Vertical Specialization in North-South Trade: Industrial Relocation, Wage and Welfare*

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Abstract

This paper presents a North-South trade model with vertically linked industries and examines how declining costs of trade across stages of production encourage vertical specialization and affect wages and welfare. As trade costs fall below a threshold, the production of all final goods relocates to the South and vertical specialization emerges. In some industries, production of intermediate goods also relocates against comparative costs because of benefits of co-location, and further declines in trade costs lead to reshoring. A country may temporarily lose from falling trade costs, but both countries can be better off after trade costs fall sufficiently.

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1. Introduction

A significant fraction of the present North-South trade comprises trade in products at different stages of production. Developed countries export skill-intensive components to developing countries and reimport products containing the exported components. North-South trade of this sort has grown rapidly since the late 1980s (Amador and Cabral, 2009). Today it is widely acknowledged that advances in transportation and communication technology play a crucial role in this shift, by reducing both transport costs and the coordination costs linked to timely arrival or correct specifications of intermediate inputs. Reduced frictions in trade across stages of production have permitted firms to take advantage of cross-country wage gaps without large losses of efficiency from spatial separation of the production stages. As a result, labor-intensive downstream stages have concentrated in low-wage countries, while high-wage countries have specialized in skill-intensive upstream stages.

The development of such division of labor between countries—we call it 'vertical specialization' following Hummels et al. (2001)—have prompted harsh debates, especially in rich countries, with the fear that the spread of vertical specialization leads to downward pressure on wages and/or rising income inequality. However, a number of studies on the effects of globalized production on wages and welfare, most of which are based on offshoring models (Jones and Kierzkowski, 1990; Feenstra and Hanson, 1996; Kohler, 2004; Markusen, 2006, Grossman and Rossi-Hansberg, 2008; Rodriguez-Clare, 2010; Baldwin and Robert-Nicoud, 2014),[1] have shown mixed results so far. A new trend called 'reshoring' also contributes to the complexity of the issue. Although much of low-skill manufacturing still takes place in low-wage countries, some production, including component manufacturing, is returning to high-wage countries. In early 2010s, for example, General Electric and Ford reshored production of their products (water heaters and trucks) from offshoring destinations such as China and Mexico to the United States

[1] 'Offshoring models' refer to a class of models where the production process consists of multiple stages or tasks that are internationally mobile.

(US), and in 2014, Boeing announced the repatriation of jobs mainly related to the manufacturing of airplane parts from overseas to the US (Vanchan et al., 2018).[2] This trend of reverse relocation adds to the difficulty in determining possible consequences of declining trade frictions.

This paper investigates how improvements in the opportunities for trade across stages of production spur the growth of vertical specialization and affect wages and welfare. An important contribution is the presentation of a simple North-South trade model, in which the emergence of vertical specialization is followed by the reverse flow of production relocation. The model allows us to examine the welfare implications of reduced frictions in trade across stages of production during a phase of reshoring as well as at the time of emergence of vertical specialization.

We consider the economy with a continuum of industries, where each industry comprises upstream and downstream sectors. We assume that the market structure of each individual industry follows Ethier's (1982) division-of-labor model; the upstream sector is monopolistically competitive, while the downstream sector is competitive.[3] In this class of models, non-tradability of intermediate goods creates centripetal forces encouraging co-location of upstream and downstream firms. In our model, trade costs for intermediate goods, which represent various frictions in trade across stages of production, provide an incentive for the co-location of firms. The centrifugal forces encouraging dispersed production of final and intermediate goods stem from international differences in factor prices and technologies. The emergence of vertical specialization depends on the balance between these opposing forces.

In addition, we assume that production technologies in upstream and downstream sectors

[2] In addition to reshoring by other US companies, such as NCR (an ATM maker), Energid Technologies (a developer of advanced software and robotics systems) and Element Electronics (a television manufacturer), Vanchan et al. (2018) also present 10 cases over the past decade of production reshored to the United Kingdom, including four cases of component sourcing.

[3] The division-of-labor model represents "a wide class of models attempting to formally characterise and analyse the Adam Smith–Allyn Young notion of division of labour" (Francois and Nelson, 2002). Ethier's (1982) model is one member of this class of models and has been widely used in international trade theory (e.g. Markusen, 1990; Francois, 1992; Matsuyama, 1996; Rodriguez-Clare, 1996; Rodrik, 1996; Venables, 1996a; Chakraborty, 2003; Eckel, 2008).

differ in the following two respects. First, downstream technologies are uniform across countries and industries, while upstream technologies differ across countries as well as industries. Second, only final goods can be produced with unskilled labor, but the production of intermediate goods requires skilled labor. These assumptions permit the model to produce vertical specialization consistent with the reality of international supply chains; developing countries tend to be in the downstream position typically characterized by standard technology and low-skill production (IMF, 2012; Baldwin, 2013).

Given the assumptions, falling trade costs for intermediate goods entail the rapid spread of vertical specialization followed by reverse relocation. In our model, vertical specialization emerges in a discontinuous manner; as trade costs fall below a threshold, the production of the final good in all industries, which are initially located in the North, relocates to the South with low unskilled labor costs. At the same time, the production of intermediate goods in a certain range of industries also moves to the South, but some industries facing production relocation overshoot in terms of their comparative production costs. An inevitable result of this overshoot is reshoring; the relocated production of intermediate goods in some industries sequentially returns to the North with a corresponding decline in trade costs. This resurgence of the upstream sectors in the North stimulates a further expansion in trade based on vertical specialization.

Falling trade costs improve overall welfare by lowering the price index for final goods, while any particular country may suffer welfare losses due to reduced wage rates for skilled labor. Unskilled workers become better off from a lower price index, but skilled workers may be worse off, depending on the phase of growth of vertical specialization. In the North, for instance, the wage rate for skilled labor faces downward pressure as the economy enters into vertical specialization. This effect can outweigh the positive effect of the declining price index and, hence, lead to losses for skilled workers. In this case, it is possible that skilled workers as a group suffer larger losses compared with unskilled workers, so that the North's welfare decreases with the emergence of vertical specialization. However, such welfare losses may be temporary, and it is

possible that both countries become better off after trade costs have reduced sufficiently.

Much has been written about vertical specialization in the last quarter century. A number of researchers have analyzed the wage effects of globalized production in various offshoring models, with a specific focus on the wage rate for unskilled labor (e.g. Feenstra and Hanson, 1996; Kohler, 2004; Grossman and Rossi-Hansberg, 2008). Our work contributes to the literature by clarifying the non-monotonic effects of growing vertical specialization on the wage rate for skilled labor. Our research is analogous in spirit to that of Amiti (2005) on the location of vertically linked industries. Using the Heckscher-Ohlin type of model, Amiti showed that an overall decline in trade costs for final and intermediate goods eventually relocates the final-good production from a developed (capital abundant) country to a developing (labor abundant) country; that is, an across-the-board decline in trade costs finally leads to the emergence of vertical specialization between the North and South. In contrast, our research focuses on the role of trade costs for intermediate goods and shows that the reshoring of production in upstream sectors follows the emergence of vertical specialization. Like us, Baldwin and Venables (2013) also show that reshoring arises because of the overshoot of production relocation in intermediate goods. However, their study differs from ours in motivation. Because they focused on the determination of optimal offshoring from the firm's viewpoint, their analysis did not account for welfare aspects.

