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Beyond Icebergs:
Modeling Globalization as Biased Technical Change

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Abstract

We propose a new approach to model costly international trade, which includes the standard approach, the "iceberg" transport cost, as a special case. The key idea is to make the technologies of supplying the good depend on the destination of the good. To demonstrate our approach, we extend the Ricardian model with a continuum of goods, due to Dornbusch, Fischer and Samuelson (1977), by introducing multiple factors of production and by making each industry consist of the domestic division, which supplies the good at home, and the export division, which supplies the good abroad. If the two divisions differ only in the total factor productivity, our model becomes isomorphic to the DFS model with the iceberg transport cost. When the two divisions differ also in the factor intensity, globalization changes the relative factor prices *in the same direction* across the countries, in sharp contrast to the usual Stolper-Samuelson effect, which suggests that the relative factor prices move in different directions in different countries.

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1. Introduction.

In this paper, we propose a new approach to model costly international trade. The key idea is to make the technologies of supplying the goods depend on the destination of the goods. By using the word, "supply," we mean to include all the activities associated with delivering the goods to the customers in a particular market. It includes not only the production and the shipping of the goods, but also the marketing and customer services, which involve communication with the dealers, customers, and even government agencies. If it is more costly to supply goods to the foreign markets than the domestic market, this approach naturally generates the home market bias, leading to deviations from the law of one price, as well as endogenously determined nontraded goods (i.e., the goods that are potentially "tradeable" but not traded in equilibrium.)

Our approach includes the standard approach to model costly trade, the "iceberg" transport cost, as a special case. According to the iceberg approach, commonly attributed to Samuelson (1954), the technologies of producing the goods are the same, whether the destination of the goods is at home or abroad. The cost of trade takes the form of "shrinkage" in transit so that only a fraction of the good shipped abroad actually arrives. Our approach would generate the same result with the iceberg approach if we would impose the additional restriction that the technologies of supplying the goods differ across the destinations of the goods only in the total factor productivity. Our approach is more flexible than the iceberg approach in that it allows for the possibility that supplying the goods abroad may use the factors in a different proportion from supplying the goods at home. This flexibility enables us to explore the effects of globalization that cannot be captured by using the iceberg approach.

For example, imagine that the cost of supplying the goods abroad decline relative to the cost of supplying domestically. Such a change in the relative cost can happen for many different reasons, such as technological advances in information technologies (telegraphs, telephones, facsimiles, internet, communication satellites, etc), a tariff reduction, a harmonization of the regulations across countries, a wider acceptance of English as the global business language, an emergence of the global consumer culture that reduces the need to make the goods and services tailor-made for each country, etc. The resulting globalization means a reallocation of the factors from supplying the goods at home to supplying the goods abroad. If we are to model this process

by reducing the iceberg transport cost, globalization can change relative factor demands only through the standard Stolper-Samuelson effect. That is to say, relative factor demands of a country can change only when the country's exported goods and its imported goods have different factor intensity. This also means that globalization tends to move the factor prices in different directions in different countries. If the wage rate of white-collar workers relative to blue-collar workers goes up in one country, it has to go down in the rest of the world. Our approach suggests that this need not be the case. If exporting goods inherently require more intensive use of some factors (say, white-collar workers, particularly those with language skills and/or international business experiences) than supplying the same goods domestically, globalization leads to an increase in the relative price of those factors in all the countries. Our approach thus offers a fresh perspective on the debate on the role of globalization in the recent rise in the skill premia.

Obviously, one could try to apply our approach to any existing model of international trade with the iceberg transport cost. In this paper, we have chosen the Ricardian model with a continuum of goods, developed by Dornbusch, Fischer, and Samuelson (1977), hereafter DFS. Their model offers a useful background against which to demonstrate our approach for the following reasons. First, its Ricardian structure enables us to illustrate the difference between our approach and the iceberg approach without complication of the well-understood Stolper-Samuelson effect. Second, to the best of our knowledge, DFS is the first study that derived the set of nontraded goods endogenously by making use of the iceberg transport cost. Furthermore, DFS has inspired many recent studies on competitive models of international trade with the iceberg transport cost.[2]

Section 2 develops our model, which extends the DFS model in two respects. First, it has multiple factors of production. Second, each industry consists of two divisions; the domestic division, which supplies the good at home, and the export division, which supplies the good abroad. The two divisions use different technologies, and it is assumed that it is more costly to supply the good abroad than at home. We use this model to examine the effect of an

[2]See, e.g., Obstfeld and Rogoff (1996, Chapter 4), Eaton and Kortum (2002), and Alvarez and Lucas (2004).

improvement in the export technologies on the trade patterns and the factor prices.[3] Section 3 considers the special case, where the technologies of the domestic and export divisions differ only in the total factor productivity. With this additional restriction, an improvement in the export technologies leads to a globalization, but has no effect on the relative factor prices. Indeed, it is demonstrated that this special case is isomorphic to the DFS model with the iceberg transport cost. Section 4 considers the general case, where the domestic and export divisions may differ also in the factor intensity. It shows how an improvement in the export technologies leads to globalization as well as a change in the relative factor prices. Section 5 considers an application to the debate on the role of globalization in the recent rise in the skill premia. Under the assumption that the export division is more skilled labor intensive than the domestic division, globalization leads to a rise in the skill premia in all the countries, if the globalization is caused by a reduction in the tariff, or by the technical change that primarily in the export divisions or by skill labor augmenting technical change. Section 6 concludes.

2. The Basic Model.

Consider the following variation of the DFS model. The world economy consists of two countries, Home and Foreign, and there are a continuum of competitive industries, indexed by $z \in [0,1]$, which produces good z. The Home consumers have the identical Cobb-Douglas preferences with b(z) being the expenditure share of good z, with $\int_0^1 b(z)dz = 1$. Thus, the Home demand for good z is given by $D(z) = b(z)E/p(z)$, where p(z) is the Home price of good z and E is the Home aggregate expenditure. Likewise, the Foreign demand for good z is $D^*(z) = b^*(z)E^*/p^*(z)$, where $b^*(z)$ is the Foreign expenditure share of good z with $\int_0^1 b^*(z)dz = 1$, $p^*(z)$ is the Foreign price of good z, and E^* is the Foreign aggregate expenditure.

