# Beyond Icebergs

By Kiminori Matsuyama[1]

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Abstract

We explore a flexible approach to model costly international trade, which includes the standard iceberg approach as a special case. To demonstrate our approach, we extend the Ricardian model of trade with a continuum of goods (Dornbusch, Fischer and Samuelson, 1977) by introducing multiple factors of production and by making technologies depend on destinations, i.e., whether they are supplied to the domestic market or the export market. If the two technologies differ only in total factor productivity, the model becomes isomorphic to the DFS Ricardian model with the iceberg cost. By allowing them to differ in the factor intensities, our approach enables us to explore the links between factor endowments, factor prices, and globalization that cannot be captured by the iceberg approach.

[1]For the contact information, go to http://www.faculty.econ.northwestern.edu/faculty/matsuyama/. I would like to thank Daron Acemoglu, Gadi Barlevy, Gene Grossman, and Mathias Thoenig for their comments on previous versions.

## 1. Introduction.

In this paper, we explore a flexible approach to model costly international trade. The key idea is to make the technologies depend on destinations, that is, whether they are supplied to the domestic market or the export market.[2] 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 physical shipment of the goods, but also the marketing and customer services, which involve communication with the dealers, customers, and government agencies, as well as the services related to export financing and maritime insurance. If it is more costly to supply goods to the export market 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 approach as a special case. According to this approach, commonly attributed to Samuelson (1954), the technologies of producing the goods are the same, regardless of 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 become isomorphic to the iceberg approach if we add the restriction that the technologies of supplying the goods to different markets differ only in total factor productivity. Our approach is more flexible than the iceberg approach because 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 links between factor endowments, factor prices, and globalization that cannot be captured by 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, e.g., advances in information technology (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

[2] Deardorff (1980) also allowed for the technologies to depend on the destination. However, he did not pursue any of the issues investigated in this paper.

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 the activities associated with supplying the goods to the domestic market to those associated with supplying the goods to the export market. If we are to model this process by a reduction in the iceberg 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 because of the factor content of its net exports, then the relative wage of white-collar workers must go down in its trading partners. Our approach has a different implication. 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 and/or the specialists in export finance and maritime insurance) than supplying the same goods domestically, globalization may lead to an increase in the relative price of these factors in all the countries.

To give another example, the standard Heckscher-Ohlin theory of trade relies on the cross-country difference in factor proportions as a basis of international trade, and hence it does not have a clear prediction as to how the volume of trade responds when the factor proportions change in the same direction across countries. Our model has a different implication, because the factor endowments affect international trade in a more direct manner. If servicing the foreign customers requires more skilled labor, if the transoceanic transportation is more capital intensive than the local transportation, etc., a world-wide increase in the relative supply of these factors will lead to globalization.

Obviously, one could apply our approach to any existing model of international trade that uses the iceberg approach. In this paper, we have chosen the Ricardian model with a continuum of goods, developed by Dornbusch, Fischer, and Samuelson (1977), hereafter DFS. For a variety of reasons, their model offers a useful background against which to demonstrate our approach. First, the Ricardian structure of the DFS model enables us to illustrate the difference between our approach and the iceberg approach without complication of the well-understood Hechscher-

Ohlin-Stolper-Samuelson effects. 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 approach. Furthermore, DFS has inspired many recent studies on competitive models of international trade with the iceberg approach.[3]

Section 2 develops our model, which extends the DFS model in two respects. First, it has multiple factors of production. Second, the technologies depend on whether the good is supplied to the domestic or export market, and it is assumed that it is more costly to supply the good abroad than at home. Section 3 considers the special case, where the technologies differ only in total factor productivity. With this additional restriction, an improvement in the export technologies[4] leads to globalization, but has no effect on the relative factor prices, and the factor proportions play no role in determining the extent of globalization. Indeed, it is demonstrated that this special case is isomorphic to the DFS model with the iceberg cost. Section 4 considers the general case, where the technologies may differ also in the factor intensity. It shows how an improvement in the export technologies and a change in the factor proportions lead 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 exporting goods is more skilled labor intensive than supplying them to the domestic market, it is shown that a *world-wide* increase in the relative supply of skilled labor leads to globalization, in sharp contrast to Heckscher-Ohin. It is also shown that globalization, when it is caused by (Hicks-neutral) technical change in the export sectors, by (Hicks-neutral) skilled labor augmenting technical change, or by a reduction in the trade barriers, leads to a rise in the skill premia in all the countries, in sharp contrast to Stolper-Samuelson. Section 6 demonstrates how the main insights carry over under alternative specifications. Section 6.1

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[3]See, e.g., Obstfeld and Rogoff (1996, Chapter 4), Eaton and Kortum (2002), and Alvarez and Lucas (2004). Another literature that makes extensive use of the iceberg approach is monopolistic competition models of trade. Unlike these models, the DFS model has advantage in highlighting the difference between the two approaches without complications of the market structure, monopoly power, and expanding product variety.

[4]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.

allows for the possibility that the export sectors use the factors located in the country of destinations. Section 6.2 introduces the factor intensity differences across goods. Section 7 concludes.

## 2. The Basic Model.

Consider the following variation of the DFS (1977) model. The world economy consists of two countries, Home and Foreign, and there are a continuum of competitive industries, identified by the good it produces, $z \in [0,1]$. 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.