The remainder 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 the determination of wage rates for skilled labor. In section 4, we show how vertical specialization emerges and evolves with the decline in trade costs for intermediate goods. In section 5, we examine the welfare consequences of falling trade costs. Section 6 offers concluding remarks.

2. The Model

We develop a North-South trade model with two sectors—namely, manufacturing and agriculture—and two factors, skilled and unskilled labor. The manufacturing sector comprises a

continuum of industries à la Dornbusch, Fisher, and Samuelson (1977); additionally, each industry is further split into two subsectors, upstream and downstream sectors. The North and South are identical in terms of their access to downstream technology, while they are different with regard to technology in the upstream and agricultural sectors. The endowments of skilled and unskilled labor in each country are fixed. Both types of labor are internationally immobile but freely mobile between sectors.

In the manufacturing sector, industries are indexed by z, which varies over the unit interval $[0,1]$. In each industry, the upstream sector produces differentiated intermediate goods, and the downstream sector assembles the intermediate goods into a homogeneous final good. The intermediate goods are produced with the increasing-returns-to-scale technology, and their market is monopolistically competitive; meanwhile, the final good is produced with the constant-returns-to-scale technology, and its markets are perfectly competitive. The final goods are traded costlessly between the countries, whereas trade in intermediate goods is subject to frictions related to the costs of separating production stages across borders (i.e., trade costs or communication and coordination costs).[4] We assume that these trade frictions take the form of iceberg trade costs, $\tau > 1$.

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 consider this good a numeraire and assume that the agricultural sector always operates in both countries.

Skilled and unskilled labor differ in the types of production activities they can perform. Upstream firms require knowledge-intensive activities such as R&D or headquarter services,

[4] We ignore the role of trade costs for final goods. Our purpose is to examine the effects of reduced friction in trade across production stages rather than the effect of an across-the-board decline in trade costs for all goods. Thus, we simplify our model by normalizing trade costs for final goods to zero. Additionally, even in the presence of trade costs for final goods, our main results not change if these costs are assumed to be sufficiently small relative to trade costs for intermediate goods.

which can be performed by skilled labor. The knowledge-intensive activities are associated with a fixed cost. In contrast, other production activities are considered simple work that demand no specific skills and which can be performed by either unskilled labor or skilled labor. We assume that, with respect to this simple work, there is no difference between skilled and unskilled labor in terms of efficiency. Such simple work is associated with a variable cost.

In the remainder of this section, we explain the details of our model. We exclusively describe the North because analogous equations hold for the South. Throughout this paper, variables applicable to the South are marked with asterisks.

2.1. Preferences

All consumers have an 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. α represents the amount of income spent on each final good and is assumed to be strictly less than each consumer's income.[5] Assuming that each consumer is endowed with one unit of skilled or unskilled labor and supplies it inelastically, the above preferences imply that the aggregate demand for the final good in industry z is given by:

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

where $P(z)$ is the price of the final good in industry z, and H and L stand for the number of skilled and unskilled workers, respectively.

2.3. Agriculture

[5] This assumption implies that consumers always consume the agricultural good (i.e., $x_A > 0$).

The agricultural good is produced through simple work performed by labor. Production technology for the agricultural sector requires a units of labor for one unit of the agricultural good. Since the agricultural good is the numeraire, the wage rate of unskilled labor is given by $1/a$. This is also the lowest wage rate at which a consumer endowed with skilled labor is willing to work as a skilled worker, that is, the reservation wage of skilled workers. In addition, we assume the North can produce the agricultural good more efficiently than the South:

Assumption 1: $a < a^*$.

Therefore, the wage rate of unskilled labor is higher in the North than in the South.

2.4. Manufacturing

In each industry, the final good is produced by using labor and industry-specific intermediate goods. The intermediate goods are aggregated using a symmetric CES production function, as in Dixit and Stiglitz (1977). The composite of intermediate goods is combined with labor—strictly, skilled and/or unskilled labor—according to a Cobb-Douglas technology with share coefficients β and $1-\beta$.[6] Then, the unit cost for the final good produced in industry z is given by:

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

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

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

where $i(z)$ and $i^*(z)$ denote a particular variety of intermediate good produced in the North and the South, respectively, and $p(\cdot)$ is the price of an intermediate good with the corresponding

[6] For simplicity, we assume that the share coefficients are identical across industries. Even though we allow for differences between industries in share coefficients, our main results hold if the cross-industry variation in share coefficients remain sufficiently small.

variety index. $n(z)$ and $n^*(z)$ denote the number of varieties of intermediate goods produced in the North and the South, respectively, and $\sigma > 1$ is the elasticity of substitution for each pair of intermediate goods.

Each industry is different in terms of upstream technology, but within each industry, the upstream firms all have access to the same technology. In industry z, $f(z)$ units of skilled labor are needed as a fixed input for the knowledge-intensive activity needed 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 the fixed cost, each firm produces a distinct variety, since it can perform better by introducing a new variety than by competing for market share in the existing varieties. At equilibrium, all firms earn zero profits due to free entry and exit. Let $T(z)$ be the technology index defined as:[7]

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

We assume that $T(z)$ is differentiable and strictly decreasing in z:

Assumption 2: $dT(z)/dz < 0$.

As we will see later, this assumption implies that the North has a comparative advantage in the production of intermediate goods in the lower-indexed industries, while the South has a comparative advantage in the higher-indexed industries.

Finally, we derive the equilibrium prices of intermediate goods. Under the present 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

[7] This technology index is essentially the same as those presented in Kikuchi et al. (2006) and Kikuchi and Shimomura (2017), both of which explore the relation between trade patterns and cross-country technical differences in monopolistic competition models.

$\tau > 1$, 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 pricing rule:

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

This shows that 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 terms of marginal cost, as well as the fixed input requirement in industry z.

3. Wage rate for skilled labor

Before analyzing the impacts of reduced frictions in trade in intermediate goods, it is helpful for us to consider the determination of the equilibrium wage rate for skilled labor. As stated in the previous section, the wage rate for skilled labor has a lower bound given by the wage rate for unskilled labor. If there is a strong demand for skilled labor, its wage rate exceeds the lower bound. In this case, all skilled workers serve upstream firms to engage in the knowledge-based activities. In contrast, if the demand is weak, the wage rate for skilled labor will equal the lower bound, and some skilled workers will engage in simple work.

