Discussion Paper, Series A, No.2015-288

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9.2015

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Industrial Location and North-South Trade in Vertically-linked Industries*

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Abstract

This study clarifies how a reduction in trade costs affects location and economic welfare in an economy with a vertically-linked industry. We focus on location in upstream and downstream sectors and economic welfare for a reduction in trade costs for intermediate goods. We show that the reduction in trade costs makes upstream and downstream production in the North move to the South, and further liberalization makes some of the upstream productions remove back to the North. We also demonstrate that such reduction in trade costs improves world welfare but does not necessarily benefit for each country.

Keywords: Industrial location; Vertically-linked industries; North-South trade

JEL classifications: F12; F15; F21; R12

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*We would like to thank Kazunobu Hayakawa, Jota Ishikawa, Toshiyuki Matsuura, Takumi Naito, Armand J. Garcia Pires for their variable comments and suggestions. The usual disclaimer applies. This work was partially supported by JSPS KAKENHI Grant Numbers 26380318 and 15K05450. Kurata also gratefully acknowledges the support by a grant-in-aid from Zengin Foundation for Studies on Economics and Finance.

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1 Introduction

In the last several decades, we have witnessed dramatic change of firms' production location in vertically-linked industries. In the past, for market proximity, firms in upstream and downstream industries tend to locate in the same region in a country. Upstream firms producing intermediate goods enjoys the location near those producing final goods (forward linkage) and downstream firms producing final goods tend to locate near those producing intermediate goods (backward linkage). Of late, however, many firms producing final goods choose different locations from firms producing intermediate goods, and vice versa. In this situation, vertical specialization and supply-chain trade occur. They lead to recent increase in trade volume all over the world[1]. In most cases, firms move their location to developing countries with low wage. Further, quite recently, we observe "reshoring" of manufacturing; some firms in developed countries which have plants in foreign countries move their plants back to their home countries.

A decline in trade costs is a major reason for such dramatic change in production location. Trade costs, including transport costs and policy barriers such as tariffs, have been significantly declined in the recent economy.[2] Furthermore, progress of information and communication technology (ICT)

[1]On the recent expansion of vertical specialization and supply-chain trade, see Hummels, et al. (2001) and Baldwin and Lopez-Gonzalez (2014).

[2]For example, the average import tariffs are declined approximately 14% in 1952 to 3.9% in 2005 as a result of trade liberalization and air transport cost dropped by 92% between 1955 and 2004. (WTO, 2008).

reduces trade costs by making communications at trade costless, which is critical for the vertically-linked industries.

We are interested in how a reduction in trade costs makes the location change in vertically-linked industries. We focus on location between the developed and developing countries with different technologies and wage levels. In general, the developed countries tend to have superior technologies, while the developing countries tend to have low wage levels. In vertical-linked industries, forward and backward linkage affect the location as well. So, the determination of production location is a little bit complex. In the recent trend of trade liberalization, it is interesting to see how the production location change for a reduction in trade costs.

Several studies examine the effect of a reduction in trade costs on location in vertically-linked industries. Venables (1996) describes the effect of transport costs on the location between two symmetric regions. Baldwin and Venables (2013) focus on production process ("Snake" and "Spider") to explain the change in location between developed and developing countries in vertically-linked industry. We have a different approach to them to address the question.

Furthermore, such change in location must lead to affect wage, income, and economic welfare. Although several existing studies illustrate the change in firm or industrial location, there are not many studies focusing on the change in welfare associated with the change in production location. Clarifying the change in economic welfare must be significant from the viewpoint

of policies in the vertically-linked industries.

The purpose of this paper is to clarify the effect of a reduction in trade costs on location and economic welfare.[3] In order to address the above questions, we consider a North-South trade model with a vertically-linked industry. The North and the South have two production sectors, manufacturing and agricultural sectors, and the former consists of the upstream industry providing intermediate goods whose market is monopolistically competitive, and the downstream industry providing final goods whose market is perfectly competitive. The intermediate goods are specific part of the final goods and highly-advanced goods necessary for some knowledge-intensive activities. Two kinds of labor, skilled and unskilled labor, exist in the economy. Skilled labor can be used as a fixed input to engage in the knowledge-incentive activities in upstream industry,[4] while unskilled labor is used as a variable input to conduct simple work in the downstream industry and agricultural sector. The North has superior technology while the South has a lower wage level

[3]We have a quite similar motivation to Fujita and Thisse (2006). They consider an industry whose technology requires skilled and unskilled labors for the production. In their model, skilled labor is used for headquarter services required for the production of the goods. Under this setting the headquarter services works as an intermediate good. However, because the headquarter service is inside a firm, it is not delivered through markets and no trade costs other than communication cost are considered in the intermediate goods sector. In contrast, we consider the firms in upstream and downstream firms separately and the intermediate good is obtained from the market. Furthermore, in their model, the skilled labor is assumed to be mobile between regions. In reality, however, the movement of labor is not so smooth in some regions and countries. For example, the United Nations (2011) reports that the share of immigrants in Asia is only 1.5%, which implies that the labor movement in Asia is not smooth.

[4]Skilled labor can also do simple work as unskilled labor, but in this case there are no differences in efficiency of production.

for unskilled labor. As an initial situation, all firms in the upstream and downstream industries locate in the North. Then, we examine the effect of the reduction in trade costs on industrial location, real wage in labor, and social welfare.

As trade costs, we focus on trade cost for intermediate goods because we think it is relatively more important than that for final good for the location in vertically-linked industry. Firms producing intermediate goods must care the specific needs for firms producing final goods. So, they have some invisible costs as well as transport cost. Considering recent progress of ICT, we believe that we need to clarify the effect of a reduction in the trade cost for intermediate goods.