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 ($j = 1, 2, \ldots, J$). 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 not only as capital, land, and labor, but also as different types of labor, with different skill levels, expertise, and specialties. Second, the technologies may depend on the destination of goods. More specifically, we may think of each industry consisting of the two sectors. One is called the domestic sector and the other the export sector. The domestic sector 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 sector 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 costs, including all sorts of communication costs, as well as the shipping costs, including the insurance and other financial costs.[5] 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.[6] Likewise, the unit cost of the domestic sector of the Foreign industry z is $a^*(z)\Phi^*(w^*)$, while the unit cost of the export sector 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 sectors. We will use them to examine the effect of the technical change in the export sectors.[7] Furthermore, we will make 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 goods 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, insuring etc.) goods to the export market is more costly than supplying (i.e., producing, marketing, shipping, insuring 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

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[5] Recall that we identify "industries" and "sectors" by the goods they produce and by the market they serve. Hence, all the factors that go into the same good must be considered as part of the same industry, even though they may be employed by many different firms scattered across many different industries. Likewise, all the factors that go into the same goods heading for the same destination must be considered as a part of the same sectors. For example, the payment made by a manufacturer or a distributor and received by the insurer for its coverage of the domestic (international) shipping has to be included in the cost of the domestic (export) sector, just like the payment for any raw materials that go into the goods supplied to the domestic (export) market has to be included in the cost of the domestic (export) sector. In other words, to the extent that the factors employed in the maritime insurance industry are involved, either directly or indirectly, in exporting a particular good, they should be considered as a part of the same export sector, even if its manufacturer, its distributor, and its insurer may be in different categories in the standard industry classification.

[6] Some readers might think that certain activities required for exporting impose the fixed cost for an exporting firm. The presence of the fixed cost for a firm does not invalidate our assumption that each sector has CRS technologies. As Alfred Marshall and many others pointed out, the correct unit of analysis in a competitive model is the industry or sector, but the firm. The fixed cost at a firm level can be the variable cost at an industry level, because the size of the industry changes as the number of firms in the industry adjusts. (Any introductory economics textbook should explain how the U-shaped average cost curve of a firm is consistent with the constant average cost curve of an industry.)

[7] Our specification implicitly assumes that exporting goods do not require any factors local to the export market. More generally, the unit cost function of the Home (Foreign) export sector should also depend on w* (w). It turns out that such a generalization, while more realistic, lead to substantial notational burdens, neither undermine the main result nor generate much additional insight. We offer more discussion in Section 6.1.

goods (and industries), the technologies differ only in total factor productivity, but not in factor intensity. Within each industry, on the other hand, the domestic and export sectors 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. We deliberately rule out the factor intensity differences across goods, in order to isolate our result from the well-known Hechscher-Ohlin-Stolper-Samuelson mechanism.[8]

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 only 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 (i.e., potentially 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

[8] We will suggest, however, how the two mechanisms may be usefully combined in Section 6.2.

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

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

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 sector 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 sector of the Home industries.

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

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

where $\alpha_j^*(w^*) \equiv w_j^*\Phi_j^*(w^*)/\Phi^*(w^*)$ is the share of factor j in the domestic sector 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 sector 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 $\Phi(w)$ and $\Psi(w)$ 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

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

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 $J-1$ independent equilibrium conditions in addition to eq. (5). Thus, eqs. (1)-(5) altogether contain 2J+1 independent equilibrium conditions. They jointly determine 2J+1 unknowns, the two marginal industries, m and m*, and $2J-1$ relative factor prices (i.e., 2J absolute factor prices, w and w*, up to a scale.) We can use eqs. (1)-(5) to examine the effects of factor endowments, by shifting V and V*, as well as the effects of globalization caused by technological change in the export sectors, by shifting the two parameters, $\tau$ and $\tau^*$.

## 3. Unbiased Globalization: Restoring DFS (1977).

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

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

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

(9) $w_j^*V_j^* = \alpha_j^*(w^*)w^*V^*$, (j = 1, 2,…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 primal functions underlying $\Phi(w)$, where the technologies of the domestic and export sectors 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 sectors 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," $W = \Phi(w)$.[9] 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) $A(m)/\tau = W/W^* = B^*(m)L^*/[1-B(m^*)]L$,

[9]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.

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

while (8) and (9) become

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

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

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 sectors but also the Foreign export sectors. Intuitively, as the improved export technologies enables the Home export sectors to replace the Foreign domestic sectors in (m, m'), the Home wage rate goes up relative to the Foreign wage rate, which leads to a replacement of the Home domestic sectors by the Foreign export sectors in (m*',m*). This causes a reallocation of the Home labor from the domestic sectors in (m*', m*) to the export sectors in (m, m'). At the same time, the Foreign labor is reallocated from the domestic sectors in (m, m') to the export sectors 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 sectors *in both countries*.

Under (A3), however, this reallocation of labor from the domestic to the export sectors 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 sectors is Hicks-neutral, hence their relative factor demands are unaffected. Furthermore, the export sectors use all the factors in the same proportion with the domestic sectors. 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.[10]

Note also that eqs. (12)-(13) are entirely independent of V and V*. Hence, the factor proportions have no effect on the patterns of trade. This is because the change in the relative factor prices would not affect the relative cost of the two sectors.[11]

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), except that they 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 sectors) 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 sectors 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 a broad interpretation of the iceberg cost. 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 sectors produce different goods, each tailored made for each market, and that the total factor productivity of the export sector is a fraction of that of the domestic sector. As long as the two sectors use all the factors in the same proportion,

[10]Needless to say, even when the domestic and export sectors 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 intensity differ across the goods. See, for example, Section 6.2.

[11]Needless to say, even when the domestic and export sectors use the factors in the same proportion in each industry, factor endowments could affect the patterns of trade through the well-known Heckscher-Ohlin effect, if the factor intensity differ across the goods. See, for example, Section 6.2.

these two specifications give the identical results. In short, we can view as a decline in the iceberg cost as a special form of technical changes that benefit the export sectors.