[3]By "an improvement in the export technologies," we mean general technical changes that improve the efficiency of supplying the goods to the foreign markets (relative to the domestic market), which are not specific to a particular good or industry. It should not be confused with "an export-biased technical change," the well-known concept that can be found in most standard textbooks of international trade, first proposed by Hicks (1953). The latter is an industry-specific technical change that improves the efficiency of production in an exporting industry. This type of technical change does not change the cost of supplying the same good to the foreign markets relative to the domestic market. It changes the relative cost of producing the exportable goods to the importable goods.

This paper departs crucially from DFS in two respects. First, there are J factors of production, with $V = (V_1, V_2, \ldots, V_J)^T$ and $V^* = (V_1^*, V_2^*, \ldots, V_J^*)^T$ being the column vectors of the Home and Foreign factor endowments, where V_j and V_j^* are the Home and Foreign endowments of the j-th factor (j = 1, 2, …, J). The factors are nontradeable and the factor prices are given by the row vectors, $w = (w_1, w_2, \ldots, w_J)$ and $w^* = (w_1^*, w_2^*, \ldots, w_J^*)$. We may think of these factors as different types of labor, with different skill levels, expertise, and specialties. Second, the technologies may depend on the destination of goods. More specifically, each industry consists of the two divisions, the domestic and the export divisions. The domestic division of industry z at Home can supply one unit of good z to the Home market at the cost of $a(z)\Phi(w)$, while its export division can supply one unit of good z to the Foreign market at the cost of $a(z)\Psi(w;\tau)$. It should be noted that the word, "supply," here means to include all the activities needed to deliver the good to the consumers in a particular market. It includes not only the production cost, but also the marketing and shipping costs, and all sorts of communication costs. Both Φ and Ψ are assumed to be linear homogeneous, increasing, and concave in w. Thus, they satisfy the standard properties of the unit cost functions associated with CRS technologies. Likewise, the unit cost of the domestic division of the Foreign industry z is $a^*(z)\Phi^*(w^*)$, while the unit cost of the export division of the Foreign industry z is $a^*(z)\Psi^*(w^*;\tau^*)$. Note the presence of the shift parameters, τ and τ^*, in the cost functions of the export divisions. We will use them to examine the effect of the technical change in the export divisions. Furthermore, we will assume the following assumptions.

(A1) $A(z) \equiv a^*(z)/a(z)$ is continuous and decreasing in z.

(A2) $\Phi(w) < \Psi(w;\tau)$; $\Phi^*(w^*) < \Psi^*(w^*;\tau^*)$.

The first assumption, (A1), is borrowed directly from DFS. It means that the industries are indexed according to the patterns of comparative advantage; Home (Foreign) has comparative advantage in lower (higher) indexed goods. (A2) implies that supplying (i.e., producing, marketing, shipping, etc.) goods to the export market is more costly than supplying (i.e., producing, marketing, shipping, etc.) goods to the domestic market. This model may be viewed as a hybrid of the Ricardian model of trade and the factor proportion models of trade. Across the

industries, the technologies differ only in the total factor productivity, but not in the factor intensity. Within each industry, on the other hand, the domestic and export divisions may differ not only in total factor productivity, but also in factor intensity. It should be noted, however, that, unlike the standard factor proportion models of trade, the factor intensity differences are based on the destination of the goods, not on the goods themselves. Our objective here is to explore the effects of technical change that improves the efficiency of the export divisions relative to that of the domestic divisions across all the industries. We deliberately rule out the factor intensity differences across the goods, in order to isolate our result from the well-known Stolper-Samuelson mechanism.

The consumers everywhere purchase the goods from the lowest cost suppliers. Hence, the price of good z is equal to $p(z) = \min\{a(z)\Phi(w), a^*(z)\Psi^*(w^*;\tau^*)\}$ and $p^*(z) = \min\{a(z)\Psi(w;\tau), a^*(z)\Phi^*(w^*)\}$. Assumptions (A1) and (A2) thus imply that, for any factor prices, w and w*, there are two marginal industries, $m < m^*$,

(1) $A(m) = \Psi(w;\tau)/\Phi^*(w^*)$,

(2) $A(m^*) = \Phi(w)/\Psi^*(w^*;\tau^*)$,

such that the Home industries supply to the Home and Foreign markets in $z \in [0,m)$; only the Foreign industries supply to the Home and Foreign markets in $z \in (m^*,1]$, and only the Home industries supply to the Home market and only the Foreign industries supply to the Foreign market in $z \in (m,m^*)$. In other words, Home exports and Foreign imports in $z \in [0,m)$ and Home imports and Foreign exports in $z \in (m^*,1]$. There is no trade in $z \in (m,m^*)$. These goods are endogenously nontraded goods; that is to say, they are tradeable goods that are not traded in equilibrium. The patterns of production and trade are illustrated in Figure 1.