From the analysis, we obtain the following results: (i) If trade cost is below the threshold level, the downstream firms move to the South and vertically intra-industry trade occurs. Following this move, some of the upstream firms also move to the South, but further reduction in trade cost makes the upstream firms to move back to the North; (ii) Wage for unskilled labor increases as trade cost declines, while wage for skilled labor does not necessarily increased because of the drastic jump of the production location; and (iii) A decline in trade cost improves overall welfare, but does not necessarily improve each country's welfare. In particular, there are possibilities that the North's welfare is decreased by the reduction in trade costs because of a reduction in wage for skilled labor. The results suggest that the recent trend of regional trade agreements leads to reshoring of firms and is favorable

for the world economy, but it may not be favorable for developed countries.

The reminder of this paper is organized as follows. In section 2, we propose a model to address our questions. In section 3, we clarify a mechanism behind determination of wage rate for skilled labor. In section 4, we consider how a reduction in trade costs affects industrial location and trade patterns. In section 5, we clarify how the change in industrial location affects the economic welfare. Lastly, in section 6, we provide simple concluding remarks.

2 The Model

We develop a North-South trade model with two sectors, manufacturing and agriculture, and two factors, skilled and unskilled labors. The manufacturing sector comprises a continuum of industries à la Dornbusch, Fisher, and Samuelson (1977) and each industry is further split into two subsectors, upstream (intermediate-good) and downstream (final-good) sectors. The North and South are identical for access to the downstream technology, while they are different in regard to technology in the upstream and agricultural sectors. The agricultural sector is a single production sector in which a homogeneous good is produced with the constant-returns-to-scale technology. The market of the agricultural good is perfectly competitive and it can be freely shipped between countries. In what follows, we regard this good as a numeraire and assume that the agricultural sector always operates in the both countries.

In the manufacturing sector, industries are indexed by z, which varies over the unit interval $[0, 1]$. In each industry, upstream sector produces differenti-

ated intermediate goods, and downstream sector assembles the intermediate goods into a homogeneous final good. The intermediate goods are produced with increasing-returns-to-scale technology and its markets are monopolistically competitive, while the final good is produced with constant-returns-to-scale technology and its markets are perfectly competitive. The final goods are costlessly traded between countries, whereas the intermediate goods are subject to iceberg trade cost, $\tau > 1$.

We assume that supplies of skilled and unskilled labors are fixed and that these labors are immobile between countries but freely mobile between sectors. Each of them supplies one unit of either skilled or unskilled labor. The upstream firms requires the knowledge-intensive activities such as R&D or headquarter services, which are conducted by the skilled labor. The knowledge-intensive activities are associated with fixed cost. In contrast, the other production activities are regarded as simple works that no specific skills are necessary. The simple works can be done by unskilled labor as well as skilled labor. We assume that in the simple work there is no difference between skilled and unskilled labor in terms of efficiency. Such simple works are associated with variable cost.

In the rest of this section, we explain the details of our model. Here we simply describe the North because the analogous equations hold for the South. Throughout this paper, asterisks are attached on variables related to the South.

2.1 Demand

All consumers have identical preference expressed by the following quasi-linear utility functions:

$$u = \alpha \int_0^1 \ln x(z) dz + x_A, \quad \alpha > 0, \tag{1}$$

where $x(z)$ and x_A stand for each consumer's consumption of the final good in industry z and the agricultural good, respectively. Under the preferences, the amount of income spent on each final good equals to α, which is assumed to be strictly less than each consumer's income.[5]

Let H and L be the supply of skilled and unskilled labor, respectively. Then, there are $H + L$ consumers in the North. The aggregate demand for the final good z is obtained by

$$X(z) = \frac{\alpha(H + L)}{P(z)}, \tag{2}$$

where $P(z)$ represents the price of the final good in industry z.

2.2 Supply

We first state about the agricultural sector. The agricultural good is produced due to the simple work by using labor. Production technology for the agricultural sector requires a units of labor for one unit of the agricultural good. Since the agriculture good is the numeraire, wage rate of unskilled labor, which will be a lower bound for wage rate of skilled labor, is given by

[5]This assumption implies that consumers always consume the final goods, i.e., $x_A > 0$.

$1/a$. In addition, we assume the North can produce the agricultural good more efficiently than the South, i.e., $a < a^*$. Therefore, the wage rate of unskilled labor is higher in the North than in the South.

We next describe the manufacturing sector. In each industry, final good is produced by using labor and industry-specific intermediate goods. The intermediate goods are aggregated by a symmetric CES production function as in Dixit and Stiglitz (1977). The composite of intermediate good is combined with labor, strictly, skilled and/or unskilled labor, according to a Cobb-Douglas technology with share coefficients β.[6] Then, unit cost for the final good produced in industry z is given by

$$C(z) = AG(z)^{\beta} a^{\beta-1}, \tag{3}$$

where $A \equiv \beta^{-\beta}(1-\beta)^{\beta-1}$ and $G(z)$ is a price index for the intermediate-good defined as

$$G(z) \equiv \left[\int_0^{n(z)} p(i(z))^{1-\sigma} di + \tau^{1-\sigma} \int_0^{n^*(z)} p(i^*(z))^{1-\sigma} di^* \right]^{\frac{1}{1-\sigma}}, \tag{4}$$

where $p(\cdot)$ is a price of an intermediate good with the corresponding varieties index, $n(z)$ and $n^*(z)$ denote the number of variety of intermediate goods produced in the North and the South, respectively, and $\sigma > 1$ is the elasticity of substitution between every pair of intermediate goods.