According to this broad interpretation, however, a reduction in $\tau$ and $\tau^*$ can occur not only through an improvement in transport technologies, but also through any changes that help to lower the cost of servicing 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.[12]

Perhaps more importantly, this broad interpretation also suggests a natural way of going beyond the iceberg specification. Once we 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. A priori, such possibility would be difficult to deny. Exporting naturally requires and generates more demand for skilled labor with the expertise in the areas such as international business, language skills, and maritime insurance. The transoceanic transportation is more capital intensive than the local transportation. As will be seen below, this opens up the possibility that factor proportion changes *in the same direction* both at Home and Foreign leads to globalization, as well as 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 sectors, 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 sectors share the same technology, but the Foreign government imposes import tariffs on the Home goods at the uniform rate of $\tau - 1$, and the Home government imposes import tariffs on the Foreign goods at the uniform rate equal to $\tau^* - 1$, under the assumption that the tariff revenues are entirely wasted

[12] We do not intend to claim any novelty in offering this interpretation. The most perceptive reader of the literature always understood that "iceberg" is nothing but a metaphor, and "the transport cost" is a short-hand way of saying that "the transport and other technical, financial, political and cultural obstacles that put the foreign producers in disadvantage relative to the domestic producers." Nevertheless, it is inevitable that a significant number of readers interpret such expression too literally and too narrowly. The discussion here is intended as a cautionary remark for those readers.

so that they do not affect the aggregate expenditure of the two countries.[13] Then, the above result suggests that a reduction in the import tariffs 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. Biased Globalization

We are now going to show how the factor proportion affects globalization and how technical changes in the export technologies can affect the relative factor 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 (and introducing asymmetry would merely obscure the key mechanism), let us focus on the case where the two countries are the mirror images of each other. That is,

(M) $A(z)A(1-z) = 1.$

$b(z) = b^*(z)$, $b(z) = b(1-z)$ (so that $B(z) = B^*(z)$ and $B(z) + B(1-z) = 1$ for $z \in [0,1/2]$),

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

Note that the symmetry does not mean that the two countries are identical. Rather, they are the mirror images of each other. More specifically, because A(z) is strictly decreasing in z, $A(z)A(1-z) = 1$ implies that $A(z) > 1$ for $z \in [0,1/2)$, $A(1/2) = 1$ and $A(z) < 1$ for $z \in (1/2,1]$. Without these cross-country differences in total factor productivity, trade would not take place.

Under the mirror image assumption, the equilibrium is symmetric, $w = w^*$, $m = 1-m^* < ½$, and the equilibrium conditions are now reduced to

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

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

Eq. (16) shows that, given the factor prices, an improvement in the export technologies (a change in $\tau$ that causes a downward shift of $\Psi$) leads to an increase in m (and a decline in $m^* = 1-m$).

[13] Imagine, for example, that Foreign (Home) government confiscate a fraction $1-1/\tau$ ($1-1/\tau^*$) of the Home (Foreign) goods and use them for the public goods, which enter in the preferences of their residents in a separable form.

The RHS of Eq. (17) is the demand for factor j. It shows that a shift in $\tau$ 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 sectors (those with $\beta_j > \alpha_j$) and reduces demand for those used more intensively in the domestic sectors (those with $\beta_j < \alpha_j$). Thus, globalization can affect the factor demand by changing the composition between the domestic and export sectors. Second, it could affect by changing the relative factor demand within the export sectors, if $\beta_j(w;\tau)$ depends on $\tau$. Note that there is an important special case, where a shift in $\tau$ could affect the factor demand only through the first route. This is the case where the technical change in the export sectors 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 $\tau$, which allow us to simply drop $\tau$ to denote it as $\beta_j(w)$. Under (A4), the RHS of eq. (17) no longer depends on $\tau$. Thus, a shift in $\tau$ affects the factor demands only by changing the composition of the domestic and export sectors.[14]

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

(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 sectors. (Recall that $\Phi$ and $\Psi$ are linear homogeneous and that the factor shares, $\alpha_j$ and $\beta_j$, satisfy the homogeneity of degree zero). Note that the RHS of eq. (19) is the relative demand curve for factor 1 over factor 2.

[14]On the other hand, a shift in $\tau$ 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 $\beta_j$ becomes independent of $\tau$.

Figures 3 depict eqs. (18)-(19) over the $(m, \omega)$-space, under the assumption that the export sector is more factor 1 intensive than the domestic sector; $\alpha_1(\omega) < \beta_1(\omega;\tau)$. This factor intensity assumption implies that eq. (18) is downward-sloping.[15] Intuitively, a lower $\omega$ makes the cost of the export sectors decline more than the cost of the domestic sectors, 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 sectors at the expense of the domestic sector (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 $\omega$ in a stable factor market equilibrium. Thus, eq. (19) is upward-sloping, whenever the factor market is stable.[16] Figures 3 are drawn under the assumption that the factor market equilibrium is always stable, so that the curve depicting eq. (19) is everywhere upward-sloping.[17] The equilibrium is given by point E, at the intersection of the two curves.

Figure 3a depicts the effects of an increase in $V_1/V_2$. It shifts the upward-sloping curve downward, and the equilibrium moves from point E to point E'. The result is a decline in $\omega$ and an increase in m. Note that, due to the symmetry assumption, this captures the effects of a *world-wide* increase in the relative supply of the factor used more intensively in export activities. This leads to a decline in the cost of supplying the foreign markets relative to the cost of supplying the domestic markets, which leads to a globalization, measured either in the share of the traded industries, $m+1-m^* = 2m$, or in the Trade/Income ratio, $B^*(m)+B(1-m^*) = 2B(m)$. The effect is thus different from the Heckscher-Ohlin mechanism, which relies on the *difference* in factor proportions across the countries.

Figure 3b depicts the effects of a decline in $\tau$, which shifts eq. (18), the downward-sloping curve, to the right. Under (A4), i.e., when the improvement in the export technologies

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

[16] 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).

[17] This is the case, for example, if $\Phi$ and $\Psi$ are Cobb-Douglas so that $\alpha_1$ and $\beta_1$ are constant. Of course, without making some restrictions on the functional forms of $\Phi$ and $\Psi$, one cannot rule out the possibility that the relative factor demand, $f(\omega, m; \tau)$, may be increasing in $\omega$ over some ranges, and eq. (19) may permit multiple factor price equilibriums. If so, the curve depicting eq. (19) over the $(m, \omega)$-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

satisfies the Hicks-neutrality, eq. (19) is independent of $\tau$, so that the upward-sloping curve remains intact. Hence, the equilibrium moves from E to E'. The result is an increase in both m and $\omega$. An improvement in the export technologies not only leads to a globalization. It also leads to an increase in the relative price of the factor used intensively in the export sectors.