From the standard result of the duality theory of production (see, e.g., Dixit and Norman 1980), each unit of good z produced and purchased in Home generates demand for Home factor j equal to $a(z)\Phi_j(w) = p(z)\Phi_j(w)/\Phi(w)$, where subscript j signifies the partial derivative with respect to w_j. Similarly, each unit of good z produced in Home and purchased in Foreign generates demand for Home factor j equal to $a(z)\Psi_j(w;\tau) = p^*(z)\Psi_j(w;\tau)/\Psi(w;\tau)$. Thus, the equilibrium condition for the market for Home factor j is given by

$$V_j = [\Phi_j(w)/\Phi(w)] \int_0^{m^*} [p(z)D(z)]dz + [\Psi_j(w;\tau)/\Psi(w;\tau)] \int_0^{m} [p^*(z)D^*(z)]dz, \quad (j = 1, 2,\ldots J),$$

where the first (second) term of the RHS is the derived demand for Home factor j from supplying goods to the domestic (export) market. By using $p(z)D(z) = b(z)E$ and $p^*(z)D^*(z) = b^*(z)E^*$, this condition can be rewritten to

$$V_j = [\Phi_j(w)/\Phi(w)]B(m^*)E + [\Psi_j(w;\tau)/\Psi(w;\tau)]B^*(m)E^*, \qquad (j = 1, 2,\ldots J)$$

where $B(z) \equiv \int_0^z [b(s)]ds$ and $B^*(z) \equiv \int_0^z [b^*(s)]ds$ are the Home and Foreign expenditure shares of the goods in [0, z]. They are strictly increasing and satisfy $B(0) = B^*(0) = 0$ and $B(1) = B^*(1) = 1$. This condition can be further simplified as

$$(3) \qquad w_jV_j = \alpha_j(w)B(m^*)wV + \beta_j(w;\tau)B^*(m)w^*V^* \qquad (j = 1, 2,\ldots J)$$

by defining $\alpha_j(w) \equiv w_j\Phi_j(w)/\Phi(w)$ and $\beta_j(w;\tau) \equiv w_j\Psi_j(w;\tau)/\Psi(w;\tau)$, and making use of the budget constraints in the two countries, $E = wV$ and $E^* = w^*V^*$. Eq. (3) can be easily interpreted. Since $B(m^*)$ is the fraction of the Home aggregate income spent on the Home industries and $\alpha_j(w)$ is the share of factor j in the domestic division of the Home industries, the first term of the RHS of eq. (2) is the income earned by Home factor j derived from the domestic market. The second term is the income earned by Home factor j derived from the export market, because $B^*(m)$ is the fraction of the Foreign aggregate income spent on the Home industries, and $\beta_j(w;\tau)$ is the share of factor j in the export division of the Home industries.

Similarly, the equilibrium condition for the market for Foreign factor j is given by

$$(4) \qquad w_j^*V_j^* = \alpha_j^*(w^*)[1-B^*(m)]w^*V^* + \beta_j^*(w^*;\tau^*)[1-B(m^*)]wV, \quad (j = 1, 2,\ldots J),$$

where $\alpha_j^*(w^*) \equiv w_j^*\Phi_j^*(w^*)/\Phi^*(w^*)$ is the share of factor j in the domestic division of the Foreign industries; $\beta_j^*(w^*;\tau^*) \equiv w_j^*\Psi_j^*(w^*;\tau^*)/\Psi^*(w^*;\tau^*)$ is the share of factor j in the export

division of the Foreign industries; 1−B(m*) is the fraction of the Home aggregate income spent on the Foreign industries; and 1−B*(m) is the fraction of the Foreign aggregate income spent on the Foreign industries.

Recall that the linear homogeneity of Φ(w) and Ψ(w) implies $\sum_{j=1}^{J} \alpha_j(w) = \sum_{j=1}^{J} \beta_j(w;\tau) = 1$. Hence, adding up (3) for all j yields

(5) $[1-B(m^*)]wV = B^*(m)w^*V^*$.

This may be viewed as the balanced trade condition, as the LHS is the total value of the Foreign export and the RHS is the total value of the Home export. Likewise, adding up (4) for all j also yields eq. (5). This means that each of eq. (3) and eq. (4) offers J −1 equilibrium conditions in addition to eq. (5). Thus, eqs. (1)-(5) altogether contain 2J+1 equilibrium conditions. They jointly determine 2J+1 unknowns, the two marginal industries, m and m*, and the 2J −1 relative factor prices (i.e., the 2J absolute factor prices, w and w*, up to a scale.) We can use eqs. (1)-(5) to examine the effects of globalization caused by technological change in the export divisions, by shifting the two parameters, τ and τ*.

3. Globalization as Unbiased Technical Change: Restoring the DFS (1977) model.

Let us first consider the following special case of (A2).

(A3) $\Psi(w;\tau) = \tau\Phi(w)$ with $\tau > 1$; $\Psi^*(w^*;\tau^*) = \tau^*\Phi^*(w^*)$ with $\tau^* > 1$.

Thus, the cost function of the export division can be obtained by a homogeneous shift of the cost function of the domestic division. This assumption thus implies that both divisions have the same factor intensity; $\beta_j(w;\tau) = \alpha_j(w)$ and $\beta_j^*(w^*;\tau^*) = \alpha_j^*(w^*)$. The two divisions differ only in the total factor productivity. Furthermore, a shift in the shift parameters, τ and τ*, the technical change in the export divisions, satisfies the Hicks-neutrality.

With (A3) and using eq. (5), eqs. (1)-(4) become

(6) $A(m) = \tau\Phi(w)/\Phi^*(w^*)$,

(7) $A(m^*) = \Phi(w)/\tau^*\Phi^*(w^*)$,

(8) $w_jV_j = \alpha_j(w)wV$, $(j = 1, 2,\ldots J)$

(9) $w_j^*V_j^* = \alpha_j^*(w^*)w^*V^*$, $(j = 1, 2,\ldots J)$

To simplify the above equations further, let us define $F(x) \equiv \min_q \{qx \mid \Phi(q) \geq 1\}$. It is linear homogeneous, increasing and concave in x, and satisfies $\Phi(w) \equiv \min_x \{wx \mid F(x) \geq 1\}$. Thus, it can be interpreted as the primary functions underlying $\Phi(w)$, where the technologies of the domestic and export divisions of the Home industry z may be described by $F(V^D(z))/a(z)$ and $F(V^E(z))/\tau a(z)$, where $V^D(z)$ and $V^E(z)$ are the vector of factors used in the domestic and export divisions of industry z. Since all the J factors are used in the same proportion in all the activities in equilibrium, they must be used in the same proportion with the factor endowment in equilibrium. Hence, since F_j is homogeneous of degree zero, $w_j = p(z)F_j(V)/a(z) = p^*(z)F_j(V)/\tau a(z) = \Phi(w)F_j(V)$ for all j. Therefore, from the linear homogeneity of F,