Each industries are different in upstream technology, but the upstream firms have access to the same technology within each industry. In industry z,

[6]For simplicity, we assume the share coefficients are identical across industries.

$f(z)$ units of the skilled labor are needed as a fixed input for the knowledge-intensive activity to produce a particular variety of intermediate good, and $b(z)$ units of labor are required to produce one unit of output. In the presence of fixed cost, each firm produces a distinct variety since it can do better by introducing a new variety than by competing for market share in the existing varieties. In equilibrium, all firms earn zero profits due to free entry and exit. Let $T(z)$ be a technology index as

$$T(z) = \frac{f^*(z)}{f(z)} \cdot \left(\frac{b^*(z)/a^*}{b(z)/a} \right)^{\sigma-1}. \tag{5}$$

We assume that $T(z)$ is differentiable and strictly decreasing in z. This assumption implies that the North has a comparative advantage in production of intermediate goods in a lower spectrum of industries and the South does in a higher spectrum.

Finally, we derive the equilibrium prices of intermediate goods. Under the downstream technology, the North's demand for intermediate good $i(z)$ is given by

$$d(i(z)) = \beta p(i(z))^{-\sigma} G(z)^{\sigma-1} C(z) Y(z) \tag{6}$$

where $Y(z)$ is the output of the final good produced in industry z. With iceberg trade costs $\tau > 1$, the South's demand for the intermediate good is obtained as

$$d(i^*(z)) = \phi \beta p(i(z))^{-\sigma} G^*(z)^{\sigma-1} C^*(z) Y^*(z), \tag{7}$$

where $\phi \equiv \tau^{1-\sigma} < 1$. An individual upstream firm is negligible in its size relative to the whole upstream market, so it takes as given all terms other

than price, $p(i(z))$, in the above demand functions. Therefore, the first order condition yields the following the pricing rule:

$$p(i(z)) = p(z) = \frac{\sigma}{\sigma - 1} \cdot \frac{b(z)}{a}. \tag{8}$$

This shows that the equilibrium prices are set as a constant markup over marginal cost. From (8), we also find that the technology index given in (5) reflects the difference between countries in marginal cost as well as fixed input requirement in industry z.

3 Wage rate for skilled labor

Before analyzing industrial location, it is helpful for us to consider the determination of the equilibrium wage rate for skilled labor. Focusing on the North, the equilibrium wage rate for skilled labor equals to either of the rate such that the demand for the skilled labor equals its supply or its lower bound, i.e., the wage rate for unskilled labor, $1/a$. If there is a strong demand, wage rate of the skilled labor exceeds the lower bound. In this case, all owners of the skilled labor serve upstream firms to engage in the knowledge-based activities. In contrast, if the demand is weak, the wage rate for the skilled labor equals to its lower bound and some owners of skilled labor engage in the simple work.

In order to derive the equilibrium wage rate, we consider the situation in which there is a strong demand such that the skilled labor is engaged only in the knowledge-intensive work and only in the North produces the

intermediate goods in industry $z \in [0, \bar{z})$.[7]

Let $\bar{H}$ and $\bar{L}$ be the total endowments of skilled and unskilled labor in the economy, respectively. First, from (2), the aggregate consumer's spending on the final good in industry z equals to $\alpha(\bar{H} + \bar{L})$. Second, from (4) the final sector in industry z spends $100 \times \beta\%$ of its revenue on intermediate goods. Finally, the pricing rule given in (8) and the zero-profit condition imply that each upstream firm spends $100 \times 1/\sigma\%$ of its revenue on fixed input. Putting all results together, we find that the total fixed cost incurred by upstream firms in industry z equals to $\alpha\beta(\bar{H} + \bar{L})/\sigma$. Since the North solely produces intermediate goods in the interval $[0, \bar{z})$ and the South does those in the interval $(\bar{z}, 1]$, the North and South's aggregate demand for skilled labor are respectively given by

$$H_D = \frac{\alpha\beta(\bar{H} + \bar{L})\bar{z}}{\sigma w} \quad \text{and} \quad H_D^* = \frac{\alpha\beta(\bar{H} + \bar{L})(1 - \bar{z})}{\sigma w^*}, \tag{9}$$

Substituting each country's skilled labor endowment into the LHS of each demand equation and solving for the wage rate, we obtain the equilibrium wage rates of skilled labor in the North and South as

$$w = \frac{\alpha\beta(\bar{H} + \bar{L})\bar{z}}{\sigma H} \quad \text{and} \quad w^* = \frac{\alpha\beta(\bar{H} + \bar{L})(1 - \bar{z})}{\sigma H^*}. \tag{10}$$

Equations (10) show that in each country, wage rate for skilled labor rises as the range of domestic industries with positive outputs of intermediate goods becomes larger. This is because it leads to a rise in the demand for the country's skilled labor as fixed input for the knowledge-intensive activities.

[7] In the subsequent section, the value of $\bar{z}$ will be endogenously determined.

If the wage is lower than the lower limit, i.e., the wage rate of unskilled labor, $1/a$, some owners of skilled labor devote to simple work and receive the lower-limit wage.[8]

We can analytically find the value of $\bar{z}$ for which the wage rate of skilled labor equals to its lower limit for each country. Let z_N and z_S be such values of $\bar{z}$ for the North and South, respectively. By inserting the lower-limit wages into the LHS in (10) and solving for $\bar{z}$, we obtain

$$z_N = \frac{\sigma}{\alpha\beta(\bar{H}+\bar{L})} \cdot \frac{H}{a} \quad \text{and} \quad z_S = 1 - \frac{\sigma}{\alpha\beta(\bar{H}+\bar{L})} \cdot \frac{H^*}{a^*}. \tag{11}$$

If the range of domestic industries with positive outputs of intermediate goods is so large that $\bar{z}$ exceeds z_N, in the North, skilled labor is used only in the knowledge-intensive activities and its wage rate is given by (10). In contrast, if the range of such industries is extremely small and $\bar{z}$ falls short of z_N, the skilled labor is used not only in the knowledge-intensive activities but in the simple work, and its wage rate equals to $1/a$, the lower limit of the wage. Likewise, the South's wage rate of skilled labor is given by (10) if $\bar{z}$ falls short of z_S, or $1/a^*$ otherwise.

4 Industrial Location

This section investigates impacts of a fall in trade costs on industrial location. We start from the situation where all industries, both upstream and

[8]Note that there is no differences between skilled and unskilled labor in terms of efficiency in the simple work.

downstream, operate only in the North because of large trade costs.[9]

4.1 One-way trade

In the initial situation, final goods are produced only in the North. Then, the South specializes in the agricultural sector and traditional one-way trade emerges. We now find a lower bound of trade costs for which the initial situation with one-way trade is a sustainable equilibrium.

First, we explore trade costs for which the North sorely produces all intermediate goods, assuming that all final goods are produced only in the North. Then, the presence of large trade costs ensures that all the production of intermediate goods occurs in the North. We can find a threshold of trade costs which all of the production in the intermediate goods occurs in the North.

Lemma 1

Suppose that all final goods are produced only in the North. Then, all upstream industries operate only in the North if

$$\phi < \frac{\sigma H \cdot T(1)}{\alpha\beta(\bar{L} + \bar{H})a^*} \equiv \hat{\phi}, \tag{12}$$

Proof. *See Appendix A.*

Lemma 1 shows that all the productions of intermediate goods occur in the North if trade costs are sufficiently large. Production location of intermediate

[9]As in a number of existing models with input-output linkages and trade costs, our model also entails multiple equilibria in the presence of large trade costs. Strictly, for large value of τ, the equilibrium division of industries between countries cannot be determined uniquely in a higher spectrum of industries.

goods depends not only on the level of trade costs but also cross-country differences in technology and factor prices. The relative importance of the latter declines as an increase in trade costs. Due to the presence of trade costs, upstream firms in the North have an advantage over those in the South in terms of market access. As an increase in trade costs, this market-access effect becomes more crucial than any other factors.

Next, we focus on the production of the final goods, assuming that all intermediate goods are produced only in the North. As in the case of the intermediate goods, the presence of large trade costs ensures that all the production of final goods occurs in the North. We can obtain a threshold of trade costs that all of the production in the final goods occurs in the North.

Lemma 2

Suppose that all intermediate goods are produced only in the North. Then, all downstream industries operate only in the North if

$$\phi < \left(\frac{a}{a^*}\right)^{(1-\beta)(\sigma-1)/\beta} \equiv \bar{\phi}. \tag{13}$$

Proof. *See Appendix B.*

The threshold $\bar{\phi}$ in (13) consists of the relative wage rate of unskilled labor in both countries. This illustrates the South's advantage in assembly costs of final good, because $a < a^*$ holds. In contrast, no trade costs are necessary to sell produced intermediate goods locally. So, other things being equal, unit costs for production in the downstream sectors are lower in the North than in the South. As the level of trade costs rises, the North's advantage in local

production becomes crucial. Thus, if trade costs are so large that (13) holds, the North's advantage in local production dominates the South's advantage in assembly cost and all the production of final goods are produced in the North.

Putting the above results together, we can find a lower bound of trade costs which the South specializes in the agricultural sector in equilibrium. From Lemmas 1 and 2, the specialization is sustainable in equilibrium if trade costs are sufficiently large, so that $\phi < \min\{\hat{\phi}, \bar{\phi}\}$. For analytical simplicity, in the subsequent analysis, we assume $\bar{\phi} < \hat{\phi}$.[10] Given this assumption, a sufficient condition for the equilibrium to be sustainable is given by (13).

Proposition 1

Equilibrium in which all industries operates only in the North is sustainable as long as (13) is satisfied.

4.2 Vertical specialization

Let us move on to the analysis of changes in industrial location induced by falling trade costs. From Lemma 2, the equilibrium with one-way trade is no longer sustainable once trade costs become small enough to satisfy $\bar{\phi} < \phi$. In this case, the final good production moves to the South and vertical international specialization occurs in the manufacturing sector.

[10]This assumption enables us to avoid the problem of indeterminacy on international devision of industries due to multiple equilibria. To see this, suppose that $\hat{\phi} < \bar{\phi}$ and consider the case in which ϕ rises and, as a result, takes a value between $\hat{\phi}$ and $\bar{\phi}$. Then, from Lemma 1, it is expected that industrial location will change. This change entails the above-mentioned indeterminacy problem because $\bar{\phi}$ gives an upper bound of ϕ for which multiple equilibria arise.

Lemma 3

For $\bar{\phi} < \phi$, all downstream industries operate only in the South.

Proof. *See Appendix C.*

The South, which has cheaper unskilled labor forces, can produce the final good at a lower unit cost relative to the North in all industries. The reason is that in the presence of small trade costs, the cross-country difference in assembly cost becomes significant as a determinant of the gap in the unit cost for production in the downstream sector. The other determinant, the difference in price index for the intermediate good, is less important because trade costs are now not so large.[11] Therefore, if trade costs are so small that $\bar{\phi} < \phi$ holds, the South's advantage in an assembly costs dominates in all industries, so that the South produces all final goods.

In contrast, the production location of the intermediate good depends on the differences between countries both in technology and in factor prices.

Lemma 4

For $\bar{\phi} < \phi$, the upstream sector in industry z operates in the North if

$$\frac{w}{w^*} < T(z) \cdot \phi. \tag{14}$$

Otherwise, it operates in the South.

Proof. *See Appendix D.*

[11] Trade costs are the sole source of the difference in the price index for the intermediate good.

Lemma 4 implies that under a given relative wage of skilled labor, w/w^*, the North exclusively produces intermediate goods in a lower spectrum and the South in a higher spectrum of the industries. To obtain the intuition behind the result, it is useful to rewrite (14) by using (5) as

$$\frac{w^* f^*(z)}{w f(z)} \cdot \left(\frac{b^*(z)/a^*}{b(z)/a} \right)^{\sigma-1} \cdot \phi > 1. \tag{15}$$

Equation (15) shows that the South has a cost disadvantage against the North in the upstream sector in industry z. The first term on the LHS is the ratio of the South's fixed cost to the North's and the second term reflects the analogous ratio for the marginal cost. Because $dT(z)/dz < 0$, these ratios are decreasing in z, so the South is less competitive due to higher production costs in a lower spectrum of industries. The third term, ϕ stands for the market access effect. Since the final goods are produce only in the South, upstream firms in the South have an advantage over those in the North in terms of market access. Hence, the South's disadvantage in production cost is discounted by $\phi < 1$.

As is clear form Lemma 4, we need to derive the relative wage of skilled labor, w/w^*, before turning to the determination of the equilibrium distribution of upstream sectors between countries. This relative wage is obtained by the process in Section 3. As in Section 3, the North sorely produces the intermediate goods in industry $z \in [0, \bar{z})$ and does not produce in the other industry $z \in (\bar{z}, 1]$. Further, we assume that skilled labor is used only as fixed input in the both countries, i.e., $z_N < z_S$. Then, if $\bar{z}$ is in the interval

$[z_N, z_S]$, the relative wage of skilled labor is given by

$$\frac{w}{w^*} = \frac{\bar{z}H^*}{(1-\bar{z})H} \equiv \Omega(\bar{z}) \tag{16}$$

from equation (10).[12] From (16), it is shown that the relative wage of the skilled labor increases in $\bar{z}$. An increase in $\bar{z}$ induces an expansion (reduction) in the range of industries where the North (South) produces the intermediate goods, which leads to a larger (smaller) demand for skilled labor as fixed input in the North (South).

We now find the cross-country distribution of upstream sectors in equilibrium. To keep our analysis simple, we assume the following:

$$\Omega(z_N) < T(z_N) \cdot \phi \quad \text{and} \quad T(z_S) \cdot \phi < \Omega(z_S) \quad \text{for all} \quad \phi \in [\bar{\phi}, 1]. \tag{17}$$

Figure 1 illustrates the determination of $\bar{z}$. We put the index of industries z on the horizontal axis and the relative wage of skilled labor $\omega \equiv w/w^*$ on the vertical axis. We denote $\bar{\omega}$ as an equilibrium value of the relative wage. Downward- and upward-sloping curves represent $T(z) \cdot \phi$ and $\Omega(z)$ schedules, respectively. Under this assumption, the equilibrium value of $\bar{z}$ is uniquely determined at the intersection of these schedules in the interval $[z_N, z_S]$.

Together with Lemma 3, the figure shows that in equilibrium the North solely produces the intermediate goods in the interval $[0, \bar{z})$, while the South in the interval $(\bar{z}, 1]$.

[12] The relative wage of skilled labor is not given by (16) if $\bar{z}$ is not in interval $[z_N, z_S]$. In this case, the wage rate of skilled labor either in the North or the South equals its lower limit, or the reciprocal of labor limit coefficient in the agricultural sector.

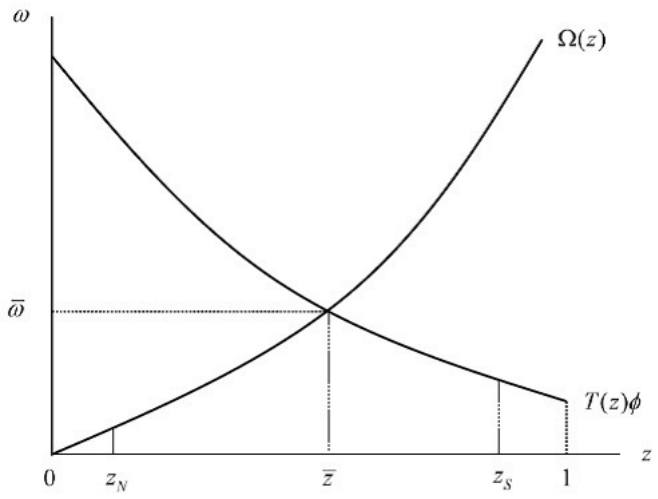


Figure 1: Equilibrium distribution of industries

To summarize all the result regarding industrial location under $\bar{\phi} < \phi$, we obtain the following proposition:

Proposition 2

For $\bar{\phi} < \phi$, we obtain the following pattern in equilibrium: (i) The South sorely produces all final goods; (ii) The North sorely produces the intermediate goods in industry $z \in [0, \bar{z})$ and the South in industry $z \in (\bar{z}, 1]$, where $\bar{z}$ represents the industry index satisfying $T(\bar{z}) \cdot \phi = \Omega(\bar{z})$.

From Propositions 1 and 2, it is shown that industrial location drastically changes as trade costs fall below the critical value implied by $\bar{\phi}$. If trade costs become small enough to reach the critical value, all the production of final goods moves from the North to the South. Simultaneously, all the

production of intermediate goods in industries from z_0 to 1 also moves to the South, where $\bar{z_0}$ denotes the equilibrium value of $\bar{z}$ when trade costs equal to the critical value, i.e., $\phi = \bar{\phi}$. After these changes, the North exports the intermediate goods in industries from 0 to $\bar{z}_0$ to the South and imports the final goods from the South. Vertical international specialization emerges in industries from $\bar{z}_0$ to 1.

It is noteworthy to examine the effect of further declines in trade costs. After the drastic changes in industrial location, a fall in the level of trade costs makes some of the shifted production of intermediate goods returns to the North. This can be confirmed with the aid of Figure 1. A rise in ϕ causes an upward shift in the $T(z) \cdot \phi$ schedule and hence results in an increase in $\bar{z}$. The reason for this change in $\bar{z}$ is that the market-access effect is reduced by falling trade costs. As trade costs fall, the market-access effect becomes less important. Thus, the South loses its competitiveness in production of intermediate goods in industries where its cost advantage is small.

5 Welfare

This section focuses on the welfare effects of falling trade costs. We will first explore how each consumer's utility changes with a continuous decline in trade costs, and then go on to investigations into changes in social welfare of each country.

5.1 Individual consumer's utility

Preliminary to the analysis of each consumer's utility changes, it is useful to derive an indirect utility function for a representative consumer. Utility function given in (1) yields the following indirect utility function:

$$v = -\alpha P + I + \alpha(\ln \alpha - 1), \tag{18}$$

where P is a price index for the final good defined as

$$P = \int_0^1 \ln P(z) dz \tag{19}$$

and I represents consumer's income. The price index P declines as falling trade costs and gives rise to changes in industrial location.[13] This fall in the price index immediately implies an increase in the utility of the unskilled labor because the wage rate of unskilled labor is given by the reciprocal of labor input coefficient in the agricultural sector. In the analysis of utility of the skilled labor, however, it is necessary to take changes in the wage rate of skilled labor into consideration as well.

Falling trade costs lower the price index for the final good if industrial location changes in response to such declines in trade costs. The price index for the final good, P, jumps to a lower level as trade costs fall below the critical value, and declines continuously with trade costs after vertical specialization emerges. The reason for the first discontinuous drop in P is that the final good production in each industry is made more efficient due to drastic changes in industrial location. The continuous fall after the emergence of

[13]The proof of this property is available upon request to the authors.

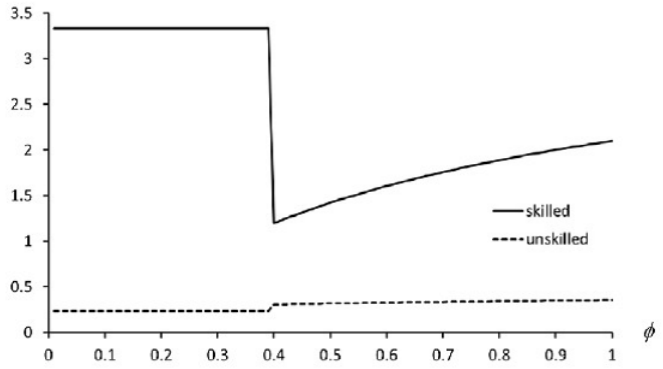
vertical specialization is attributed to a decline in the c.i.f price of each variety of intermediate good imported by the South. These price-index-reducing effect enhances the utility of unskilled labor owner in the both countries.

As the price index for the final good, wage rate of skilled labor also changes if falling trade costs induce the cross-country shift of production. In the North, the wage rate of skilled labor, w, exhibits a downward jump as trade costs fall below the threshold, and it rises continuously after vertical specialization emerges. The range of industries wherein the North produces the intermediate goods is significantly reduced by the initial drastic changes in industrial location. By this change, the demand for the North's skilled labor as fixed input sharply declines, so the equilibrium value of w jumps downward.

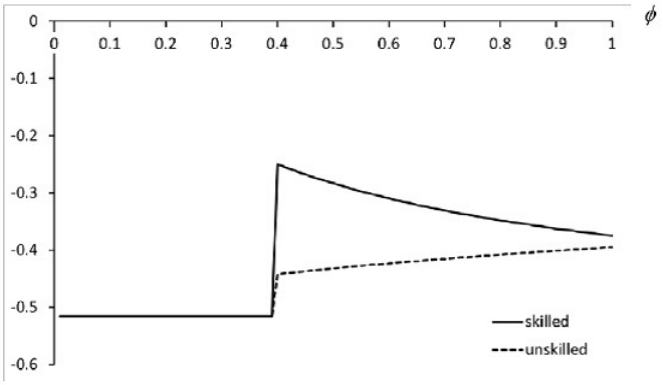
After the vertical specialization emerges, the upper bound of z for which the North produces intermediate goods, $\bar{z}$, increases continuously with ϕ. This rise in $\bar{z}$ causes a monotonous increase in the demand for the skilled labor in the North and hence yields a continuous rise in w. In the South, since a change in $\bar{z}$ has the opposite effect on the demand for the country's skilled labor, the wage rate of its skilled labor initially jumps upward and subsequently manifests a continuous fall.

In contrast with the case of unskilled labor, it is possible that owners of skilled labor lose from falling trade costs. If changes in the wage rate of skilled labor outweigh those in the price index for the final good in terms of the influence on the utility of skilled labors, falling trade costs reduce

their utilities in the phase with declines in the wage rate of skilled labor. In the North, such welfare losses for skilled labor owners can arise as trade costs fall below the critical value. In the South, skilled labor owners ma see their utility fall continuously with trade costs after the emergence of vertical specialization.



(a) North



(b) South

Figure 2: Utilities

A numerical example of utility changes is summarized in Figure 2,[14] which shows the utilities of skilled and unskilled labor owners as a function of ϕ for the case where the effect of changes in the wage rate of skilled labor dominates. In both countries, utility of a representative unskilled-worker owner jumps upward at the critical value of ϕ, that is at $\phi = \bar{\phi} \approx 0.397$, and subsequently, it rises continuously. These changes are due to the beneficial effect of a decline in P induced by a fall in trade costs. The utility of a representative skilled-labor owner changes in a parallel direction with the wage rate of skilled labor. In the North, it jumps downward at $\phi = \bar{\phi}$ and increases continuously in interval $(\phi, 1]$. In the South, it changes in the opposite direction.

5.2 Social welfare

World welfare, the sum of all consumer's utility, is always improved by a decline in trade costs, while changes in each country's welfare are ambiguous if they are accompanied by a fall in the utility of skilled labor owner. The improvement in world welfare results from a decline in the price index of the final good, P, for the total incomes earned by the skilled-labor owners is constant independently of the level of trade costs.[15]

[14]Figures 2 and 3 are constructed assuming that the marginal and fixed labor requirements, $b(z)$, $b^*(z)$, $f(z)$ and $f^*(z)$, are given by the following functions: $b(z) = b \cdot \exp(cz)$; $f(z) = f$; $b^*(z) = b^* \cdot \exp(c^* z)$; $f^*(z) = f^*$, where $b < b^*$, $c > c^*$, and $f < f^*$. The parameter values used in calculation are as follows: $H = 0.2; H^* = 1; L = 2; L^* = 15; a = b = f = 1, a^* = b^* = 4; f^* = 12; c = 0.5; c^* = 0.25; \alpha = 0.15; \beta = 0.6; \sigma = 2$.

[15]Note that incomes of all skilled-labor owners aggregate to $\alpha\beta(\bar{H} + \bar{L})/\sigma$, which equals to the total fixed costs incurred by all upstream firms.

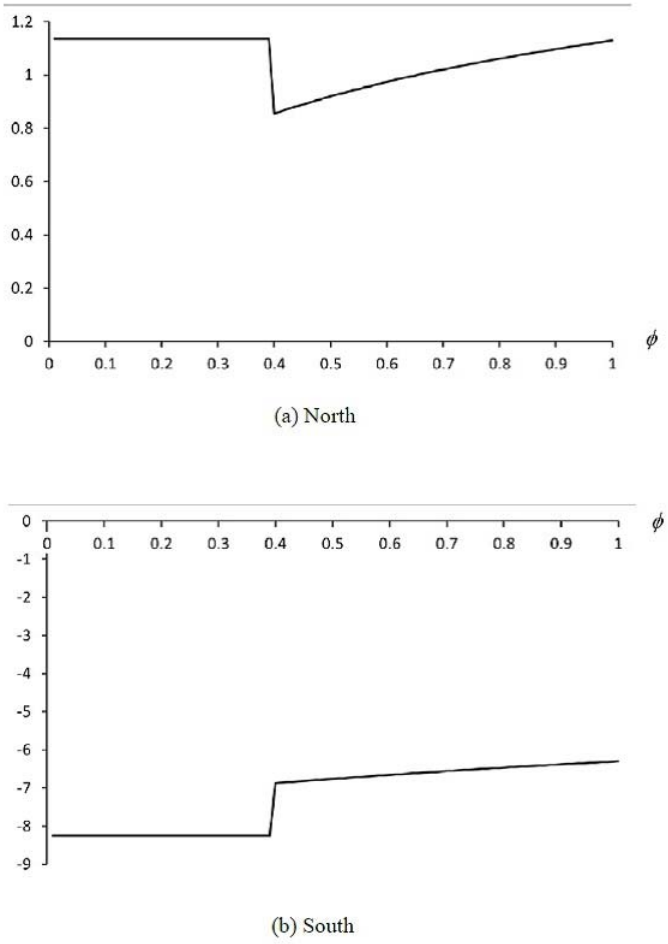


Figure 3: Social welfare

However, falling trade costs do not always enhance welfare of both countries. This is illustrated in Figure 3, which is depicted for the same parameter set an that in Figure 2. The South's welfare is improved by falling trade costs, while changes in the North's strongly reflect those in the utility of the skilled labor owner. In the figure, the North cannot restore the initial welfare level

even if trade costs become small sufficiency.[16]

6 Concluding Remarks

We have investigated the effect of a reduction in trade costs on industrial location and economic welfare in a two-factor North-South trade model. Starting from the situation where the trade cost for the intermediate good is quite high, all firms in the manufacturing sector in the North, we consider a decline in trade cost for the intermediate good.

We have obtained the following results. As a trade cost for the intermediate goods is below the threshold level, all of the final-good productions move to the South with lower wage. Vertical intra-industry trade then occurs. This location change in the final-goods production induces that in the intermediate-goods production. A further decline in the trade cost, however, lead to relocations of some of the intermediate-goods productions back to the North with high productivity. A decrease in the trade cost raises wages for unskilled labor, but does not necessarily increase wages for skilled labor, and this may deteriorate economic welfare especially in the North, which has more skilled labor. Nevertheless the Northern welfare is deteriorated or not, a decline in the trade cost improves world economic welfare.

In the analysis, we simplify some factors in order to clarify the effects. For example, we do not consider trade costs on final goods to focus on the role

[16]The North's welfare is constant at about 1.11354 before vertical specialization emerges, but it falls to about 1.1301 when there is no trade costs, i.e., $\phi = 1$.

of that on intermediate goods. In addition, we consider each of intermediate goods as a specific factor for a final goods production. We might consider some trans-sector intermediate goods. They should be considered in our future research.

Appendix A: Proof of Lemma 1

Lemma 1 implies that if (12) is satisfied, the following relation holds for all $z \in [0, 1]$:

$$\pi^*(z) < \pi(z) = 0, \tag{A1}$$

where $\pi(z)$ and $\pi^*(z)$ are the profit of a representative upstream firm in industry z in the North and South, respectively. The sufficiency of (12) is proved from the following two results:

(i) For a given w/w^*, (A1) holds in equilibrium if and only if

$$\frac{w}{w^*} < \frac{T(z)}{\phi}, \tag{A2}$$

and (ii) In equilibrium, the relative wage of skilled labor, w/w^*, is given by

$$\frac{w}{w^*} = \frac{\alpha\beta(\bar{H} + \bar{L})a^*}{\sigma H} \tag{A3}$$

if the upstream sectors in all industries operate only in the North. Note that (A2) is equivalent to (12) when z equals to unity and w/w^* is given by (A3). If (12) holds for the relative wage given in (A3) and $z = 1$, it follows that (A1) holds for all $z \in [0, 1]$ in equilibrium from $dT(z)/dz < 0$.

Proof of (i): First, we derive the profits and associated revenues in equilibrium. Taking account of the pricing rule given by (8), it is shown that $\pi(z)$ and $\pi^*(z)$ can be expressed as

$$\pi(z) = \frac{r(z)}{\sigma} - wf(z) \tag{A4}$$

and

$$\pi^*(z) = \frac{r^*(z)}{\sigma} - w^* f^*(z), \tag{A5}$$

where $r(z)$ and $r^*(z)$ are the revenue of a representative firm in each country. From (2), consumer's aggregate spending on the final good produced in industry z equals to $\alpha(\bar{H} + \bar{L}) \equiv E$. Noting that the final good is now produced only in the North, in the view of this and by using (6), $r(z)$ and $r^*(z)$ can be written as

$$r(z) = p(z)^{1-\sigma} G(z)^{\sigma-1} E. \tag{A6}$$

Because trade costs must be entailed to ship intermediate goods from the South to the North, r^* is given by

$$r^*(z) = \phi p^*(z)^{1-\sigma} G(z)^{\sigma-1} E. \tag{A7}$$

Note that (A7) can be rewritten by using (8) and (A6) as

$$r^*(z) = \phi \left(\frac{b(z)/a}{b^*(z)/a^*} \right)^{\sigma-1} r(z). \tag{A8}$$

Then, substituting (A8) into (A5), we obtain

$$\pi^*(z) = \phi \left(\frac{b(z)/a}{b^*(z)/a^*} \right)^{\sigma-1} \frac{r(z)}{\sigma} - w^* f^*(z). \tag{A9}$$

(A4) and (A9) implies that (A2) is equivalent to that $\pi^*(z) < \pi(z) = 0$ holds in equilibrium.

Proof of (ii): It is proved by (10) and $w^* = 1/a$. Production of all intermediate goods only by the North implies $\bar{z} = 1$ in (10). In this case, the demand for the South's skilled labor as fixed input is zero, so it follows that $w^* = 1/a^*$. Putting these together, we find that the relative wage of skilled labor is given by (A3). ■

Appendix B: Proof of Lemma 2

We find the range of ϕ for which the North has a lower unit cost than the South, so that the North solely produces the final goods. Because $n^*(z) = 0$ and shipping intermediate goods from the North to the South entails trade costs, the South's price index for the intermediate good can be expressed by using the North as

$$G^*(z) = \phi^{\frac{1}{1-\sigma}} G(z). \tag{B1}$$

Substituting (B1) into the South's unit cost, we obtain

$$C^*(z) = \phi^{\frac{\beta}{1-\sigma}} A G(z)^{\beta} a^{*\beta-1}. \tag{B2}$$

From (3) and (B2), it is shown that for all $z \in [0, 1]$, the unit cost for production in the downstream sector is lower in the North than in the South if and only if $\phi < \bar{\phi}$. ■

Appendix C: Proof of Lemma 3

Making use of (3), (4), (8), and (13), we show that

$$\begin{aligned} C(z) &= A\left[n(z)p(z)^{1-\sigma} + \phi n^*(z)p^*(z)^{1-\sigma}\right]^{\beta/(1-\sigma)} a^{\beta-1} \\ &= A\left[\bar{\phi}n(z)p(z)^{1-\sigma} + \bar{\phi}\phi n^*(z)p^*(z)^{1-\sigma}\right]^{\beta/(1-\sigma)} a^{*\beta-1} \\ &> A\left[\phi n(z)p(z)^{1-\sigma} + n^*(z)p^*(z)^{1-\sigma}\right]^{\beta/(1-\sigma)} a^{*\beta-1} = C^*(z), \end{aligned}$$

where the inequality follows from $\bar{\phi} < \phi < 1$. Therefore, the South's unit cost is lower than the North's for any z. ■

Appendix D: Proof of Lemma 4

The proof is similar to that on the result (i) in Appendix A. Given that the final good is produced only in the South, trade cost parameter, ϕ enters the expression for the revenue of an upstream firm in the North instead of that in the South. That is,

$$r(z) = \phi p(z)^{1-\sigma} G(z)^{\sigma-1} E; \quad r^*(z) = p^*(z)^{1-\sigma} G(z)^{\sigma-1} E.$$

The same logic as the proof of the result (i) applies in the remainder of the proof. ■

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