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 sectors (i.e., if it increases the export sector's demand for factor 1 relative to factor 2 at each relative factor price), then the upward-sloping curve shifts upward, when the downward-sloping curve moves to the right. The relative factor price, $\omega$, 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.[18]

It is worth reminding the reader that the case of the Hicks-neutral technical change in the export sector, (A4), depicted in Figure 3b, can be reinterpreted as a reduction in import tariffs. According to this interpretation, (A4) means that the cost functions of the export sector 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 3b captures the effect of a reduction in the tariff. 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 sectors relative to those used intensively in the domestic sectors both at Home and at Foreign.

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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).

[18] A strong form of non-neutrality can certainly overturn the result. For example, imagine that factor-1is the foreign language skill, required only in the export sector. If the primitive technology prevents any international communication, demand for factor-1 is zero and $\omega = 0$. As the technology improves, this generates demand for factor-1, and $\omega$ goes up. However, if the technology continues to improve, demand for factor-1 and hence $\omega$ could go down. Under the Hicks-neutrality, this cannot happen, as technical change affects factor prices only through its effects of the composition between the two sectors.

Another thought-experiment that can be conducted by means of Figure 3b is the effects of a change in A(z). Specifically, let us generalize A(z) to $[A(z)]^{\theta}$, where the power, $\theta > 0$, is the shift parameter. This keeps the mirror image assumption, and a higher θ raises $[A(z)]^{\theta}$ for $z \in [0, 1/2)$, and reduces $[A(z)]^{\theta}$ for $z \in (1/2,1]$, thereby magnifying the cross-country difference in total factor productivity in each industry. This change shifts the downward-sloping curve upward, which leads to a higher m and a higher ω, as shown in Figure 3b. The intuition should be clear. As the two countries become more dissimilar, there are more reasons to trade, which shifts the demand in favor of the factors used more intensively in the export sectors.

## 5. An Application: Globalization, Technical Change, 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.[19] Imagine that there are two types of factors, $J = 2$, which are skilled and unskilled labor. Furthermore, suppose that the export sector is more skilled labor intensive than the domestic sector.[20] Then, Figure 3a suggests that a world-wide increase in the relative supply of skilled labor leads to globalization. Figure 3b suggests that the skill premia in all the countries rise as a result of globalization caused by technical changes that take place in the export sectors (or by a reduction in the trade barriers).

However, we do not *need* to assume that the technical changes are specific to the export sectors 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 sector is more skilled-labor intensive.

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[19]For an overview of this literature, see Feenstra (2000).

[20]The assumption is consistent with the empirical evidence that export firms employ more non-production workers than production workers, to the extent that non-production workers may be viewed as a proxy for skilled labor, as commonly done. Maurin, Thesmar, and Thoenig (2002) offers more direct evidence, because their French dataset provides detailed information on skill structure within both the production and non-production units of the firms. They have found that export firms employ more skilled labor than nonexporters. Interestingly, they have found that the very act of exporting require skilled labor force. (That is, more skilled labor is needed when they sell the products outside of France, but the skill intensity does not vary much on whether they export to developed markets, such as the US or to developing countries, such as China and India.) Furthermore, such firm/plant level evidence may underestimate the skill intensity of the export activities, because many manufacturing firms rely on trading companies (such as the famous Japanese Sohgoh Shosha) and maritime insurance companies for their export needs. In order to account for the factor content of the export goods properly, those working in the trading and insurance sectors need to be included in the export sector (to the extent that they are involved, directly or indirectly, in the export activities).

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 sectors 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, $\tau$ and $\tau^*$, enter in the cost functions of both the domestic and export sectors. Contrary to what was assumed in the previous analysis, the technical changes are no longer specific to the export sector. Now, a reduction in $\tau$ (and $\tau^*$) means a skilled-labor augmenting technical change, and hence it reduces the costs of both the domestic and export sectors 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 $\tau$ is now skilled-labor augmenting, $\tau$ 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, $V_s/\tau$.

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.[21] That is to say, we assume that

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

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

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

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

respectively. These equations can be analyzed by means of Figure 3b. The assumption that the export sector 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 sector more than the cost of the domestic sector. 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 depends on τ. However, unless the nonneutrality is too strong, the effect would be qualitatively similar.

In summary, we have shown the two scenarios in which globalization leads to a rise in the skill premia in all the countries. In the first scenario, globalization is driven by (Hicks-neutral) technical changes that take place in the export sectors (or by a reduction in the trade barriers). In the second scenario, globalization is driven by the skill-labor augmenting technical changes. In

[21]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.

both scenarios, the assumption that the export sector is more skilled-labor intensive than the domestic sector plays a critical role.

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 skilled labor intensive in our model is trade itself, not the types of the goods traded.

Perhaps more importantly, our 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. The present study identifies the two scenarios that suggest that "globalization vs. skilled-biased technical changes" is a false dichotomy. In one scenario, it is a false dichotomy, because globalization *is induced by* skilled-labor augmenting technical changes. In the other, it is a false dichotomy, because globalization *is* inherently skill-biased.[22]

## 6. Alternative Specifications

In the above model, many assumptions are made in order to simplify the analysis and to avoid distracting the reader's attention away from the key mechanism. Relaxing some of these

[22]The Acemoglu model 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 of the countries, and hence suggests that all trade should be skill-biased. This might make our argument more appealing to many

assumptions is possible, but such a generalization would lead to a significant increase in the notational burden and obscure the key mechanism without much additional insights. In this section, we will instead illustrate, by means of specific examples that permit relatively simple equilibrium characterization, how the main results may carry over under alternative specifications.