(10) $wV = \Phi(w)F(V) = WL$,

where W and L are defined by $W \equiv \Phi(w)$ and $L \equiv F(V)$. In other words, we can aggregate all the factors into the single quantity index, "labor", $L = F(V)$, with the single price index, "the wage rate," $W = \Phi(w)$.[4] Likewise, by defining $F^*(x) \equiv \min_q \{qx \mid \Phi^*(q) \geq 1\}$,

(11) $w^*V^* = \Phi^*(w^*)F^*(V^*) = W^*L^*$,

where the quantity index, $L^* = F^*(V^*)$, is the Foreign "labor" endowment and the price index, $W^* = \Phi^*(w^*)$, is the Foreign "wage rate." Using (10)-(11), eqs. (5)-(7) become

(12) $A(m)/\tau = W/W^* = B^*(m)L^*/[1-B(m^*)]L$,

(13) $A(m^*)\tau^* = W/W^* = B^*(m)L^*/[1-B(m^*)]L$,

[4]Recall that $W = \Phi(w)$ and $L = F(V)$ are scalars, while w is a J-row dimensional vector and V is a J-dimensional column vector.

while (8) and (9) become

(14) $V_j = \Phi_j(w)L, \qquad (j = 1, 2,\ldots J),$

(15) $V_j^* = \Phi_j^*(w^*)L^*, \qquad (j = 1, 2,\ldots J).$

Note that eqs. (12)-(13) jointly determine m and m* as a function of τ and τ^*, as shown in Figure 2. A decline in τ shifts the steeper curve, representing (12), to the right, and as a result, leads to a higher m, a lower m*, and a higher W/W*. Note that an improvement in the Home export technologies not only expands the Home export divisions but also the Foreign export divisions. Intuitively, as the improved export technologies enables the Home export divisions to replace the Foreign domestic divisions in (m, m'), the Home wage rate goes up relative to the Foreign wage rate, which leads to a replacement of the Home domestic divisions by the Foreign export divisions in (m*',m*). This causes a reallocation of the Home labor from the domestic divisions in (m*', m*) to the export divisions in (m, m'). At the same time, the Foreign labor is reallocated from the domestic divisions in (m, m') to the export divisions in (m*', m*). Likewise, a decline in τ^* leads to a lower m*, a higher m, and a lower W/W*. Thus, an improvement in the export technologies, regardless of whether it takes place at Home or at Foreign, leads to a growth of trade and a reallocation of labor from the domestic to export divisions *in both countries*.

Under (A3), however, this reallocation of labor from the domestic to the export divisions does not have any effect on the relative factor prices within each country. Note that, eqs. (14)-(15) are independent of τ and τ^*, as well as of m, m*, and W/W*. The relative factor prices within each country are determined solely by eqs. (14)-(15). Recall that technical change in the export divisions is Hicks-neutral, hence their relative factor demands are unaffected. Furthermore, the export divisions use all the factors in the same proportion with the domestic divisions. Hence, the relative factor demands cannot change through the composition effect,

either. When globalization does not change the relative factor demands, it has no effect on the relative factor prices.[5]

It is worth pointing out that the above model, under (A3), is essentially the same with the DFS model. For example, if we set $\tau = \tau^* = 1$, then $m = m^*$ and eqs. (12)-(13) collapse into $A(m) = W/W^* = B^*(m)L^*/[1-B(m)]L$. This is isomorphic to the equilibrium condition of the basic model of DFS (1977, Section I), which assumed $B(z) = B^*(z)$. This should come as no surprise. The two critical departures of the present model from DFS (i.e., the multiplicity of the factors and the distinction between the domestic and export divisions) are inconsequential in this case, because (A3) means that all the activities have the same factor intensity, which allow us to aggregate all the factors into the single composite, "labor," as in the basic DFS model, and because, with $\tau = \tau^* = 1$, both the domestic and export divisions produce the identical goods with the identical technologies, again as in the basic DFS model. DFS (1977, Section IIIB) also extended their model to allow for transport costs. Following the iceberg model of Samuelson (1954), they assumed that a fraction g of good z shipped to the export market actually arrives. Therefore, in order to supply one unit of good z to the Foreign country, Home must produce and ship 1/g units of good z, which make the price of the Home good z in the Foreign market equal to $a(z)W/g$. Eqs. (12)-(13) are identical to the equilibrium conditions for the DFS model with the iceberg transport cost if we set $\tau = \tau^* = 1/g > 1$. This suggests an alternative interpretation of the iceberg transport cost commonly used in the literature. Instead of thinking that each industry produces with the same technology both for the domestic and export markets, but only a fraction of the goods shipped arrives to the export market, one can think that the domestic and export divisions produce different goods, each tailored made for each market, and that the total factor productivity of the export division is a fraction of that of the domestic division. As long as the two divisions use all the factors in the same proportion, these two specifications give the identical results. In short, we can view as a decline in the iceberg transport cost as a special form of technical changes that benefit the export divisions.

According to this alternative interpretation, however, a reduction in τ and τ^* can occur not only through an improvement in transport technologies, but also through any changes that

[5]Needless to say, even when the domestic and export divisions use the factors in the same proportion in each industry, globalization could change the factor prices through the well-known Stolper-Samuelson effect, if the factor

help to lower the cost of serving the export markets. Such changes may include an improvement in communication and information technologies (telegraphs, telephones, facsimiles, internet, communication satellite, etc), a harmonization of the regulations across countries, a wider acceptance of English as the common business language, as well as an emergence of the global consumer culture that reduces the need to make the goods tailor-made for each country. Perhaps more importantly, this alternative interpretation also suggests a natural way of going beyond the iceberg specification. Once we can start thinking about the possibility that the destination of the good affect the technologies of supplying the good, we may start thinking about the possibility that it affects not only the total factor productivity but also the factor intensity. As will be seen below, this opens up the possibility that a change in the export technologies, and the resulting growth of trade and reallocation of the factors from the domestic to export divisions, lead to a change in the relative factor prices *in the same direction* both at Home and Foreign.

Before proceeding, it is worth pointing out that one could reinterpret eqs. (12)-(15) as the equilibrium conditions for the case where the domestic and export divisions share the same technology, but the Foreign government imposes the tariff on the Home goods at the rate equal to $\tau - 1$, and the Home government imposes the tariff on the Foreign goods at the rate equal to $\tau^* - 1$, under the assumption that the tariff revenues are entirely wasted so that they do not affect the aggregate expenditure of the two countries. Then, the above result suggests that a reduction in the tariff leads to a globalization (an increase in m and a decline in m*), but it does not affect the relative factor prices under (A3).

4. Globalization as Biased Technical Changes

We are now going to show how technical changes in the export technologies can affect the relative prices, if we drop the restrictive assumption, (A3). Recall the equilibrium conditions are given by eqs. (1)-(5). Since the key mechanism does not rely on the asymmetry between Home and Foreign, let us focus on the case, where the two countries are the mirror images of each other. That is,

(M) $A(m)A(1-m) = 1$; $B(m) = B^*(m)$ with $B(m) + B(1-m) = 1$;

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intensity differ across the goods.

$\Phi = \Phi^*$, $\Psi = \Psi^*$ (so that $\alpha_j = \alpha_j^*$, $\beta_j = \beta_j^*$), and $V = V^*$, and $\tau = \tau^*$.

Then, in symmetric equilibrium, $w = w^*$, $m = 1-m^* < ½$, and the equilibrium conditions are now reduced to

(16) $A(m) = \Psi(w;\tau)/\Phi(w)$,

(17) $V_j = \{\alpha_j(w) + [\beta_j(w;\tau)-\alpha_j(w)]B(m)\}wV/w_j$ $(j = 1, 2,\ldots J)$.

Eq. (16) shows that, given the factor prices, an improvement in the export technologies (a change in τ that causes a downward shift of Ψ) leads to an increase in m (and a decline in $m^* = 1-m$). The RHS of Eq. (17) is the demand for factor j. It shows that a shift in τ could affect the factor demand for two separate routes. First, it could affect through international trade. A higher m increases the demand for the factors used more intensively in the export divisions (those with $\beta_j > \alpha_j$) and reduces demand for those used more intensively in the domestic divisions (those with $\beta_j < \alpha_j$). Thus, globalization can affect the factor demand by changing the composition between the domestic and export divisions. Second, it could affect by changing the relative factor demand within the export divisions, if $\beta_j(w;\tau)$ depends on τ. Note that there is an important special case, where a shift in τ could affect the factor demand only through the first route. This is the case where the technical change in the export divisions satisfies the Hicks-neutrality:

(A4) $\Psi(w;\tau) = \tau\Psi(w)$ with $\tau > 1$ and $\Psi(w) > \Phi(w)$.

In this case, $\beta_j(w;\tau)$ is independent of τ, which allow us to simply drop τ to denote it as $\beta_j(w)$. Under (A4), the RHS of eq. (17) no longer depends on τ. Thus, a shift in τ affects the factor demands only by changing the composition of the domestic and export divisions.[6]

To analyze eqs. (16)-(17) further, let us consider the two-factor case (J = 2). Then, eqs. (16)-(17) become

[6]On the other hand, a shift in τ cannot affect the factor demand only through the second route. This is because, in order to shut down the first route, we must assume $\beta_j(w;\tau) = \alpha_j(w)$, and hence β_j becomes independent of τ.

(18) $A(m) = \psi(\omega;\tau)/\varphi(\omega)$

(19) $$\frac{V_1}{V_2} = \left[\frac{\alpha_1(\omega) + [\beta_1(\omega;\tau) - \alpha_1(\omega)]B(m)}{1 - \alpha_1(\omega) - [\beta_1(\omega;\tau) - \alpha_1(\omega)]B(m)} \right] \Big/ \omega ,$$

where $\omega \equiv w_1/w_2$ ($= \omega^* \equiv w_1^*/w_2^*$) is the relative factor price; $\varphi(\omega) \equiv \Phi(\omega,1) = \Phi(w_1,w_2)/w_2$, $\psi(\omega;\tau) \equiv \Psi(\omega,1;\tau) = \Psi(w_1,w_2;\tau)/w_2$; $\alpha_1(\omega) = 1 - \alpha_2(\omega)$ and $\beta_1(\omega;\tau) = 1 - \beta_2(\omega;\tau)$ are the shares of factor 1 in the domestic and export divisions. (Recall that Φ and Ψ are linear homogeneous and that the factor shares, α_j and β_j, satisfy the homogeneity of degree zero). Note that the RHS of eq. (19) is the relative demand curve for factor 1 over factor 2.

Figure 3 depicts eqs. (18)-(19) over the (m, ω)-space, under the assumption that the export division is more factor 1 intensive than the domestic division; $\alpha_1(\omega) < \beta_1(\omega;\tau)$. This factor intensity assumption implies that eq. (18) is downward-sloping.[7] Intuitively, a lower ω makes the cost of the export divisions decline more than the cost of the domestic divisions, therefore trade take places in a larger fraction of the industries (i.e., a higher m and a lower $m^* = 1-m$). Under the same factor intensity assumption, an expansion of the export divisions at the expense of the domestic division (a higher m and a lower $m^* = 1-m$) leads to an increase in the relative demand for factor 1. This in turn leads to a higher ω in a stable factor market equilibrium. Thus, eq. (19) is upward-sloping, whenever the factor market is stable.[8] Figure 3 is drawn under the assumption that the factor market equilibrium is always stable, so that the curve depicting eq. (19) is everywhere upward-sloping.[9] The equilibrium is given by point E, at the intersection of the two curves.

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[7]Algebraically, log-differentiating eq. (18) yields $d\omega/dm = \omega A'(m)/A(m)[\beta_1(\omega;\tau) - \alpha_1(\omega)] < 0$.

[8]To see this algebraically, let the RHS of eq. (19), the relative factor demand, denoted by $f(\omega, m; \tau)$. Then, $\beta_1(\omega;\tau) > \alpha_1(\omega)$ implies $f_m > 0$. The Walrasian stability of the factor market equilibrium requires that relative demand curve is decreasing in the relative price: i.e., $f_\omega < 0$. Thus, $d\omega/dm = -f_m/f_\omega > 0$ along the stable factor market equilibrium satisfying eq. (19).

[9]This is the case, for example, if Φ and Ψ are Cobb-Douglas so that α_1 and β_1 are constant. Of course, without making some restrictions on the functional forms of Φ and Ψ, one cannot rule out the possibility that the relative factor demand, $f(\omega, m; \tau)$, may be increasing in ω over some ranges, and eq. (19) may permit multiple factor price equilibriums. If so, the curve depicting eq. (19) over the (m, ω)-space could have an S-shape. In such a case, the downward-sloping part corresponds to an unstable equilibrium, and hence only the upward-sloping parts are relevant for the comparative statics. For this reason, we will not discuss such "pathological" cases of downward-sloping eq. (19) in what follows. This is nothing but the famous "Correspondence Principle" of Samuelson (1947).

A reduction in τ shifts eq. (18), the downward-sloping curve, to the right. Under (A4), i.e., when the improvement in the export technologies satisfies the Hicks-neutrality, eq. (19) is independent of τ, so that the upward-sloping curve remains intact. Hence, the equilibrium moves from point E to point E'. The result is an increase in both m and ω. An improvement in the export technologies not only leads to a globalization, which can be measured either in the share of the traded industries, $m+1-m^* = 2m$, or in the Trade/Income ratio, $B^*(m)+B(1-m^*) = 2B(m)$. It also leads to an increase in the relative price of the factor used intensively in the export divisions.

The analysis would become a little bit more complex when (A4) does not hold, i.e., when the improvement in the export technologies violates the Hicks-neutrality. However, unless the nonneutrality is too strong, the result would go through. If the technical improvement favors factor 1 over factor 2 within the export divisions, then the upward-sloping curve shifts upward, when the downward-sloping curve moves to the right. The relative factor price, ω, unambiguously goes up. It also leads to an increase in m, unless the nonneutrality is too strong and the upward-sloping curve shifts too much. If the improvement favors factor 2 over factor 1, then the upward-sloping curve shifts downward, while the downward-sloping curve moves to the right. It leads unambiguously to an increase in m. The relative factor price also goes up, unless the nonneutrality is too strong and the upward-sloping curve shifts too much.

It is worth reminding the reader that the case of the Hicks-neutral technical change in the export division, (A4), depicted in Figure 3, can be reinterpreted as a reduction in the tariff. According to this interpretation, (A4) means that the cost functions of the export division is given by $a(z)\Psi(w)$ at Home and $a^*(z)\Psi(w)$ at Foreign, but the tariffs at the rate equal to $\tau-1$ are levied to all the imports. Then, one can interpret that Figure 3 captures the effect of a reduction in the tariff.[10] Thus, globalization, whether it is caused by a Hicks-neutral improvement in the export technologies or a reduction in the tariff, leads to a rise in the prices of the factors used intensively in the export divisions relative to those used intensively in the domestic divisions both at Home and at Foreign.

[10] In the symmetric case, the additional effect of the tariff revenue does not affect the equilibrium, as long as each government transfers its revenue to its own residents.

5. An Application: Globalization and Skill Premia

The model presented above can be useful for thinking about the debate on the role of globalization in the recent rise in the skill premia. Imagine that there are two types of labor; skilled and unskilled. Suppose that the export division is more skilled labor intensive than the domestic division. Furthermore, suppose that technical changes that take place primarily in the export divisions or a reduction in the tariffs lead to globalization. This would lead to a rise in the skill premia in all the countries.

However, we do not *need* to assume that the technical changes take place primarily in the export divisions to obtain the above result. Skilled-labor augmenting technical changes can also have the same effect, as long as we maintain the assumption that the export division is more skilled-labor intensive.

To see this, let us now modify the above model as follows. There are two factors, now labeled as s for skilled labor and u for unskilled labor. The cost functions of the domestic and export divisions of industry z are given by $a(z)\Phi(\tau w_s, w_u)$ and $a(z)\Psi(\tau w_s, w_u)$ at Home and $a^*(z)\Phi^*(\tau^* w_s^*, w_u^*)$ and $a^*(z)\Psi^*(\tau^* w_s^*, w_u^*)$ at Foreign. Note that the shift parameters, τ and τ^*, enter in the cost functions of both the domestic and export divisions. A reduction in τ (and τ^*) now means a skill-labor augmenting technical change, and hence it reduces the costs of both the domestic and export divisions for fixed wage rates. We also need to replace (A2) by

(A5) $\Phi(\tau w_s, w_u) < \Psi(\tau w_s, w_u)$ and $\Phi^*(\tau^* w_s^*, w_u^*) < \Psi^*(\tau^* w_s^*, w_u^*)$.

Then, by following the same steps as done in Section 2, we can conduct the analysis of this modified model and derive its equilibrium conditions, analogous to eqs.(1)-(5).

Instead of repeating the whole analysis, let us focus on the case where the two countries are the mirror-images of each other. Then, the equations analogous to eqs. (18)-(19) are given by

(20) $A(m) = \psi(\tau\omega)/\varphi(\tau\omega)$,

(21) $$\frac{V_s/\tau}{V_u} = \left[\frac{\alpha_s(\tau\omega) + [\beta_s(\tau\omega) - \alpha_s(\tau\omega)]B(m)}{1 - \alpha_s(\tau\omega) - [\beta_s(\tau\omega) - \alpha_s(\tau\omega)]B(m)}\right] \Big/ (\tau\omega),$$

where $\omega \equiv w_s/w_u$ ($= \omega^* \equiv w_s^*/w_u^*$) is the price of skilled labor measured in unskilled labor. The intuition behind eqs. (20)-(21) should be clear. Because a reduction in τ is now skilled-labor augmenting, τ enters in these equations only through the "effective" price of skilled labor measured in the units of unskilled labor, $\tau\omega$, and through the "effective" supply of skilled labor, V_s/τ.

As before, we further focus on the special case, where the technical changes satisfy the Hicks-neutrality. A skilled labor augmenting technical change can be Hicks-neutral if and only if the functional forms for Φ and Ψ are Cobb-Douglas.[11] That is to say, we assume that

(A6) $\Phi(\tau w_s, w_u) = (\tau w_s)^{\alpha}(w_u)^{1-\alpha}$, $\Psi(\tau w_s, w_u) = \Gamma(\tau w_s)^{\beta}(w_u)^{1-\beta}$, $0 < \alpha < \beta < 1$.

where the parameter, Γ, is sufficiently large to ensure that $\Phi(\tau w_s, w_u) < \Psi(\tau w_s, w_u)$ in equilibrium. Then, eqs. (20)-(21) become

(22) $A(m) = \Gamma(\tau\omega)^{\beta-\alpha}$,

(23) $$\frac{V_s}{V_u} = \left[\frac{\alpha + (\beta-\alpha)B(m)}{(1-\alpha)-(\beta-\alpha)B(m)}\right] \Big/ \omega,$$

respectively. These equations can be analyzed by means of Figure 3. The assumption that the export division is more skilled-labor intensive, $\alpha < \beta$, implies not only that eq. (22) is downward-sloping and eq. (23) upward-sloping in the (m-ω) space. It also implies that a skilled-labor augmenting technical change (a reduction in τ) shifts the downward-sloping curve to the right, because it reduces the cost of the export division more than the cost of the domestic division. Hence, it leads to globalization and an increase in skill premia. Needless to say, if we drop the assumption of Hicks-neutrality, the analysis would be more complex, because eq. (21) generally

[11] We skip the proof, because this is formally equivalent to the following well-known result in the neoclassical growth literature, first shown by Uzawa (1961); technical changes are both Hicks-neutral (TFP-augmenting) and Harrod-neutral (labor-augmenting) if and only if the aggregate production function is Cobb-Douglas.

depends on τ. However, unless the nonneutrality is too strong, the effect would be qualitatively similar.

In summary, we have shown that, when the export division is more skilled-labor intensive than the domestic division, a globalization leads to a rise in the skill premia in all the countries, if the globalization is driven by a reduction in the tariff, or by (Hicks-neutral) technical changes that are skill-labor augmenting and/or take place primarily in the export divisions.

It is beyond the scope of this paper to survey the vast literature on the role of globalization in the recent rise of the skill premia. Much of the literature draws a sharp distinction between two possible causes; skill-biased technical change and international trade. Most economists seem to discount the role of trade in favor of skill-biased technical changes for a couple of reasons. First, according to the factor proportion theory of trade, an increase in trade can explain the recent rise in the skill premium in the skill-labor abundant United States, but not the similar rise in the skill premia among the skill-labor scarce trading partners. Second, the factor proportion theory of trade also suggests that the rise in the skill premium in the US must be accompanied by the rise in the relative price of the skill-labor intensive goods, which has not been observed empirically. Our explanation is not subject to these criticisms because what is skill labor intensive in our model is trade itself, not the types of the goods traded. Therefore, globalization leads to reallocation of labor towards more skill-intensive activities in all the countries.

Perhaps more importantly, the above analysis questions the validity of the dichotomy between skilled biased technical change and international trade. In this respect, it is worth mentioning Acemoglu (2003) and Thoenig and Verdier (2003), which developed sophisticated models of endogenous technical changes to show how international trade stimulates skill-biased technical changes. Their studies suggest that "globalization vs. skilled biased technical changes" is a false dichotomy, because globalization *induces* skilled-biased technical change. This study suggests that it is a false dichotomy, because globalization *is* a form of skilled biased technical change.[12]

[12]The Acemoglu model (and the Thoenig and Verdier model to significant extent) relies on the asymmetry of the countries, and hence has the implication that North-South trade should be skill-biased. On the other hand, our model does not rely on the asymmetry, and hence suggests that all trade should be skill-biased. This might make our

6. Concluding Remarks

In this paper, we have proposed a new approach to model costly international trade, which includes the standard approach, the "iceberg" transport cost, as a special case. The key idea is to make the technologies of supplying the good depend on the destination of the good. To demonstrate our approach, we have extended the Ricardian model with a continuum of goods, by introducing multiple factors of production and making each industry consist of the domestic division, which supplies the good at home, and the export division, which supplies the good abroad. If the two divisions differ only in the total factor productivity, our model becomes isomorphic to the DFS model with the iceberg transport cost. When the two divisions differ also in the factor intensity, globalization changes the relative factor prices *in the same direction* across countries, in sharp contrast to the usual Stolper-Samuelson effect, which suggests that the relative factor prices move in different directions in different countries. The analysis in this paper offers a fresh perspective on the debate on the role of globalization in the recent rise in the skill premia.

The iceberg transport cost has been used widely in many different classes of international trade models. Although we have highlighted the difference between our approach and the iceberg approach using the DFS model as a background, our approach should be useful as a more flexible alternative to the iceberg approach in other models, as well. Indeed, applications of our approach need not to be restricted to those models that previously used the iceberg transport cost. It can be useful for any situation where the international activities are inherently more costly than the domestic activities.[13]

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argument more appealing to many economists who think that North-South trade is too small to have had much of an effect. (We thank Daron Acemoglu for making this observation.)

[13]For example, consider the recent literature on the patterns of global sourcing, such as Grossman and Helpman (forthcoming) and Antras and Helpman (2004). In these models, setting up the organization abroad is more costly than setting it up domestically, but the location does not change the type of the resources required. However, it would be more plausible to assume that FDI or international sourcing would require different types of skill than building plants at home or domestic sourcing. (Just think of all those highly compensated international business consultants sent abroad to supervise the oversea operations.) Our approach should provide a useful tool for modeling such situations.

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Figure 1: The Patterns of Trade:

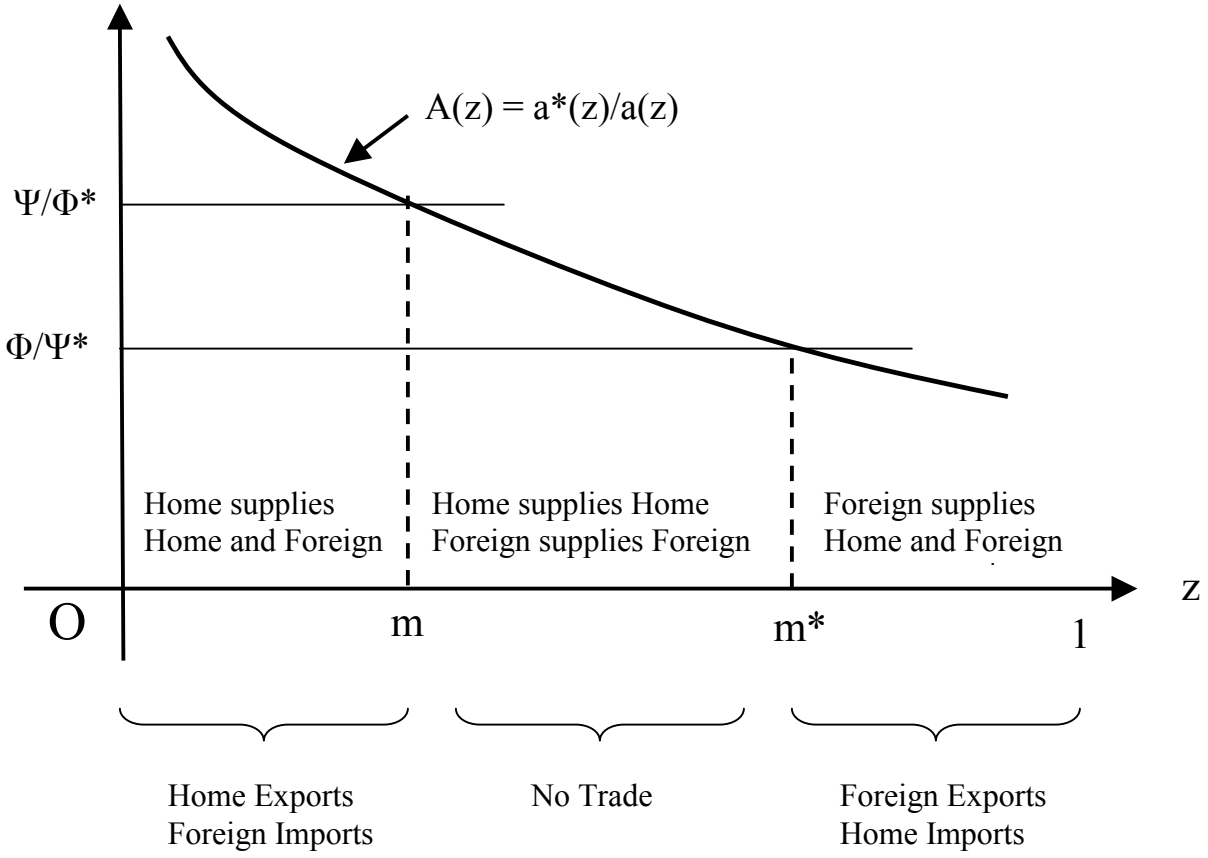

Figure 2: Unbiased Globalization

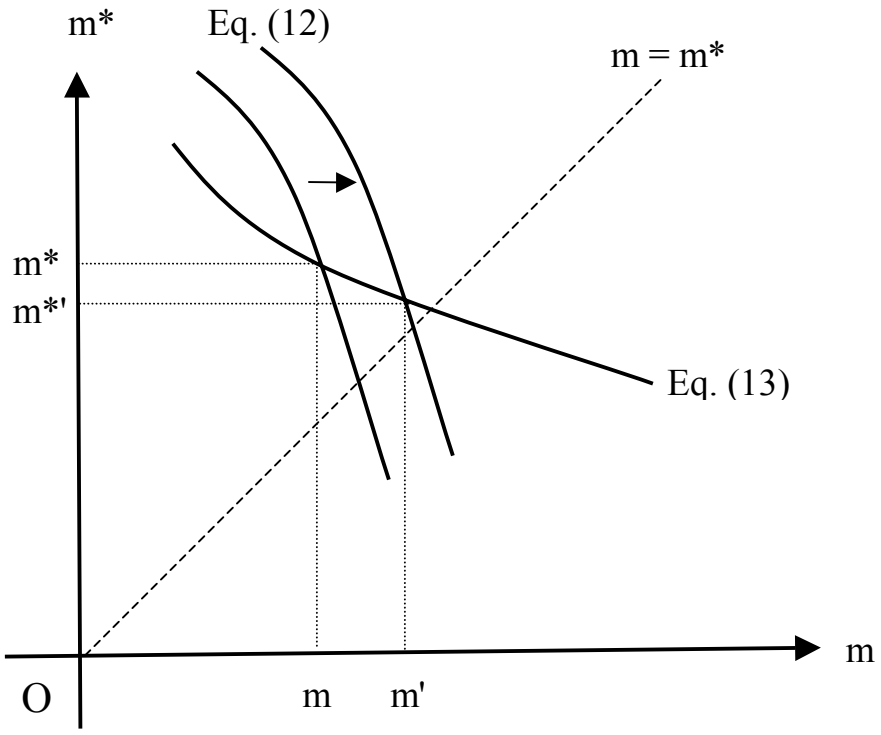

Figure 3: Biased Globalization