Let us now consider the situation in which the demand for skilled labor is so strong that all skilled workers engage in the knowledge-intensive work in both countries. In this case, if the intermediate goods in range $[0, \bar{z})$ of industries are produced only in the North and those in range $(\bar{z}, 1]$ of industries are produced only in the South,[8] the equilibrium wage rates of skilled labor in the North and South are respectively given by:

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

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

where $\bar{H}$ and $\bar{L}$ are the total endowments of skilled and unskilled labor in the economy. The equilibrium wage rates in (9) are derived by using three simple results obtained in the present setting. First, from (2), the aggregate consumer's spending on the final good in industry z equals to $\alpha(\bar{H}+\bar{L})$. Second, from (3), 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. Drawing all these results together, we find that the total fixed cost incurred by the upstream firms in industry z equals $\alpha\beta(\bar{H}+\bar{L})/\sigma$. Since the North produces intermediate goods in the interval $[0,\bar{z})$ and the South produces them in the interval $(\bar{z},1]$, the North and South's aggregate demand for skilled labor are respectively given by:

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

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 as (9).

Equation (9) shows that, in each country, the wage rate of skilled labor decreases as the range of domestic industries with positive outputs of intermediate goods becomes smaller. This is because a narrower range of such industries leads to the reduced demand for the country's skilled labor as a fixed input for the knowledge-intensive activities. Therefore, if the range of domestic industries producing positive outputs of intermediate goods is sufficiently small, the wage rate of skilled labor will equal the reservation wage level—which is to say, the wage rate of unskilled labor—and some skilled workers will devote themselves to simple work.[9]

We can analytically determine the value of $\bar{z}$ for which the wage rate of skilled labor equals

[9] Note that we assume there are no differences between skilled and unskilled labor in terms of their efficiency in performing simple work.

the reservation wage level for each country. Let z_N and z_S be the value of $\bar{z}$ for the North and South, respectively. By inserting reservation wages (i.e., $1/a$ and $1/a^*$) into the LHS of (9) and solving for $\bar{z}$, we obtain

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

In the North, for example, if the range of the domestic industries with positive outputs of intermediate goods is so large that $\bar{z}$ exceeds z_N, skilled labor will be used only in the knowledge-intensive activities, and its wage rate will be given by (9). In contrast, if the range of such industries is extremely small and $\bar{z}$ falls short of z_N, skilled labor will be used not only in undertaking knowledge-intensive activities but also in simple work, and its wage rate will equal $1/a$, the reservation wage level. Likewise, the South's wage rate of skilled labor is given by (9) if $\bar{z}$ falls short of z_S, and $1/a^*$ otherwise.

4. Specialization pattern

This section investigates the impact of decreasing friction in trade in intermediate goods, or falling τ, on each country's specialization pattern. We start from the situation where all industries, both upstream and downstream, operate only in the North in the presence of large trade costs.[10] First, we will find the lower bound of trade costs for which the equilibrium with all manufacturing production located in the North is sustainable. Next, we will show that if trade costs fall below the critical value, the production of all final goods moves to the South, so vertical specialization between the North and South emerges.

[10] As in existing models with input-output linkages and trade costs (e.g., Venables, 1996b; 1999), our model also entails multiple equilibria in the presence of large trade costs. Strictly, for large values of τ, the equilibrium division of industries between countries cannot be determined uniquely in a range of the higher-indexed industries.

4.1. The equilibrium with one-way trade

Let us consider the equilibrium in which the South specializes in the agricultural sector and, hence, the traditional one-way trade emerges. To find the lower bound of trade costs for which the equilibrium is sustainable, we begin by exploring values of trade costs for which only the North produces intermediate goods, given that all final goods are produced only in the North. After that, we will make a similar analysis about the final goods on the assumption that all intermediate goods are produced only in the North. Finally, by integrating each result, we derive the critical value of trade costs.

Given that all final goods are produced only in the North, the presence of large trade costs ensures that the production of intermediate goods in all industries occurs only in the North. We can find a threshold of trade costs, beyond which only the North produces intermediate goods.

Lemma 1. *Suppose that Assumption 2 holds and that all final goods are produced solely in the North. Then, all upstream industries operate only in the North if*

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

Proof. *See Appendix A.*

Lemma 1 shows that the production of intermediate goods in all industries occurs only in the North if trade costs are sufficiently large (Note that the larger the trade costs are, the smaller ϕ is). The production location of intermediate goods depends not only on the level of trade costs, but also on cross-country differences in technology and factor prices. The relative importance of the latter declines with an increase in trade costs. In the presence of trade costs, upstream firms in the North have an advantage over those in the South, in terms of market access. Therefore, as trade costs increase, this *market-access* advantage 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 the production of all final goods occurs only in the North. We can obtain a threshold of trade costs, beyond which only the North produces final goods.

Lemma 2. *Suppose that all intermediate goods are produced solely 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.*

Lemma 2 shows that the production of all final goods occurs only in the North when trade costs are sufficiently large. By Assumption 1, the threshold $\bar{\phi}$ in (13) is less than one, which reflects the lower assembly cost in the South. However, downstream firms in the North have an advantage over those in the South in terms of proximity to suppliers; downstream firms in the North face no trade costs when they purchase the intermediate goods produced in the North. As trade costs increase, this benefit of proximity to suppliers becomes more crucial than the South's advantage in assembly cost.

Drawing these results together, we can find the lower bound of trade costs for the equilibrium in which the South specializes in the agricultural sector. From Lemmas 1 and 2, the specialization is sustainable in equilibrium if trade costs are sufficiently large, so that $\phi < \min\{\hat{\phi}, \bar{\phi}\}$. It would be natural to suppose that final-good production comprising simple tasks would be technologically easier to relocate in response to a decline in trade costs, relative to the intermediate-goods production. In the following analysis, therefore, we will make the following assumption:

Assumption 3: $\bar{\phi} < \hat{\phi}$.

This implies that, if trade costs are slightly less than the level implied by $\bar{\phi}$, in all industries downstream firms attempt to locate in the South, while there is no such incentive for upstream firms. Given this assumption, a sufficient condition for a sustainable equilibrium is given by (13).

Proposition 1. *Suppose that Assumptions 2 and 3 hold. Then, the equilibrium in which all industries operate only in the North is sustainable if* $\phi < \bar{\phi}$.

4.2. The emergence of vertical specialization

We now analyze the changes in specialization pattern, induced by falling trade costs. From Lemma 2, the equilibrium with one-way trade is no longer sustainable once trade costs become sufficiently small enough to satisfy $\phi > \bar{\phi}$. In this case, the production of all final goods moves to the South and vertical specialization occurs in the manufacturing sector.

Lemma 3. *Suppose that Assumptions 1, 2 and 3 hold. Then, for* $\phi > \bar{\phi}$ *all downstream industries operate only in the South.*

Proof. *See Appendix C.*

The South, with cheaper unskilled labor forces, can produce the final good at a lower unit cost relative to the North, in all industries. 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—namely, the difference in the price index for the intermediate good—is less important, because trade costs are now not very large.[11] Therefore, if trade costs are so small that $\phi > \bar{\phi}$ holds, the South's advantage in terms of

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

assembly cost dominates in all industries, and so the South will produce all the final goods.

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

Lemma 4. *Suppose that Assumptions 1, 2 and 3 hold. Then, for* $\phi > \bar{\phi}$ *the upstream sector in industry* z *operates in the North if*

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

Otherwise, it operates in the South.

Proof. *See Appendix D.*

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

$$\frac{w^* f^*(z)}{wf(z)} \times \left[\frac{b^*(z)/a^*}{b(z)/a} \right]^{\sigma-1} \times \phi > 1.$$

This 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 that of the North; the second term reflects the analogous ratio for marginal costs. By Assumption 2, the product of these ratios is decreasing in z, and so the South tends to lose competitiveness in the lower-indexed industries due to higher production costs. The third term, ϕ, stands for the effect of the market-access advantage, which alleviates the South's disadvantage with respect to production cost; since the final goods are produced only in the South, upstream firms in the South have an advantage over those in the North, in terms of market access.

We need to derive the relative wage of skilled labor, w/w^*, to determine the equilibrium distribution of upstream sectors between countries. As in Section 3, let us consider the case where upstream firms in industry $z \in [0, \bar{z})$ operate only in the North, while those in industry $z \in (\bar{z}, 1]$ operate only in the South. Then, from (9), we obtain[12]

$$\frac{w}{w^*} = \frac{\bar{z}H^*}{(1-\bar{z})H} \equiv \Omega(\bar{z}). \tag{15}$$

From this, we see that the relative wage of 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 a fixed input in the North (South). Hence, w/w^* is increasing in $\bar{z}$.

We now find the cross-country distribution of upstream sectors in equilibrium. Figure 1 illustrates the determination of $\bar{z}$, where the relative wage of skilled labor, $\omega \equiv w/w^*$, is on the vertical axis and $\bar{\omega}$ denotes its equilibrium value. Downward- and upward-sloping curves represent $T(z)\phi$ and $\Omega(z)$ schedules, respectively. Together with Lemma 4, the figure shows that, in equilibrium, only the North produces the intermediate goods in the interval $[0, \bar{z})$, while the South produces intermediate goods in the interval $(\bar{z}, 1]$.[13]

(Figure 1)

To summarize all the results regarding the specialization pattern under $\phi > \bar{\phi}$, we obtain the following proposition:

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[12] In the following analysis, we assume that $z_N < z_S$ (see (11) for z_N and z_S) to ensure the existence of values of $\bar{z}$ for which skilled labor is used only in the knowledge-intensive activities in both countries. If $\bar{z}$ is not in the interval $[z_N, z_S]$, the relative wage of skilled labor is not given by (15). In this case, the wage rate of skilled labor in either the North or the South equals the reservation wage level, or the reciprocal of the labor input coefficient in the agricultural sector.

[13] To keep our analysis simple, we focus on the case in which $T(z)\phi$ and $\Omega(z)$ satisfy $\Omega(z_N) < T(z_N)\phi$ and $T(z_S)\phi < \Omega(z_S)$ for all $\phi \in [\bar{\phi}, 1]$.

Proposition 2. *Suppose that Assumptions 1, 2 and 3 hold. Then, for* $\phi > \overline{\phi}$ *we obtain the following patterns in equilibrium: (i) Only the South produces all final goods, and; (ii) Only the North produces the intermediate goods in industry* $z \in [0, \overline{z})$ *and only the South produces the intermediate goods in industry* $z \in (\overline{z}, 1]$*, where* $\overline{z}$ *represents the industry index that satisfies* $T(\overline{z})\phi = \Omega(\overline{z})$.

Together, Propositions 1 and 2 show that vertical specialization emerges in a discontinuous manner as trade costs fall below the critical value implied by $\overline{\phi}$. If trade costs become sufficiently small so as to reach the critical value, the production of all final goods moves from the North to the South. Simultaneously, the production of intermediate goods in industries from $\overline{z}_0$ to 1 will also move to the South, where $\overline{z}_0$ denotes the equilibrium value of $\overline{z}$ when trade costs equal the critical value (i.e., $\phi = \overline{\phi}$). Following these changes, the North exports the intermediate goods in range $[0, \overline{z}_0)$ of industries to the South and imports from the South the final goods incorporating the exported intermediate goods. Thus, the North-South trade based on vertical specialization takes place in the range $[0, \overline{z}_0)$ of industries.

The effect of a further decline in trade costs is noteworthy. Following the emergence of vertical specialization, a further fall in the level of trade costs will result in reshoring in which some intermediate-goods production returns to the North. This can be confirmed with the aid of Figure 1. An increase in ϕ causes an upward shift in the $T(z)\phi$ schedule, as shown by a shift to the dashed curve in the figure, and results in an increase in $\overline{z}$. As trade costs fall, the effect of the market-access advantage will become less important and production competitiveness will depend primarily on relative production costs. Thus, the South will lose its competitiveness in the production of intermediate goods where it lacks a pure relative production cost advantage. The

subsequent resurgence of those upstream sectors in the North stimulates a further expansion in trade based on vertical specialization.

5. Wages and welfare

This section focuses on the impact on wages and welfare of deceasing frictions in trade in intermediate goods, or falling τ. First, we explore how lower trade costs affect each country's wage rate of skilled labor, then we investigate changes in each consumer's utility and social welfare in each country.

5.1. Wages

The wage rate of skilled labor changes if falling trade costs induce a cross-country production shift. In the North, the wage rate of skilled labor, w, declines as trade costs fall below the threshold, so that vertical specialization emerges. After that, it rises continuously with falling trade costs. The range of industries for which the North produces the intermediate goods narrows with the emergence of vertical specialization. Because of this change, the demand for the North's skilled labor as a fixed input declines, and so the equilibrium value of w jumps to a lower level. After vertical specialization emerges, the upper bound of z for which the North produces intermediate goods, $\overline{z}$, increases continuously with falling trade costs. This increase in $\overline{z}$ (i.e., the reshoring of the intermediate-goods production) causes a monotonic 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 $\overline{z}$ 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 experiences a continuous fall.[14]

[14] Note that a discontinuous increase in the South's wage with the emergence of vertical specialization and the ensuing reshoring are both the result of falling trade costs. The rapid rise of wages in the South is often cited as one of the major reasons for an increase in reshoring (e.g., Buchanan, 2017). However, our analysis shows that such wage increases are ultimately attributable to the reduction in trade costs.

Proposition 3. *Suppose that Assumptions 1, 2 and 3 hold. Then, the wage rate of skilled labor jumps to a lower (higher) level in the North (South) as vertical specialization emerges; subsequently, the wage rate of skilled labor increases (decreases) continuously along with falling trade cots.*

5.2. Welfare

Before analyzing changes in each consumer's utility and social welfare, it is useful to derive an indirect utility function for a representative consumer. The utility function given in (1) yields the following indirect utility function:

$$v = -\alpha P + I + \alpha(\ln \alpha - 1),$$

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

$$P = \int_0^1 \ln P(z) dz, \tag{16}$$

and I represents a consumer's income, which equals the wage rate of skilled (unskilled) labor if the corresponding consumer is a skilled (unskilled) worker.

5.2.1. Utility of skilled and unskilled workers

Falling trade costs affect the well-being of both types of workers through changes in the price index for the final good. The price index P declines when falling trade costs give rise to changes in each country's specialization pattern. This fall in the price index immediately implies an increase in the utility of unskilled workers, because the wage rate of unskilled labor is the reciprocal of the labor input coefficient in the agricultural sector. In analyzing the utility of skilled workers, however, it is essential to consider changes in the wage rate of skilled labor.

Like the wage rates of skilled labor, the price index for the final good also shows a discontinuous change. The price index, P, first jumps to a lower level as vertical specialization

emerges, because drastic changes in production locations lead to final-goods production in each industry becoming more efficient. Subsequently, P declines continuously due to the direct effect of reduced trade costs—which is to say, less costly import by the South of intermediate goods.[15] These changes in the price index enhance the utility of unskilled workers in both countries.

In contrast, it is possible that skilled workers lose from falling trade costs. If changes in the wage rate of skilled labor outweigh those in the price index for the final good, falling trade costs will reduce their utility during a phase featuring a decline in the wage rate of skilled labor. In the North, such welfare losses for skilled workers can arise with the emergence of vertical specialization. In the South, skilled workers may see their utility fall after the emergence of vertical specialization.

Proposition 4. *Suppose that Assumptions 1, 2 and 3 hold. Then, the effect of falling trade costs on each consumer's utility is as follows: (i) As vertical specialization emerges, the utility of unskilled workers in both countries and skilled workers in the South jumps upward, but the utility of skilled workers in the North may decrease; (ii) After vertical specialization emerges, the utility of unskilled workers in both countries and skilled workers in the North increases continuously along with falling trade costs, but the utility of skilled workers in the South may decrease.*

A numerical example of utility changes is illustrated in Figure 2,[16] which shows the utility of skilled and unskilled workers as a function of ϕ for the case where the effect of changes in the

[15] See Appendix E for the detailed analysis on changes in P.

[16] Figure 2 assumes 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 $b < b^*$, $c > c^*$, $f < f^*$. The parameter values used in the calculation are as follows: $H = 0.2$; $H^* = 0.5$; $L = 2$; $L^* = 15$; $a = b = f = 1$; $a^* = b^* = 4$; $f^* = 12$; $c = 0.5$; $c^* = 0.25$; $\alpha = 0.15$; $\beta = 0.6$; $\sigma = 2$.

wage rate of skilled labor dominates. In both countries, the utility of a representative unskilled worker jumps upward at the critical value of ϕ —that is, at $\phi = \bar{\phi} \approx 0.39685$ —for which vertical specialization emerges; subsequently, it rises continuously. These changes are due to the beneficial effect of a decline in P, induced by a decrease in trade costs. The utility of a representative skilled worker 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 over the interval $(\bar{\phi}, 1]$. In the South, meanwhile, it changes in the opposite direction.

(Figure 2)

5.2.2. Social welfare

The initial production shift triggering the spread of vertical specialization and a further decline in trade costs enhance world welfare, the aggregate utility of all consumers. At the same time, the effect on each country's welfare is ambiguous if these changes are accompanied by a fall in the utility of skilled workers. The improvement in world welfare results from a decline in the price index for final goods, P, as the total incomes earned by skilled workers are constant, independently of the level of trade costs.[17] However, because skilled workers can lose, both countries do not always gain when trade costs fall: The North's welfare may decrease by the production shift resulting in the emergence of vertical specialization; the South may lose from falling trade costs after vertical specialization emerges.

Proposition 5. *Suppose that Assumptions 1, 2 and 3 hold. Then, the effect of falling trade costs on world welfare and each country's welfare is as follows: (i) As vertical specialization emerges, both world welfare and welfare in the South jump upward, but welfare in the North may decrease;*

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

(ii) After vertical specialization emerges, both world welfare and welfare in the North increase continuously along with falling trade costs, but welfare in the South may decrease.

Of course, it is possible that both countries become better off when trade costs are negligible (i.e. $\phi = 1$). This case is illustrated in Figure 3, which assumes the same parameter set as Figure 2. In this scenario, the South constantly gains from falling trade costs,[18] while changes in the North's welfare strongly reflect those in the utility of skilled workers. Figure 3 shows that the North eventually becomes better off, compared with its economy prior to vertical specialization. A decline in trade costs after the emergence of vertical specialization induces the reshoring of intermediate-goods production and leads to a rise in the wage rate for the North's skilled labor. Combined with a fall in the price index, this rise in the wage rate offsets the effect of the initial wage decline and, therefore, improves welfare in the North.[19]

(Figure 3)

6. Concluding Remarks

We have developed a North-South trade model with a continuum of vertically linked industries to examine the effect of declining frictions in trade across stages of production. We have assumed

[18] The South's welfare will eventually be higher with vertical specialization than without it, even if its welfare falls with trade costs in the phase of reshoring. This is because, in addition to a lower price index for the final good, the wage rate of skilled labor in the South exceeds its lower bound, $1/a^*$, after vertical specialization emerges.

[19] We can also consider a numerical example where the North ends up with lower welfare. For example, the North eventually becomes worse off if the value of H^* is twice as large as that of the present example. In this case, the North's welfare is constant at about 1.1354 before vertical specialization emerges, but it falls to about 1.1301 in the absence of trade costs. A larger endowment of skilled labor in the South makes the North's skilled labor relatively more expensive, so the production of intermediate goods across a wider range of industries shifts from the North with the emergence of vertical specialization (Note that in Figure 1, an increase in H^* makes the $\Omega(z)$ schedule shift upward and reduces the value of $\bar{z}$ for any given ϕ). This larger-scale production outflow puts a larger downward pressure on the wage rate for the North's skilled labor and, as a result, reduces the likelihood that the North restores its initial welfare level.

that production in the upstream sector requires skilled labor as fixed input and that unskilled labor can only perform downstream assembly. Considering an initial situation with relatively high trade costs for intermediate goods (i.e., large frictions in trade across stages of production) and all manufacturing industries located in the North, we have examined how falling trade costs spur the growth of vertical specialization and affect wages and welfare.

Our model shows that vertical specialization arises in a discontinuous manner and is followed by a flow of reverse relocation for intermediate-goods production. As trade costs fall below the threshold, all final-goods production moves to the South with a lower wage for unskilled labor, resulting in vertical specialization. Concurrently, production of intermediate goods for a certain range of industries relocates to the South to take advantage of co-location. However, for some of those industries, production relocation is not optimal if based purely on comparative production costs. Thus, a further reduction in trade costs leads to some intermediate-goods production being reshored to the North. This resurgence of some upstream sectors in the North generates a further expansion of vertical specialization.

A decrease in trade costs improves world welfare by lowering the price index for the final good and can be beneficial to both countries in the long run. The situation is complex for each country because its welfare does not increase monotonically with falling trade costs. Unskilled workers become better off from a lower price index, whereas changes in the utility of skilled workers depend on whether the economy is in the vertical specialization phase or the reshoring phase. As the economy shifts to vertical specialization, the North faces a decline in the wage rate of skilled labor and may suffer welfare losses. The South is likely to lose in the reshoring phase when its wage rate of skilled labor falls. However, when trade costs are small enough to be negligible, there is a chance that both countries become better off, compared with the case of traditional one-way trade.

Based on the present framework, the recent backlash against globalization observed in developed countries is expected to have two self-defeating effects on the North. First, as in

traditional trade models, protectionist measures such as tariffs reduce consumer surplus through the rise in the price index for the final goods. Second, erecting new trade barriers reduces the likelihood that the North gains from reshoring. For example, the South is most likely to raise its tariffs in retaliation for tariff hikes by the North. The tit-for-tat measures by the South effectively lead to increases in trade costs (i.e., larger τ) and prevent reshoring. Thus, the rise of protectionism in the North can jeopardize the eventual welfare gains that the North may reap from reshoring.

Our analysis includes the following simplifying assumptions to clarify the effects of trade costs: (i) we ignore trade costs on final goods; (ii) we assume that the share of intermediate goods in the final-good production cost is identical across industries; (iii) we consider only the industry-specific intermediate goods, when focusing on the role of vertical linkages between upstream and downstream sectors. Relaxing the first assumption to incorporate trade costs on final goods will modify our results. Specifically, this change will lead to the non-tradability of final goods if trade costs on those goods are relatively large. Relaxing the second and third assumptions is more analytically challenging. Including cross-industry differences in the share of intermediate goods in production cost will mean that the final-good production in all industries will no longer simultaneously relocate from the North to the South. Allowing for trans-industry intermediate goods in addition to industry-specific goods makes it difficult to determine the location of the final-good production. Our future research will address these refinements to the model.

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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

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

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

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

if the upstream sectors in all industries operate only in the North. Note that (A2) is equivalent to (12) when z is equal to unity and w/w^* given by (A3). Thus, if (A2) 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 into account the pricing rule given by (8), we show that $\pi(z)$ and $\pi^*(z)$ can be expressed as:

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

and

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

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

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

Because shipping intermediate goods from the South to the North incurs trade costs, $r^*(z)$ is given by:

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

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) imply that (A1) holds in equilibrium if and only if (A2) is satisfied.

Proof of (ii): We use (9) and $w^* = 1/a^*$. Intermediate-goods production solely by the North implies $\overline{z} = 1$ in (9). In this case, the demand for the South's skilled labor as a fixed input is zero, and so it follows that $w^* = 1/a^*$. Drawing these together, we find that the relative wage of skilled labor is given by (A3).

Appendix B: Proof of Lemma 2

We now determine the range of ϕ for which the North has a lower unit cost compared with 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 incurs trade costs, the South's price index for the intermediate good can be expressed by using the North's as:

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

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

$$C^*(z) = \phi^{\beta/(1-\sigma)} AG(z)^{\beta} a^{*\beta-1}. \quad \text{(B2)}$$

From (3) and (B2), we show 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 the definition of $\bar{\phi}$ in (13), we can show that:

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

where the inequality follows from $1 > \phi > \bar{\phi}$. 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 for result (i) in Appendix A. Given that the final good is produced only in the South, the 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,

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

The same logic as in the proof for result (i) applies to the remainder of this proof.

Appendix E. Changes in the price index for the final good

This appendix shows how the price index for the final good changes with continuous declines in trade costs. Specifically, it changes as follows: (i) The price index for the final good jumps to a lower level just as trade costs fall below the critical value implied by $\bar{\phi}$; and (ii) the price index

continuously falls with trade costs after the emergence of vertical specialization, i.e., when $\phi > \overline{\phi}$.

A downward jump

The reason for the first downward jump is that each final good is produced more efficiently because of the drastic change in industrial location associated with the emergence of vertical specialization. As trade costs shrink to slightly lower than the threshold, the production of the final good in all industries and that of the intermediate goods in industry $z \in [0, \overline{z}_0)$ shift from the North to the South, where $\overline{z}_0$ denotes the equilibrium value of $\overline{z}$ when trade costs equal the critical value (i.e., $\phi = \overline{\phi}$). To reveal the mechanism behind the fall in the final-good price index caused by the production shifts, we consider changes in the final-good prices in interval $[0, \overline{z}_0)$ separately from those in interval $(\overline{z}_0, 1]$.

In a lower spectrum of industries from 0 to $\overline{z}_0$, the price of the final good falls because of a decline in the price index for the intermediate good induced by the inter-sectoral reallocation of skilled labor forces in the North. The cross-country shift of the final-good production does not directly affect its price when $\phi = \overline{\phi}$ (This is found from (3), (B2) and the definition of $\overline{\phi}$ in (13)). In the North, skilled labor forces released from production in industries from $\overline{z}_0$ to 1 flow into the other industries. This leads to an increase in the variety of intermediate goods that the North produces in a lower spectrum of industries from 0 to $\overline{z}_0$. Thus, the price index for the intermediate good in interval $[0, \overline{z}_0)$ becomes lower, so the price of the final good also falls.

In a higher spectrum of industries from $\overline{z}_0$ to 1, the cross-country production shifts in both the downstream and upstream sectors affect the price of the final good. To see this, we will derive the equilibrium prices of the final good before and after the production shifts and compare them. Accounting for each country's production patterns under one-way trade and vertical specialization,

and making use of (3) and (4), the ratio of the two prices is given by:

$$\frac{P_I(z)}{P_{II}(z)} = \left\{ \frac{n_I(z)}{n_{II}^*(z)} \left[\frac{p_{II}^*(z)}{p_I(z)} \right]^{\sigma-1} \right\}^{\beta/(1-\sigma)} \left(\frac{a^*}{a} \right)^{1-\beta}, \tag{E1}$$

where subscripts *I* and *II* denote the variables before and after the production shifts, respectively. From (8) and the definition of $\bar{\phi}$ in (13), (E1) is rewritten as:

$$\frac{P_I(z)}{P_{II}(z)} = \left\{ \frac{n_I(z)}{n_{II}^*(z)} \left[\frac{b^*(z)/a^*}{b(z)/a} \right]^{\sigma-1} \bar{\phi} \right\}^{\beta/(1-\sigma)}. \tag{E2}$$

Keeping in mind that the total fixed costs incurred by upstream firms in each industry are $\alpha\beta(\bar{H}+\bar{L})/\sigma$ and using (9), the number of varieties of intermediate goods before and after the production shifts are obtained as follows:

$$n_I(z) = H / f(z); \quad n_{II}^*(z) = H^* / (1-\bar{z}_0) f^*(z).$$

These, together with (5) and (15), imply that (E2) is further rewritten as

$$\frac{P_I(z)}{P_{II}(z)} = \left[\bar{z}_0 \frac{T(z)\bar{\phi}}{\Omega(\bar{z}_0)} \right]^{\beta/(1-\sigma)}. \tag{E3}$$

From the definition of $\bar{z}_0$, it follows that $\Omega(\bar{z}_0) = T(\bar{z}_0)\bar{\phi}$. Hence, (E3) is equivalent to

$$\frac{P_I(z)}{P_{II}(z)} = \left[\bar{z}_0 \frac{T(z)}{T(\bar{z}_0)} \right]^{\beta/(1-\sigma)}. \tag{E4}$$

Since $T(z)$ is declining in z, (E4) is greater than unity for all $z \in (\bar{z}_0, 1]$. Therefore, the price of the final good produced in industry $z \in (\bar{z}_0, 1]$ is lowered by the shifts of production of the final and intermediate goods.

A continuous decline

The continuous decline in the price index for the final good after the emergence of vertical specialization is due to falling trade costs and thus less costly import of the intermediate goods

produced in industry $z \in [0, \bar{z})$ by the South. In contrast, the change in the production location for the intermediate good accompanying a decline in trade costs has no impact on the final-good price index because its multiple effects cancel out each other.

First, note that the price of the final good produced in industry $z \in [0, \bar{z})$ and the price of the one produced in industry $z \in (\bar{z}, 1]$ are respectively given by:

$$P(z) = \left[n(z) \phi p(z)^{1-\sigma} \right]^{\beta/(1-\sigma)} a^{*\beta-1} \equiv P_N(z) \tag{E5}$$

and

$$P(z) = \left[n^*(z) p^*(z)^{1-\sigma} \right]^{\beta/(1-\sigma)} a^{*\beta-1} \equiv P_S(z), \tag{E6}$$

where $n(z)$ and $n^*(z)$ are obtained as follows:

$$n(z) = H / \bar{z} f(z); \quad n^*(z) = H^* / (1-\bar{z}) f^*(z). \tag{E7}$$

From (E6), (E7) and (16), the aggregate effects of an infinitesimal decrease in trade costs on the final-good price index can be expressed as:

$$\frac{dP}{d\phi} = \int_0^{\bar{z}} \frac{\partial \ln P_N(z)}{\partial \phi} dz + \ln \left[\frac{P_N(\bar{z})}{P_S(\bar{z})} \right] \frac{d\bar{z}}{d\phi} \tag{E8}$$

$$+ \left\{ \int_0^{\bar{z}} \left[\frac{\partial \ln P_N(z)}{\partial n(z)} \cdot \frac{\partial n(z)}{\partial \bar{z}} \right] dz + \int_{\bar{z}}^1 \left[\frac{\partial \ln P_S(z)}{\partial n^*(z)} \cdot \frac{\partial n^*(z)}{\partial \bar{z}} \right] dz \right\} \frac{d\bar{z}}{d\phi}, \tag{E9}$$

The first term on the RHS of (E8) represents the direct effect of a fall in trade costs; i.e., a decline in P due to less costly import of intermediate goods by the South (This P-lowering effect of an increase in ϕ is shown from (E5)). The other terms in (E8) and (E9) represent the indirect effects induced by a marginal increase in $\bar{z}$ (Note that $\bar{z}$ increases with ϕ).

The second term on the RHS of (E8) shows the effect of the cross-country shift of the intermediate-goods production in the boundary industry. Keeping (5) and (15) in mind and using (E5) – (E7) with $\Omega(\bar{z}) = T(\bar{z})\phi$, it is shown that this term equals zero, or equivalently,

$P_N(\bar{z}) = P_S(\bar{z})$. This implies that the price of the final good produced in the boundary industry is unchanged even if the production location for the intermediate good in the industry switches from the South to the North.

(E9) exhibits the composite effect of changes in the number of varieties of intermediate goods produced in individual industries. After differentiating each of (E5) – (E7) with respect to the relevant variable and inserting the derivatives into (E9), this composite effect is found to be zero. The intuition is as follows. An increase in $\bar{z}$ implies an expansion in the range of industries where the North produces the intermediate goods. Therefore, as trade costs fall, the quantity of skilled labor forces available per industry decreases in the North and the number of varieties of intermediate goods that the North produces in each industry becomes smaller. This situation induces a rise in P by raising the price index for the intermediate good in interval $[0, \bar{z})$. However, it is offset by the opposite effect arising from an increase in the number of varieties of intermediate goods that the South produces in industries from $\bar{z}$ to 1.

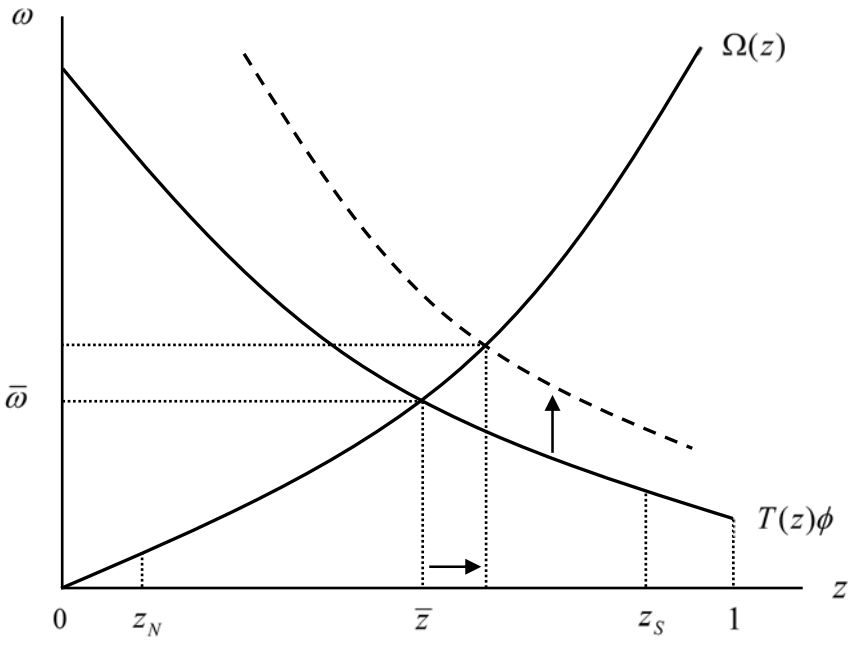
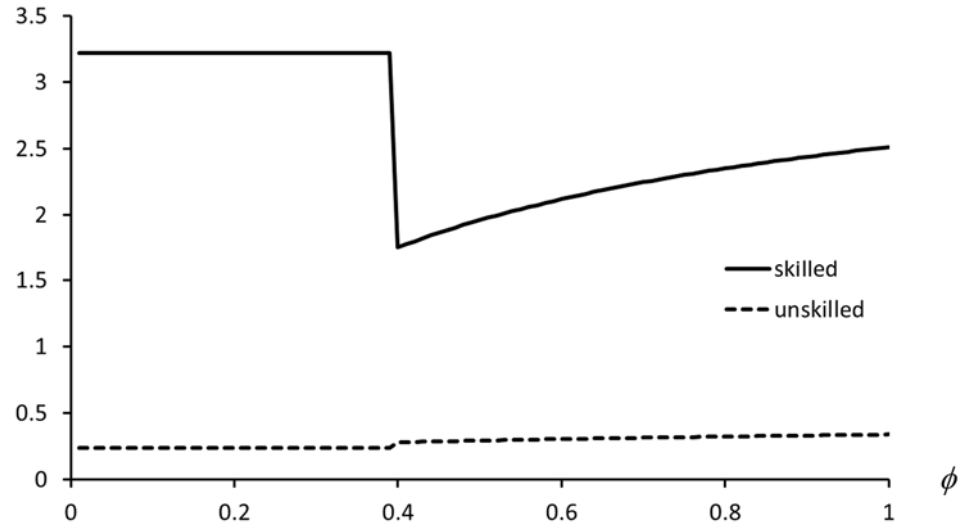
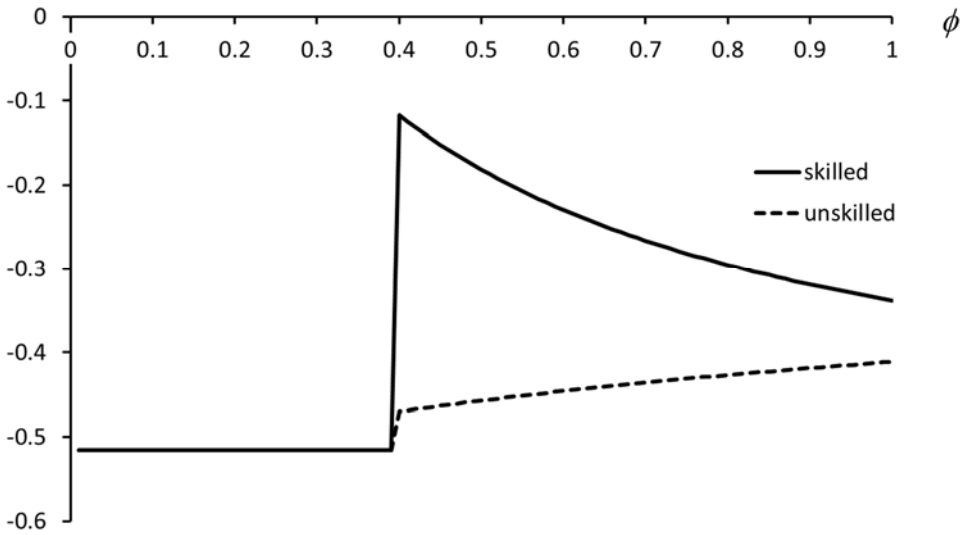


Figure 1: The equilibrium distribution of industries

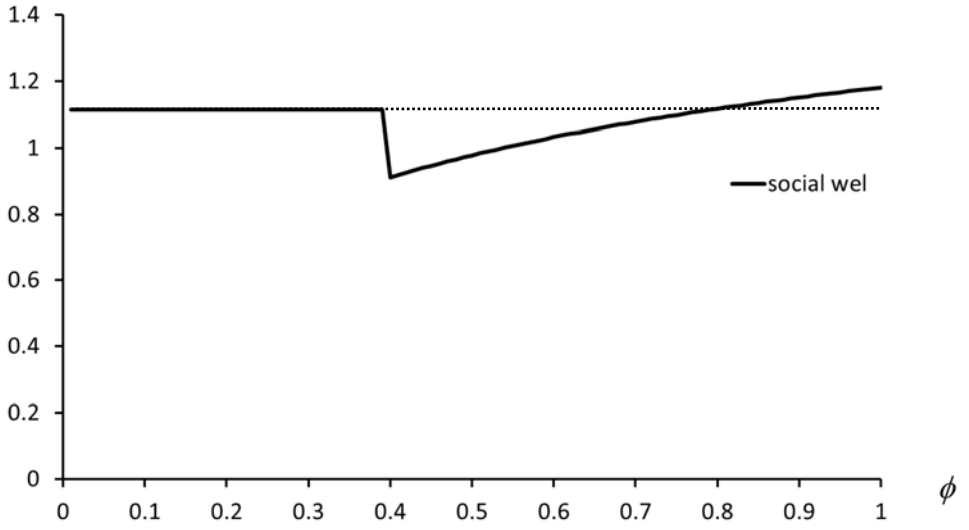


(a) North

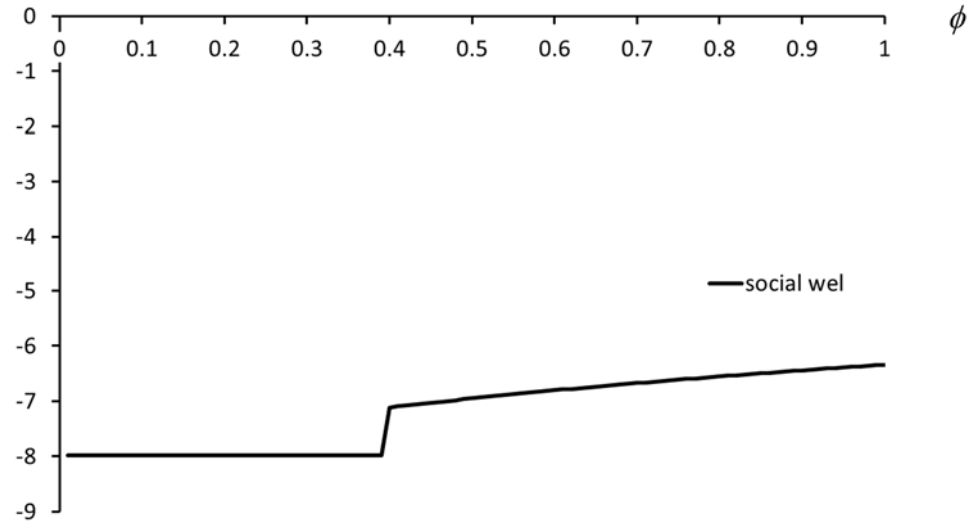


(b) South

Figure 2: Utility



(a) North



(b) South

Figure 3: Social welfare