6.1. Use of the Local Factors in the Export Market.

In the above model, the unit cost function of the Home (Foreign) export sector depends only on the factor prices at Home (Foreign). This specification implicitly assumes that exporting goods do not require any factors local to the export market. It would be more realistic to assume, for example, that US exports to Italy generate demand for factors in Italy and that Italian exports generate demand for factors in US. To capture this, let us consider the case of J =2, where the unit costs of the domestic and export sectors at Home, $a(z)\Phi$, $a(z)\Psi$, and those at Foreign, $a^*(z)\Phi^*$, $a^*(z)\Psi^*$, are Cobb-Douglas as follows;

$$\Phi(w_1,w_2) = (w_1)^{\alpha}(w_2)^{1-\alpha},$$

$$\Psi(w_1,w_2;\, w_1^*, w_2^*;\, \tau) = \tau\Gamma[(w_1)^{\beta}(w_2)^{1-\beta}]^{1-\sigma}[(w_1^*)^{\gamma}(w_2^*)^{1-\gamma}]^{\sigma},$$

$$\Phi^*(w_1^*,w_2^*) = (w_1^*)^{\alpha^*}(w_2^*)^{1-\alpha^*},$$

$$\Psi^*(w_1^*,w_2^*;\, w_1,w_2;\, \tau^*) = \tau^*\Gamma^*[(w_1^*)^{\beta^*}(w_2^*)^{1-\beta^*}]^{1-\sigma^*}[(w_1)^{\gamma^*}(w_2)^{1-\gamma^*}]^{\sigma^*}.$$

Again, the parameters, $\Gamma$ and $\Gamma^*$, need to be chosen sufficiently large to ensure that $\Phi < \Psi$ and $\Phi^* < \Psi^*$. Now, the Home export sectors use Foreign factors. Their cost share is equal to $\sigma$, a fraction $\gamma$ of which goes to Foreign factor 1. Likewise, the Foreign export sectors use Home factors. Their cost share is equal to $\sigma^*$, a fraction $\gamma^*$ of which goes to Home factor 1. Again, let us look at the case where the two countries are the mirror images of each other, the case that permits relatively simple characterization of equilibrium. That is,

(M') $A(z)A(1-z) = 1$

$b(z) = b^*(z)$, $b(z) = b(1-z)$ (so that $B(z) = B^*(z)$ and $B(z) + B(1-z) = 1$ for $z \in [0,1/2]$),

$\Phi = \Phi^*$, $\Psi = \Psi^*$ (so that $\alpha = \alpha^*$, $\beta = \beta^*$, $\gamma = \gamma^*$, $\sigma = \sigma^*$), and $V = V^*$, and $\tau = \tau^*$.

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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.)

Then, the equilibrium is symmetric, $\omega$ ($\equiv w_1/w_2$) = $\omega^*$ ($\equiv w_1^*/w_2^*$) and $m = 1-m^* < ½$, and characterized by

(24) $$A(m) = \tau\Gamma(\omega)^{[\beta(1-\sigma)+\gamma\sigma]-\alpha}$$

(25) $$\frac{V_1}{V_2} = \left[\frac{\alpha+\{[\beta(1-\sigma)+\gamma\sigma]-\alpha\}B(m)}{(1-\alpha)-[\beta(1-\sigma)+\gamma\sigma]-\alpha)B(m)}\right]\Big/\omega\,.$$

Therefore, if $\beta(1-\sigma)+\gamma\sigma > \alpha$, this equilibrium may be analyzed by means of Figure 3a and 3b. Note that $\beta(1-\sigma)+\gamma\sigma$ is the cost share of factor 1 in the export sector, which is the sum of the cost share of factor 1 located at the country of origin, $\beta(1-\sigma)$, and that of factor 1 located at the country of destination, $\gamma\sigma$. As long as the export sector is more factor-1 intensive than the domestic sector, an improvement in the export technologies will increase the relative price of factor 1 globally, and a world-wide increase in the relative endowment of factor 1 would lead to globalization. Whether all of the export sector's demand for factor 1 goes to the country of origin, as assumed in the previous model, or some goes to the country of destination, as assumed here, does not affect this implication of the model. Of course, in the presence of asymmetry across the two countries, we will have to worry about some distributional issues, but these issues would arise with or without the use of the factors local to the export market.

Following the above discussion, it should be obvious to the reader how one could allow for the possibility that the unit cost functions of the domestic sectors may depend directly on the factor prices abroad.

## 6.2. Factor Intensity Differences Across Goods

In the above model, the source of comparative advantage was assumed to be Ricardian; that is, only the total factor productivity differs across goods, but not the factor intensity. This assumption was made to highlight the role of factor intensity differences across destinations, separating the key mechanism from the well-understood Heckscher-Ohlin-Stolper-Samuelson mechanism. Introducing factor intensity differences across goods generally complicate the analysis, but we will go through one simple case to show how the two mechanisms may be usefully combined.

Suppose that there are three factors, 1, 2, and 3. Assume that the two countries share the identical technologies, but have different factor endowments, as in the standard Heckscher-Ohlin model. The unit cost functions of the domestic sector and the export sector supplying good z are given by $\Phi^z(w_1,w_2, w_3) = (w_1)^\alpha[(w_2)^{\delta(z)}(w_3)^{1-\delta(z)}]^{1-\alpha}$ and $\Psi^z(w_1,w_2, w_3; \tau) = \tau\Gamma(w_1)^\beta[(w_2)^{\delta(z)}(w_3)^{1-\delta(z)}]^{1-\beta}$ at Home, and respectively, and by $\Phi^z(w_1{*}, w_2{*}, w_3{*})$ and by $\Psi^z(w_1{*}, w_2{*}, w_3{*}; \tau)$ abroad. (We no longer need the Ricardian basis of trade, so that a(z) and a*(z) are dropped for simplicity.) Note that α and β represent the cost share of factor 1 in the domestic and export sectors, which are identical across goods. However, the cost shares of factor 2 and factor 3 differ across goods. Let us assume, in the spirit of Dornbusch, Fischer, and Samuelson (1980), that $\delta(z) \in [0,1]$ is strictly increasing in $z \in [0,1]$: that is, the higher indexed goods are more factor-2 intensive and less factor-3 intensive. Again, Γ is chosen sufficiently large to ensure that it is more costly to supply goods abroad than at home in equilibrium, that is, $\Phi^z < \Psi^z$ for all z.

