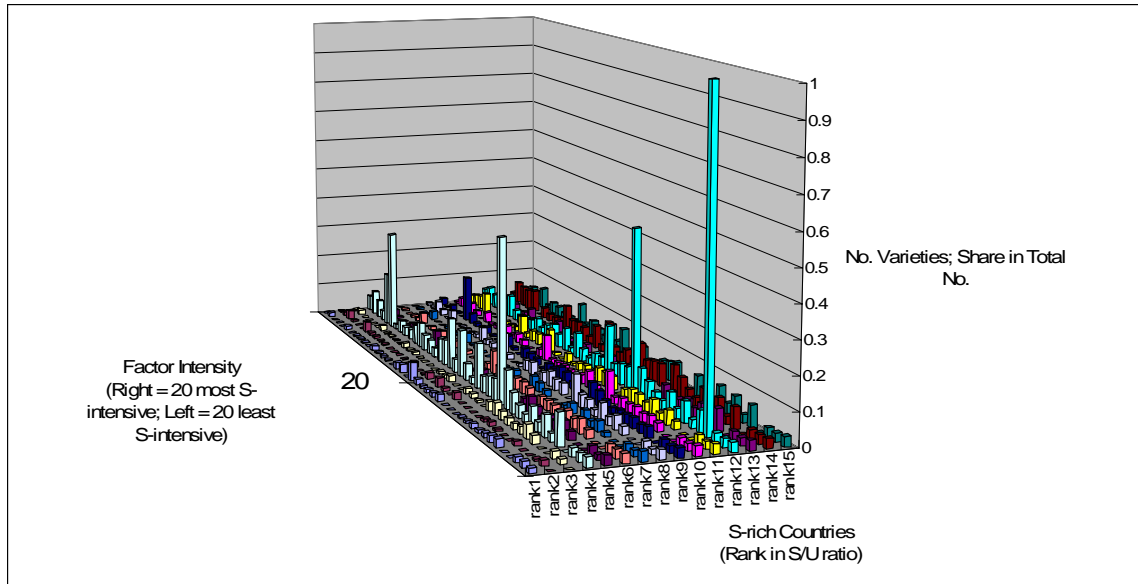
Rank in *S/U* ratio	Exporter	Average variety number share in 20 most skill-intensive industries	Average variety number share in 20 most unskill-intensive industries
1	New Zealand	0.0113	0.0084
2	Hungary	0.0065	0.0076
3	Norway	0.0161	0.0046
4	Canada	0.0758	0.0780
5	Denmark	0.0226	0.0099
6	Australia	0.0259	0.0139
7	Finland	0.0160	0.0057
8	Sweden	0.0308	0.0176
9	Israel	0.0273	0.0205
10	Belgium	0.0249	0.0200
11	Switzerland	0.0275	0.0245
12	United Kingdom	0.1250	0.0461
13	Netherlands	0.0294	0.0146
14	Germany	0.0469	0.0457
15	Japan	0.0376	0.0389

Notes: The numbers of varieties are as the shares in the total number of varieties that the U.S. imports in each industry.

Figure 5-2: Exporter's Relative Factor Abundance, Industry Factor Intensity, and Number of Varieties in U.S. Manufacturing Imports in 1990 (2): Selected Unskilled Labor-abundant Countries (relative to skilled: *U/S*)
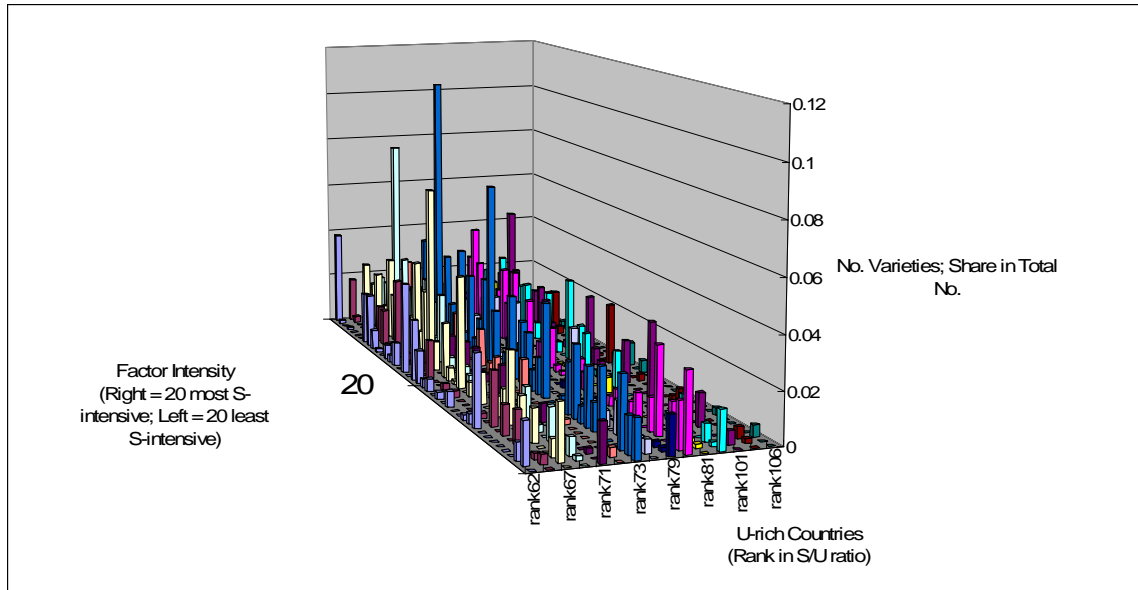
Rank in *S/U* ratio	Exporter	Average variety number share in 20 most skill-intensive industries	Average variety number share in 20 most unskill-intensive industries
106	Nigeria	0.0006	0.0011
105	Haiti	0.0014	0.0042
101	Pakistan	0.0033	0.0090
84	Guatemala	0.0028	0.0101
81	Cote d'Ivoire	0.0010	0.0014
80	India	0.0085	0.0155
79	Kenya	0.0017	0.0015
74	Turkey	0.0035	0.0078
73	Brazil	0.0147	0.0244
72	Honduras	0.0012	0.0057
71	El Salvador	0.0022	0.0051
70	Indonesia	0.0023	0.0186
67	Portugal	0.0083	0.0195
63	Jamaica	0.0029	0.0055
62	Dominican Republic	0.0037	0.0090

Notes: The numbers of varieties are as the shares in the total number of varieties that the U.S. imports in each industry.