Since international trade is costly, factor price equalization does not generally hold. If $w_2/w_3 > w_2{*}/w_3{*}$, then Home has comparative advantage in lower indexed goods and Foreign has comparative advantage in higher indexed goods, and the patterns of trade has the following form. There are two marginal goods, m < m* such that Home supplies to both markets in $z \in [0,m)$, Foreign supplies to both markets in $z \in (m{*}, 1]$, and no trade occurs in $z \in (m, m{*})$.

Again, consider the case where the two countries are the mirror images of each other, as follows.

(M'') $b(z) = b{*}(z)$, $b(z) = b(1-z)$ (so that $B(z) = B{*}(z)$ and $B(z) + B(1-z) = 1$ for $z \in [0,1/2]$),
$\delta(z) = 1-\delta(1-z)$, $V_1 = V_1{*}$, $V_2 = V_3{*} < V_3 = V_2{*}$.

Note that the two countries are not identical. They are the mirror images of each other. The key difference is that Home is relatively factor 3 abundant and Foreign is relatively factor 2 abundant. Hence, Home has comparative advantage in lower-indexed goods, while Foreign has comparative advantage in higher-indexed goods. Indeed, some algebra can verify that the equilibrium is symmetric and given by $w_1 = w_1^*$, $w_2 = w_3^* > w_3 = w_2^*$, and $m = 1-m^* < ½$ that satisfy

$$(26)\qquad \frac{w_2 V_2}{w_3 V_3} = \frac{\Sigma_2(m)}{\Sigma_3(m)}$$

$$(27)\qquad (\beta-\alpha)\log\left(\frac{w_1}{\sqrt{w_2 w_3}}\right) = \left(1-\frac{\alpha+\beta}{2}\right)(1-2\delta(m))\left[\log\left(\frac{\Sigma_2(m)}{\Sigma_3(m)}\right)-\log\left(\frac{V_2}{V_3}\right)\right]-\log(\tau\Gamma)$$

$$(28)\qquad \left(\frac{w_1}{\sqrt{w_2 w_3}}\right)\left(\frac{V_1}{\sqrt{V_2 V_3}}\right) = \frac{\Sigma_1(m)}{\sqrt{\Sigma_2(m)\Sigma_3(m)}},$$

with $\Sigma_1(m) \equiv \alpha + (\beta-\alpha)B(m)$, $\Sigma_2(m) \equiv (1-\alpha)/2 - (\beta-\alpha)D_2(m)$, $\Sigma_3(m) \equiv (1-\alpha)/2 - (\beta-\alpha)D_3(m)$, where $D_2(m) \equiv \int_0^m \delta(z)b(z)dz$ and $D_3(m) \equiv \int_0^m [1-\delta(z)]b(z)dz$. Both $D_2(m)$ and $D_3(m)$ are strictly increasing in m and satisfy $D_2(m) + D_3(m) = B(m)$. Furthermore, $D_2(m)/D_3(m)$ is strictly increasing in m from $\delta(0)/[1-\delta(0)]$ to 1.

If the export and domestic sectors differ only in total factor productivity ($\alpha = \beta$), $\Sigma_1(m) = \alpha$, $\Sigma_2(m) = \Sigma_3(m) = (1-\alpha)/2$, and the equilibrium conditions, eqs. (26)-(28), are simplified to $(w_2/w_3)(V_2/V_3) = 1$, $(V_3/V_2)^{(1-\alpha)[1-2\delta(m)]} = \tau\Gamma$, and $[w_1/(w_2w_3)^{1/2}][V_1/(V_2V_3)^{1/2}] = 2\alpha/(1-\alpha)$. In this case, an improvement in the export technologies (a decline in $\tau$) leads to globalization (a higher m), but it has no effect on the relative factor prices. An increase in $V_3/V_2$, which magnifies the cross-country factor endowment differences, leads to greater factor price differences (a higher $w_2/w_3 = w_2/w_2^* = w_3^*/w_3$), and globalization (a higher m) and it has no effect on the relative price of factor 1, measured in $\omega \equiv w_1/(w_2w_3)^{1/2}$, unless it also affects that the relative supply of the factor 1, measured in $V_1/(V_2V_3)^{1/2}$. And a change in $V_1/(V_2V_3)^{1/2}$, which keeps $V_3/V_2 = V_2^*/V_3^*$ constant, affects only $\omega$.

Under the assumption that the export sectors are more factor 1 intensive than the domestic sectors ($\alpha < \beta$), $\Sigma_1(m)$ is strictly increasing in m, and $\Sigma_2(m)$, $\Sigma_3(m)$, and $\Sigma_2(m)/\Sigma_3(m)$ are all strictly decreasing in m. Therefore, eq. (27) shows that $\omega \equiv w_1/(w_2w_3)^{1/2} =$

$w_1^*/(w_2^*w_3^*)^{1/2}$ is negatively related to m, and eq. (28) shows that $\omega$ is positively related to m. Thus, eqs. (27)-(28) jointly determine the equilibrium values of $\omega$, which may be analyzed by means of Figure 3a and Figure 3b. For example, an *world-wide* increase in the relative supply of the factor used intensively in the export sectors, measured by $V_1/(V_2V_3)^{1/2} = V_1^*/(V_2^*V_3^*)^{1/2}$ can be analyzed by a downward-shift of the upward-sloping curve, as shown in Figure 3a. The effects are hence a decline in its relative price (a lower $\omega$) and globalization (a higher m). And the resulting higher m (and a lower $m^* = 1 - m$) reduces the factor price differences (a lower $w_2/w_3 = w_2/w_2^* = w_3^*/w_2^*$), because each shifts from the domestic sectors that supply the goods that use the scare factors intensively to the export sectors that supply goods that use the abundant factors intensively. An improvement in the export technologies, and a decline in the import tariffs (a decline in $\tau$), can be analyzed by an upward-shift of the downward-sloping curve, as shown in Figure 3b. The effects are thus a rise in the relative price of that factor used intensively in the export sectors (a higher $\omega \equiv w_1/(w_2w_3)^{1/2}$) and globalization (a higher m), and a smaller factor price difference (a lower $w_2/w_3 = w_2/w_2^* = w_3^*/w_2^*$). Therefore, the main results carry over even when the source of comparative advantage is Heckscher-Ohlin, instead of Ricardian.

One novel feature that appears in this example is the effects of a change in the factor endowment differences that form the basis of trade. Consider an increase in $V_3/V_2 = V_2^*/V_3^* > 1$, which keeps $V_1/(V_2V_3)^{1/2}$ constant. This can be captured by an upward-shift of the downward-sloping curve, as shown in Figure 3b, while leaving the upward-sloping curve intact. It has the same effects with a decline in $\tau$. This is because this change makes Home even more factor 3 abundant and Foreign even more factor 2 abundant. By making the two countries become more dissimilar, and hence have more reasons to trade, it leads to an increase in m, which leads to an increase in the relative demand for factor 1, the factor used intensively in the export sectors, which further leads to a rise in its relative price of factor 1. This result is analogous to the result for a change in $\theta$ in the Ricardian model.

The above example also serves as a cautionary remark when interpreting the application of our model to the debate on the recent rise in skill premia, done in the previous section. After all, skill labor is not homogeneous in reality. Business and engineering majors are far from perfect substitutes. For example, think of factor 1 as college graduates who majored in business, factor 2 as college graduates who majored in engineering, and factor 3 as high school graduates.

A decline in $\tau$ and the resulting globalization would increase the relative wage of business majors both at Home and at Foreign. In this sense, globalization contributes to the global rise in the skill premia. However, the relative wage of engineering majors would go down at Home, where they are scarce, while it would go up at Foreign, where they are abundant, just as Stolper-Samuelson predicts. If one looks at the wage of the college graduates in general relative to high school graduates, it could go up everywhere.

## 7. Concluding Remarks

If international trade generates more demand for certain factors than domestic trade, globalization can directly affect the relative factor prices, and the factor proportions can directly influences the extent of globalization. Exporting naturally requires the use of skilled labor with the expertise in the areas such as international business, language skills, and maritime insurance. The transoceanic transportation is more capital intensive than the local transportation. This open ups the possibility that a *world-wide* increase in the factors used intensively in international trade could lead to globalization, as well as the possibility that a change in the export technologies, and the resulting globalization and reallocation of the factors from the domestic trade to international trade, could lead to a *world-wide* increase in the relative prices of the factors used intensively in international trade. The standard approach to model costly international trade, the iceberg approach, is too restrictive for capturing these effects.

In this paper, we explore a flexible approach to model costly international trade, which includes the standard iceberg approach as a special case. To demonstrate our approach, we extend the Ricardian model with a continuum of goods, due to Dornbusch, Fischer, Samuelson (1977), by introducing multiple factors of production and by making technologies depend on whether the goods are supplied to the domestic market or the export markets. If the technologies differ across the destinations only in total factor productivity, the model becomes isomorphic to the DFS model with the iceberg cost. By allowing them to differ in the factor intensities, our approach enables us to explore the links between factor endowments, factor prices, and globalization that cannot be captured by the iceberg approach. For example, a *world-wide* change in the factor proportion can lead to globalization, in sharp contrast to the Heckscher-Ohlin effect, which relies on the cross-country difference in factor proportions. It is also shown that an improvement in the export technologies 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. We also applied our analysis to the recent debate on globalization and the recent rise in the skill premia.

The iceberg approach has been used widely in many different classes of international trade models. Although we have highlighted the difference between two approaches 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. For example, starting from the influential work of Krugman (1980), the iceberg specification is the most common way of modeling costly international trade in monopolistic competition models. Our approach should provide many new insights in such models. Indeed, applications of our approach need not to be restricted to those models that previously used the iceberg approach. It can be useful for any situation where the international activities are inherently more costly than the domestic activities.[23]

[23] For example, it would be more plausible to assume that FDI or international outsourcing would require different types of skill than building plants at home or domestic outsourcing. (Just think of all those highly compensated international business consultants sent abroad to supervise the oversea operations.)

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Figure 1: Patterns of Trade:

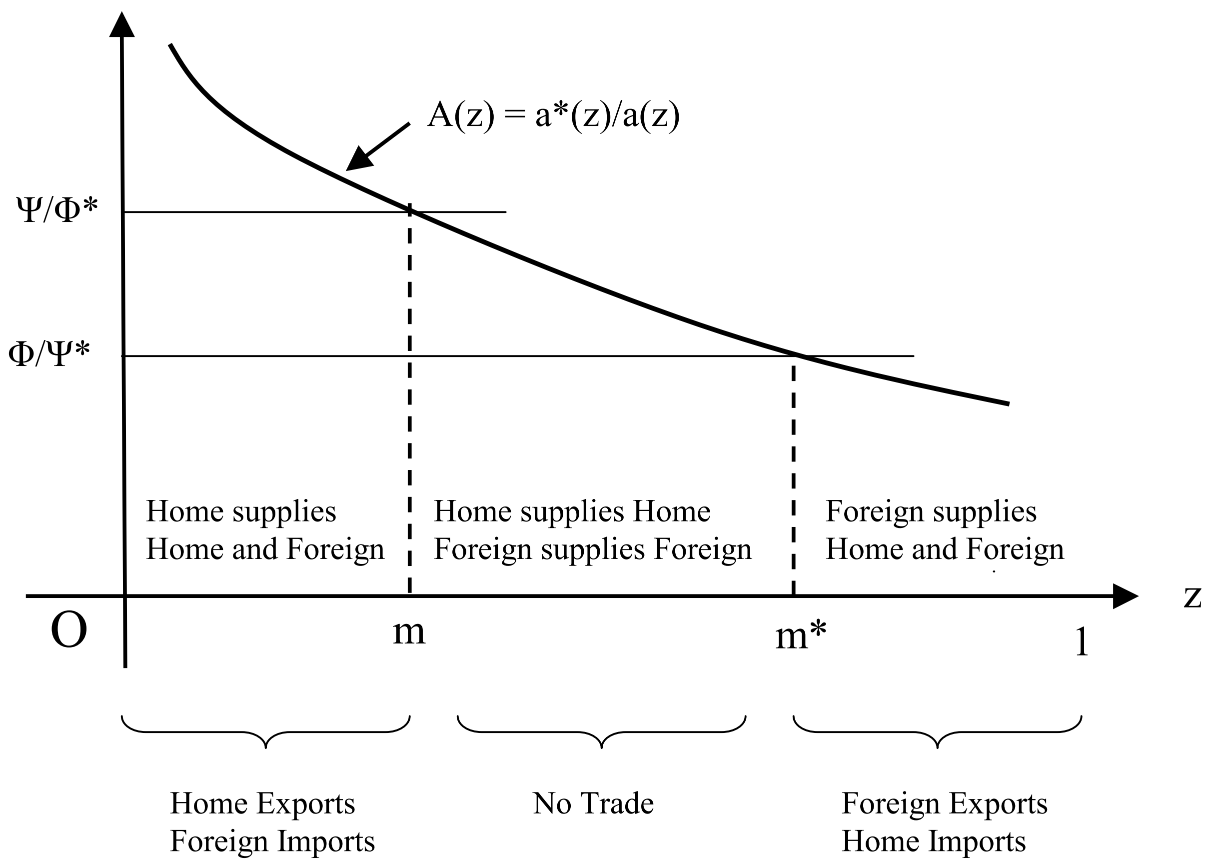
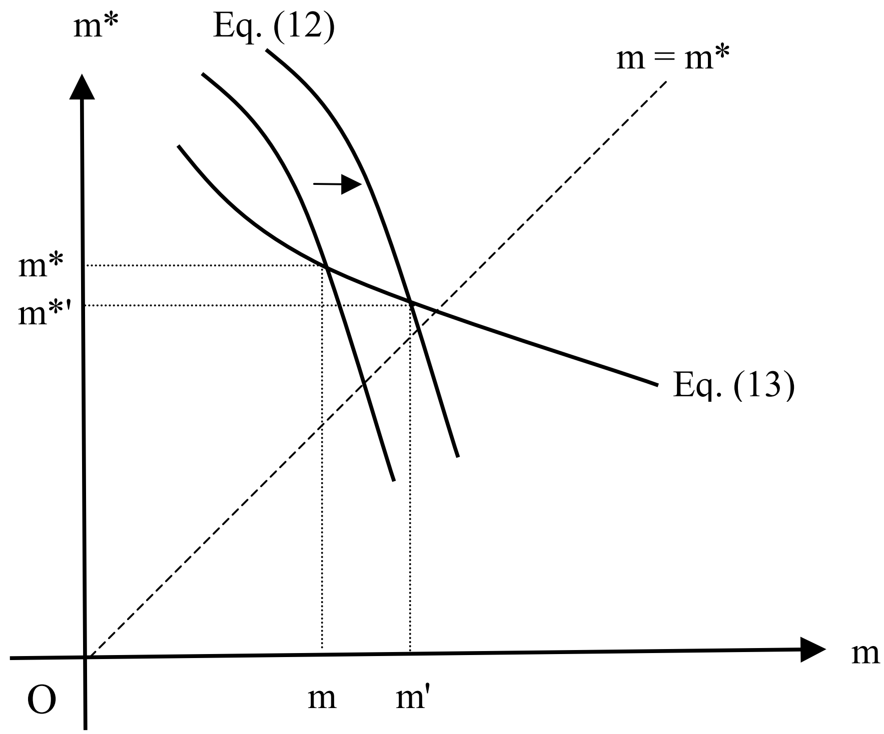


Figure 2: Unbiased Globalization



Figures 3: Biased Globalization

Figure 3a:

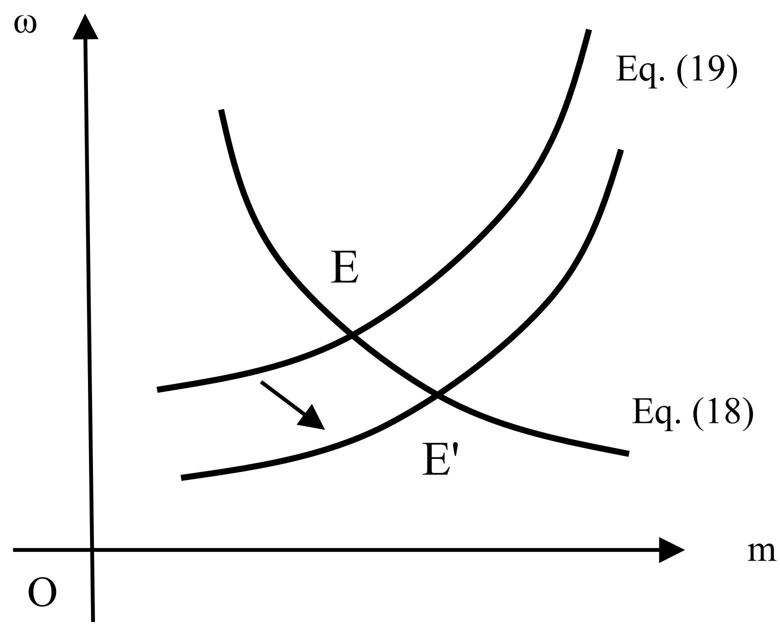



Figure 3b: