Information, International Substitutability, and Globalization

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Improved information allows home firms to rule out more potential foreign trade partners in advance of attempting to form a match. The increased responsiveness to country wage or goods price differentials resulting from this better first cut causes the general-equilibrium elasticity of substitution between national labor forces or the Armington elasticity of substitution between domestic and imported output to increase. Further results include an increase in the elasticity of domestic labor demand, an increase in the extent to which reductions in conventional trade barriers equalize national wages, and reduced "natural protection" for domestic producers. (JEL F10, F16)

The 1990's may be remembered as the decade "the information economy" came of age in the United States. As new information technology diffuses and is absorbed more deeply in the rest of the world, what changes should we be looking for in global economic interactions?

One channel through which the Internet is affecting the international economy is facilitation of search by producers for foreign distributors of their consumer goods, by assemblers for foreign suppliers of their components, by investing firms for foreign partners in their joint ventures, and so on.[1] For example, the World Trade Centers Association (WTCA), an organization whose "purpose ... is to have information available to businesses in a timely and coordinated manner," now links all of its more than 300 Centers located in over 100 countries through WTCA On-Line. The Trade Services departments of these Centers sift through the trade and investment leads posted online to find the ones that best match the needs of their member clients. The American Importers Association, representing 14,000 U.S. importers and wholesalers, advises all potential suppliers that "it is absolutely necessary for your company to have a web site" and lists "the important items you should include on your web site to get the American importers' attention." This is the source of information to which their members will turn first.[2]

As Internet connections spread and the quality of web sites improves, firms searching for

[1] The Internet may not displace, and may even enhance, more traditional sources of information that are used for this kind of search. Rauch and Trindade (2000, Table 1) document a sharp acceleration in the 1990's of the growth of periodicals and newsletters devoted to international trade and commerce, many of which are disseminated through the Internet. Scholars are beginning to quantify the impact of various information sources on international economic exchange. Richard Portes and Hélène Rey (1999) find that bilateral telephone traffic and bank subsidiaries are major determinants of bilateral trade and investment and that their inclusion sharply reduces the distance effect in gravity equations. Alessandro Nicita and Marcelo Olarreaga (2000) find that exports of Egypt, Korea, Malaysia, and Tunisia to the United States in the current year generate exports to third countries in the following year that are predicted by the third countries' bilateral newspaper trade with the United States.

[2] The information in this paragraph is based on the organizations' web sites (www.wtca.org and www.americanimporters.org) and on interviews with Trade Services staff at the San Diego World Trade Center.

suitable foreign trade and investment partners will be able to make ever better "first cuts" before arranging meetings and trying to work out deals. In making its choice of whether to conclude a deal with some foreign partner or return to the domestic market, a firm must consider the quality of its match with the foreign partner in addition to the conventional gains from trade generated by cost differentials and conventional barriers to trade such as trade taxes. As the difference between foreign and domestic match quality narrows with improving information, the relative influence of cost differentials and trade taxes on firm decisions grows. In other words, decisions by firms whether to demand domestic or foreign goods and (indirectly) demand domestic or foreign factors of production will become more responsive to cost differentials and trade taxes as information improves. Focusing on cost differentials, we can predict that the elasticity of substitution between domestic and foreign goods or between domestic and foreign factors will increase with better first-cut quality.

In this paper we will concentrate on the general-equilibrium elasticity of substitution, the reciprocal of which is computed by varying the domestic endowment of a factor of production (labor) relative to the foreign endowment and observing the change in the foreign factor price (wage) relative to the domestic factor price. This allows us to stay as close as possible to conventional general-equilibrium trade models and to analyze the key issue of international labor market integration. In a penultimate section, however, we will also analyze the partial-equilibrium elasticity of substitution computed by varying the price of foreign relative to domestic goods and observing the change in the demand for domestic relative to foreign output.

As a direct consequence of the increased general-equilibrium elasticity of substitution between national labor forces, national labor markets become more integrated in the sense that an increase in one country's labor supply has more nearly equal proportionate effects on its wages and those in its trading partner. Wages in the two countries therefore tend to move together more as information improves. A separate result is that the extent to which reduction of ad valorem trade taxes or "ice" transport costs equalizes relative national wages in-

creases. Since the volume of trade is increasing in first-cut quality, trade tax changes have a greater impact on wages when the initial volume of trade is greater, all else equal. As information becomes "perfect," the general-equilibrium elasticity of substitution becomes infinite, and our results on integration and trade liberalization converge to those of both the 2 × 2 Heckscher-Ohlin-Samuelson model and the standard one-good, two-factor model of trade in factor services that our model generalizes.

In the next section we present our simple general-equilibrium model. In Section II we solve the model and work out its basic comparative statics. Section III contains our results on improved information and labor market integration, and Section IV examines the interaction between improved information and ad valorem trade barriers. In Section V we adapt our model to analyze the Armington elasticity of substitution between domestic production and imports that plays such an important role in applied general-equilibrium trade models and in international macroeconomics. In our concluding section we discuss the implications of our results.

I. The Model

We investigate the potential impact of improved first-cut quality using the standard one-good, two-factor, two-country model of trade in factor services, augmented by introduction of a matching problem between entrepreneur-firms ("producers").[3] Wage differentials guide producers in the labor-scarce country to seek matches in the labor-abundant country, such as joint venture partners who know how to adapt the industry technology to local conditions or land developers of sites with access to the ap-

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[3] Since we have no reason to expect improved information to affect the pattern of trade in commodities any differently than reductions in conventional trade barriers (Alan V. Deardorff, 2001), we can avail ourselves of the simplicity of this model relative to the two-good (Heckscher-Ohlin-Samuelson) model. The use of the one-good model to analyze the impact of trade barriers dates back at least to Gary S. Becker (1957) and G. D. A. MacDougall (1960). Rauch and Trindade (2000, Sec. II) show that the one- and two-good models have the same qualitative properties relevant for our results, which are therefore not driven by use of the simpler model.

propriate mixes of nontraded inputs. Improved information allows producers to rule out more firms and sites in advance. The model developed in this section has also proven useful (with some adaptation) in understanding the evidence, surveyed in Rauch (2001, Sec. 4), that transnational information-sharing networks promote trade (Rauch and Alessandra Casella, 2003).

A. Endowments and Technology

The world is composed of two countries, home and foreign. In each country, there is a continuum of types of *producers* distributed over a circle of unit length.[4] For each type, there is a continuum of producers of unit mass. The producers can therefore be said to lie on a "unit cylinder." Each country is also endowed with a homogeneous, inelastically supplied mass of internationally immobile labor. Since there is an equal mass, one, of producers in both countries, the ratio of labor-producer endowment ratios across countries can be summarized by the ratio L/L^*, where L is the home labor endowment and L^* is the foreign labor endowment. In all that follows, asterisks will be used to indicate foreign variables. We assume that the foreign country is the labor-abundant country, so that $L/L^* < 1$.

Output is generated through a joint venture of two producers, and the distance between their types on the circle is an index of their complementarity or the gains from trade that result from their matching. To actively engage in production, a partnership needs to hire labor; thus output is a function of the quality of the producers' match and the labor employed:

$$(1) \qquad y_{ij} = F(x, z_{ij}),$$

where z_{ij} is the shortest arc distance between the two producers of types i and j, and x is labor. Note that the maximum value of z_{ij} is $\frac{1}{2}$. The function F is characterized by constant returns to scale.

Producers want to maximize profits. They take the wage rate w as given. With a constant returns to scale production function, total profits from the match of types i and j can be written as:

$$(2) \qquad \Pi_{ij} = z_{ij}\pi(w),$$

where the function $\pi(w)$ is decreasing and convex in w. For ease of later proofs, let us also assume that $\pi(w)$ is a constant elasticity function (as would be the case, for example, if the technology were Cobb-Douglas). The labor demand generated by a partnership is given by:

$$(3) \qquad L_{ij}^d = -z_{ij}\pi'(w),$$

where the prime sign indicates the first derivative.

B. Domestic and International Matching

The timing of the model is the following. First, home country producers travel to the foreign country, where foreign producers await them. Each home producer meets with one and only one potential foreign partner. Next, the type of one's partner is revealed,[5] successful matches are confirmed and unsuccessful ones are broken. Finally, home and foreign producers who have rejected their international matches establish domestic partnerships with other home and foreign producers, respectively, whose international matches were also unsuccessful. The home and foreign labor markets clear when all demands for labor, from domestic and international ventures, are received.

Given the model timing, we must find the outcome of domestic matching before we can solve for the results of international matching. Domestic matching proceeds as follows. Each producer selects a partner. If his choice does not select him, he gets zero. If his choice does select him, the two producers form a match and bargain over the surplus. If the bargaining breaks down, both producers get zero. Hence the surplus equals the total value of the match. We use the Nash bargaining solution, so any pair of producers that forms a match will divide the

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[4] The use of a circle of types in international trade models was popularized by Elhanan Helpman (1981). The continuum assumption facilitates comparative static analysis, just as in Rudiger Dornbusch et al. (1977).

[5] We shall see shortly that the threat point in international bargaining is the same for all types within a country, so it is not clear that anything could be gained by misrepresenting one's type if this were possible.
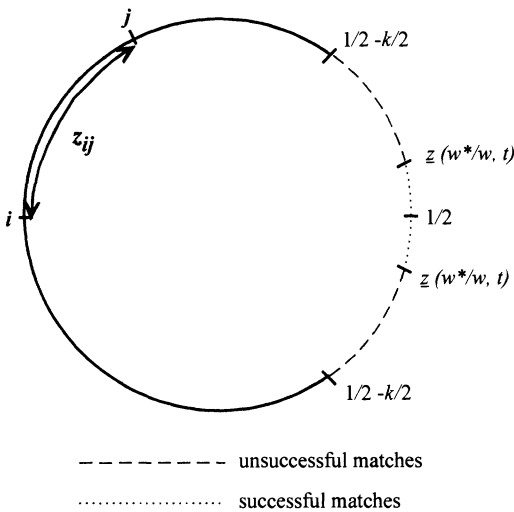
FIGURE 1. INTERNATIONAL MATCHING: DISTANCES
BETWEEN HOME PRODUCER i AND FOREIGN PRODUCER j

total match value equally between them. We assume that every producer knows at least the domestic location of his best match type. In this case it seems natural to focus on the efficient equilibrium in which each producer selects the producer opposite him on the circle (and at the same height on the cylinder). This is an equilibrium since no producer has an incentive to change his behavior after he has chosen and been chosen by his perfect complement. In this equilibrium $z_{ij} = \frac{1}{2}$ for every partnership. Domestic partnerships are assumed to have access to domestic labor only. Since each producer receives half of the profits, a home producer forming a domestic partnership earns $(\frac{1}{2})(\frac{1}{2})\pi(w) = \pi(w)/4$. Similarly, a foreign producer forming a domestic partnership earns $\pi(w^*)/4$.

We now turn to international matching. We assume that travel of home country producers to the foreign country is costless, and hence only consider equilibria in which all home country producers attempt the foreign market. Each home country producer draws a potential foreign partner from a distribution over the circle of types that is uniform with support of length $k \in (0, 1]$ and has its median at the producer's opposite type (see Figure 1).[6] k thus serves as

an index of first-cut quality, with home producers effectively able to rule out the worst $100(1 - k)$ percent of foreign types in advance: decreasing k measures improved information. International partnerships differ from domestic partnerships in two ways. First, an international partnership has the option to locate its operation in either country and can therefore have access to the labor force of either country. Second, the producer that manages the international joint venture from abroad loses a fraction t or $t^* \in (0, 1)$ of his profits. This reflects the transportation costs and trade taxes incurred when repatriating profits in terms of the numeraire good. Inclusion of trade taxes means that t or t^* can be varied by unilateral government action, which will allow us to use our model to analyze the impact of a government decision to (partially) liberalize or to further restrict trade.[7]

C. International Bargaining

If both domestic markets are active, the threat points in international bargaining of every home and every foreign producer are $\pi(w)/4$ and $\pi(w^*)/4$, respectively, where w and w^* are the international trade equilibrium wages.[8] It is then easy to see that partners in any confirmed international match will choose to locate their operation and employ labor in the low-wage country, even if the partner in the low-wage country would have lost a smaller fraction of his profits upon repatriation from the high-wage

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[6] This is consistent in the aggregate due to the symmetry of the circle and uniform distribution of home and foreign producers over types.

[7] Just as in conventional trade models, the "melting ice" model of transportation costs is nothing more than a convenient simplification and "transportation costs" is an elastic concept that might include expenses of managing an operation in another country other than the cost of transporting goods. Our results are invariant to the division of the lost profits between tax revenue collected by the government and "melting" that is lost to society. (This division would become an issue if we were to analyze welfare.)

[8] Uniformly distributed, atomless producers and the symmetry of the position of every producer on the circle ensure that the height of the remaining cylinder of producers in each country is the same for every type and thus domestically every producer can still match with his opposite type. The assumption that both domestic markets are active rules out self-confirming equilibria in which all producers anticipate that all other producers will confirm their international matches regardless of quality, leaving no domestic partners available.

country (due to lower trade taxes, for example). If the operation were located in the high-wage country, the partner from the low-wage country would have to receive more than half of the profits from the partnership to do as well as with a domestic partner, but then the partner from the high-wage country must do strictly worse than with a domestic partner. From the point of view of the partner from the high-wage country, then, the attraction of international matching is access to cheaper labor, whereas from the point of view of the partner from the low-wage country, the attraction is greater relative bargaining power than with a domestic partner.

It is now clear that the home country cannot be the low-wage country. If it were, international partnerships would demand only home labor, and demand for home labor would be relatively greater than demand for foreign labor, generating a contradiction given that supply of home labor is relatively smaller. We can also rule out $w = w^*$, since in this case because of the tax/transport cost at least one partner of an international match must do strictly worse than with a domestic partner and no international matches would be confirmed, yielding equal demand for home and foreign labor but a greater supply of the latter. It follows that in equilibrium $w > w^*$ and that all confirmed international matches will employ foreign labor. International matching thus serves to transfer labor demand from the labor-scarce to the labor-abundant country, just as does trade in the standard one-good, two-factor model. Also as in this standard model, we can think of producers and workers as using their income to purchase their own production, generating balanced international trade of producer services for numeraire output.

We can now use Figures 1 and 2 to determine the cutoff match quality for successful international partnerships. If a home country producer of type i draws a potential foreign partner of type j, denote their distance on the circle of types by z_{ij}, as represented in Figure 1. z_{ij} is uniformly distributed on the interval $[\frac{1}{2} - k/2, \frac{1}{2}]$, where $k \in (0, 1]$. Given the symmetry of the circle we can drop the subscripts from z_{ij}: every home country producer faces a uniform distribution of partner distance z, with support $[\frac{1}{2} - k/2, \frac{1}{2}]$ on the circle. We represent in Figure 2 the possibilities set that results from a
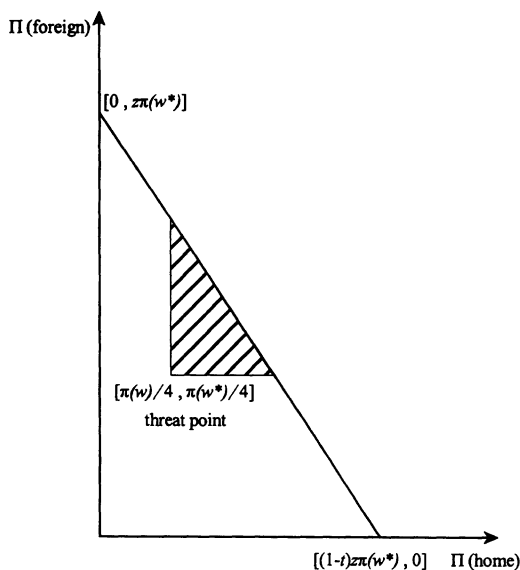
FIGURE 2. THE BARGAINING PROBLEM

potential international partnership. If the threat point is inside the Pareto frontier (the case shown in Figure 2) the two parties have an incentive to produce together, since they have a positive surplus to divide, and we assume that international matches are confirmed if and only if this condition obtains. For symmetry with domestic partnerships we apply the Nash bargaining solution to the outcome of the process of surplus division, though none of our results depends on this assumption.

The condition that the threat point is inside the Pareto frontier can be expressed as:

$$\pi(w^*)/4 < -\pi(w)/[4(1 - t)] + z\pi(w^*),$$

or alternatively as

$$(4) \quad z > z(w^*/w, t),$$

$$z \equiv \frac{1}{4} + [\pi(w)/\pi(w^*)]/[4(1 - t)]$$

$$= \frac{1}{4} + [(w^*/w)^\varepsilon]/[4(1 - t)], \quad \varepsilon > 0,$$

where $\pi(w)/\pi(w^*) = (w^*/w)^\varepsilon$ follows from our assumption that $\pi(w)$ is a constant elasticity function. This cutoff condition is represented in Figure 1. We see that $z(w^*/w, t)$ is increasing

in both arguments, as we would expect: the larger is w^*/w, the smaller are the gains from trade and the greater must be the minimum acceptable match quality, and the larger is t, the larger is the conventional barrier to trade and the greater must be the minimum acceptable match quality.

The key feature of our search and bargaining model is that some home producers draw foreign producers that yield match quality $z \leq \underline{z}$ and then return home, with both the home and foreign parties to the failed international matches finding domestic partners instead. This is consistent with the considerable heterogeneity that exists at the firm level regarding involvement in foreign transactions. Only a minority of firms even in high-wage countries like the United States have investments abroad, and in all countries studied many firms that produce tradeable goods have zero exports (Mark J. Roberts and James R. Tybout, 1997; Andrew B. Bernard and Bradford J. Jensen, 1999).[9] The result that some firms that search abroad return home empty-handed would also be obtained in a dynamic search model with an increasing marginal cost of search, but both the closeness to standard static trade models and tractability would be reduced.[10]

II. International Trade Equilibrium and Comparative Statics

Both home and foreign labor markets must clear in international trade equilibrium. To find these market clearing conditions we must derive the demands for home and foreign labor. Before doing so, two preliminary steps will help to prove and build intuition for later results.

[9] Clearly some of these firms attempted the foreign market. Swedish Trade Council export consultant Kent Goldmann (quoted in William E. Nothdurft, 1992, p. 32) stated of his clients that are marginal or failed exporters: "Sometimes their product isn't right for the market, or the country they chose was not a good fit, or their approach or agents are not right."

[10] Why should the marginal cost of search be increasing? In order to judge the quality of a match with a foreign producer a manager must be intimately familiar with his own firm's operations, and thus involved in them. If he travels abroad for a week, say, someone can cover for him, but the longer he is absent the more crucial and pressing are the unmade decisions that pile up. In other words, the opportunity cost of the manager's time is increasing.

First, we saw in the previous section that $w^* < w$ in any equilibrium of our model, but equation (4) actually yields a tighter restriction on the relationship of wages in international trade equilibrium. We see that no international partnerships can be successful if $w^*/w \geq (1 - t)^{1/\varepsilon}$, since that would imply $z > \frac{1}{2}$. For the remainder of this analysis we will assume that endowments are sufficiently different or the tax/transport cost is sufficiently low that an equilibrium with positive international trade always obtains.[11] It follows that $(1 - t)^{1/\varepsilon} \equiv \bar{\omega} < 1$ is an upper bound for w^*/w. We also see from equation (4) and Figure 1 that if $w^*/w < [(1 - 2k)(1 - t)]^{1/\varepsilon} \equiv \underline{\omega} < \bar{\omega}$, all international partnerships are successful, since this implies $\underline{z} < \frac{1}{2} - k/2$. But then demand for home labor falls to zero and $w^*/w > 1$, a contradiction. It must then be that

$$(5) \qquad w^*/w \in (\max(0, \underline{\omega}), \bar{\omega}).$$

Second, it builds intuition to compute the probability that any international partnership will be successful. From Figure 1 we see that this is given by

$$(6) \qquad P = \frac{\frac{1}{2} - \underline{z}(w^*/w, t)}{k/2}.$$

As expected, the probability of success is higher when the wage ratio is smaller, when the tax/transport cost decreases (holding the wage ratio constant), and when information improves (again holding the wage ratio constant). Also note that the sensitivity of P to both the wage ratio and the tax/transport cost is greater when first-cut quality is greater (k is smaller). This indicates the ability of producers to respond more effectively to price-based incentives as a result of improved information. Specifically, equation (6) reflects the fact that the density of producers that are "on the margin" between matching internationally and matching domestically increases as k decreases: more decision makers are in a position to take advantage of substitution opportunities. The underlying cause for the positive relationships between first-cut

[11] The precise condition that the parameters of the model are assumed to satisfy is given in the proof of Proposition 1.

quality and both labor market integration and the impact of trade liberalization is thus contained in equation (6).

Home labor is demanded only by those home producers whose international matches were unsuccessful. Summing, we get:

$$(7) \quad \frac{2}{k} \int_{1/2 - k/2}^{z} \frac{1}{4}(-\pi'(w)) \, dz$$

$$= \left(\frac{1}{4} - \frac{\frac{1}{2} - z(w^*/w, t)}{2k} \right)(-\pi'(w))$$

$$= (1 - P)\frac{1}{4}(-\pi'(w)),$$

where we used the fact that the mass of home producers equals one and applied the definition of P in the last line. Note that we used the symmetry of the problem to integrate over only half the interval in Figure 1, dividing by $k/2$ instead of k. As expected, home labor demand is increasing in the wage ratio and the tax/transport cost: as either increases, the share of international matches that is successful falls.

Foreign labor demand is the sum of labor demand by foreign producers whose international matches were unsuccessful and labor demand from successful international partnerships:

$$(7')$$

$$\frac{2}{k}\left(\int_{1/2 - k/2}^{z} \frac{1}{4}(-\pi'(w^*)) \, dz \right.$$

$$\left. + \int_{z}^{1/2} z(-\pi'(w^*)) \, dz \right)$$

$$= \left(\frac{1}{4} + \frac{z(w^*/w, t)(\frac{1}{2} - z(w^*/w, t))}{k} \right)$$

$$\times (-\pi'(w^*))$$

$$= (1 - P)\frac{1}{4}(-\pi'(w^*)) - \frac{\partial Q}{\partial w^*}.$$

Foreign labor demand is easily shown to be decreasing in the wage ratio and tax/transport cost as expected.[12] In the last line of equation (7') we introduce a new quantity, Q, which equals the profits from all successful international partnerships. In other words, Q is the same as the second integral in equation (7') if we replace $(-\pi'(w^*))$ by $\pi(w^*)$. Since $\pi(w^*)$ factors out of the integral, we can recover the labor demand integral if we take the derivative of the negative of Q with respect to w^*.

Given equations (7) and (7'), we can write the labor market clearing conditions as:

$$(8) \quad \left(\frac{1}{4} - \frac{\frac{1}{2} - z(w^*/w, t)}{2k} \right)(-\pi'(w)) = L,$$

$$(8') \quad \left(\frac{1}{4} + \frac{z(w^*/w, t)(\frac{1}{2} - z(w^*/w, t))}{k} \right)$$

$$\times (-\pi'(w^*)) = L^*.$$

Equations (8) and (8') constitute two equations in two unknowns, w and w^*. We can now prove the following proposition.

PROPOSITION 1: *An international trade equilibrium exists and is unique.*

PROOF:

An equilibrium exists if there are solutions w and w^* to the system formed by equations (8) and (8'), such that w, $w^* > 0$ and $w^*/w \in (\max(0, \underline{\omega}), \bar{\omega})$. Combining equations (8) and (8') and substituting for z using equation (4) yields:

$$(9)$$

$$\frac{2(1 - t)[(w^*/w)^\varepsilon - \underline{\omega}^\varepsilon]}{(1 + 4k)\bar{\omega}^{2\varepsilon} - (w^*/w)^{2\varepsilon}}(w^*/w)^{\varepsilon + 1} = L/L^*.$$

This is one equation in w^*/w. If $w^*/w \in (\max(0, \underline{\omega}), \bar{\omega})$, then both the numerator and the

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[12] The derivative of the numerator of the second expression with respect to z is $\frac{1}{2} - 2z$, which is negative since $z > \frac{1}{4}$ by equation (4).

denominator on the left-hand side are positive. The left-hand side of equation (9) is a monotonically increasing function of w^*/w, so if a solution for w^*/w exists it is unique. If $L/L^* = 0$ then $w^*/w = \max(0, \underline{\omega})$ is the solution. Conversely, if $w^*/w = \bar{\omega}$, we can use the definitions for $\underline{\omega}$ and $\bar{\omega}$ to show that equation (9) becomes $(1 - t)^{1 + 1/\varepsilon} = L/L^*$. But it can be shown that $L/L^* < (1 - t)^{1 + 1/\varepsilon}$ is a necessary and sufficient condition to avoid a zero-trade equilibrium, hence we have assumed that it obtains.[13] This proves that a solution for w^*/w exists and is unique. This solution can be substituted into equation (8). Given the bounds for w^*/w, it is straightforward to show that $\left(\dfrac{1}{4} - \dfrac{\frac{1}{2} - \zeta(w^*/w, t)}{2k}\right)$ is positive, and then since π' is a monotonic constant-elasticity function, a unique w exists that solves equation (8), given the solution w^*/w to equation (9). Given the uniqueness of both w^*/w and w, w^* is unique as well.

We can now perform comparative statics analysis. Consider an increase in L. Equation (9) immediately yields that w^*/w increases. The intuition is that the wage ratio increases to maintain labor market clearing in the home country (fewer international matches are successful). Equation (8′) indicates that the foreign wage must fall, and both of these facts imply that the home wage must fall as well. Conversely, an increase in L^* also causes both wages to fall, but with a *decrease* in the wage ratio. We thus see that with imperfect information ($k > 0$) national labor markets are *partially* integrated in the sense that, although an increase in either country's labor supply causes both its wage and that of its trading partner to fall, its wage falls more. In the next section we will show that the extent of labor market integration increases monotonically with first-cut quality.

As expected, w^* decreases and w increases (and thus the wage ratio falls) with increasing k or t:

PROPOSITION 2: *With changes in k or t the following results apply:*

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[13] This proof is available upon request.

(i) $dw/dk > 0$.
(ii) $dw/dt > 0$.
(iii) $dw^*/dk < 0$.
(iv) $dw^*/dt < 0$.

PROOF:
Note that the left-hand side of equation (8) [equation (8′)] increases (decreases) with both k and t. It follows that the left-hand side of equation (9) must increase with both k and t. Consequently, $d(w^*/w)/dk < 0$ and $d(w^*/w)/dt < 0$, that is, the wage ratio falls with both k and t. It then suffices to prove that $(dw/dk)(dw^*/dk) < 0$ and that $(dw/dt)(dw^*/dt) < 0$. The most straightforward way to do this is simply to totally differentiate equations (8) and (8′). The results can be summarized as follows:

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix}\begin{pmatrix} dw \\ dw^* \end{pmatrix} = \begin{pmatrix} F & G \\ H & I \end{pmatrix}\begin{pmatrix} dk \\ dt \end{pmatrix},$$

where the matrix coefficients are functions of w, w^*, and the parameters of the model. Then a straightforward use of Cramer's rule reduces the proof to showing that:

$$(DF - BH)(AH - CF) < 0 \text{ and}$$

$$(DG - BI)(AI - CG) < 0.$$

The proofs of these inequalities, as well as the explicit expressions for the coefficients, are relegated to an Appendix available upon request.

We next show that, as either type of trade barrier increases (either first-cut quality decreases or the tax/transport cost increases), the volume of trade decreases, as expected. In our model the volume of trade equals profits repatriated by home country producers. The following Lemma will be an important input to our proof.

LEMMA: *The probability of a successful match P decreases as either k or t increases.*

PROOF:
The results follow from Proposition 2 and the last line of equation (7). Since w increases with k or t, it must be that P decreases, in either case, to keep labor demand constant.

PROPOSITION 3: *The volume of trade decreases as either k or t increases.*

PROOF:

Since from Proposition 2 we have $dw/dk > 0$ and $dw/dt > 0$, it suffices to show that the *total* profits from international partnerships Q decrease as either k or t increases, because the weakening of the bargaining position of home country producers means the profits they obtain from international partnerships decrease even more. Consider an increase in k. We know from Proposition 2 and the Lemma that both w^* and P go down, both thereby contributing to an increase in the demand for foreign labor according to the last line of equation (7'). Since the foreign labor market must still clear, it must be that $-\partial Q/\partial w^*$ (which is a positive quantity) decreases. Since the expression for Q is proportional to $\pi(w^*)$, it can be written as $Q = C(w^*)^{-\varepsilon}$, where C does not depend on w^* and $-\varepsilon$ is the constant elasticity of profits with respect to the wage rate. Then $-\partial Q/\partial w^* = C\varepsilon(w^*)^{-\varepsilon-1} = \varepsilon Q/w^*$, and since w^* is decreasing it must be that Q itself decreases with k. The proof for the case when t increases is exactly analogous.

We conclude this section by proving our first "convergence" result: in the limit as information becomes perfect (k approaches zero), the ratio of national wages becomes a function of only the tax/transport cost and technology, as in the 2 × 2 Heckscher-Ohlin-Samuelson model and the standard one-good, two-factor model of trade in factor services. In particular, the ratio of national wages becomes independent of the ratio of national labor supplies. To see this, note that as k approaches zero, $\underline{\omega}$ approaches $\bar{\omega}$. Since $\underline{\omega}$ is positive for $k < \frac{1}{2}$, it follows from Proposition 1 that there is a solution for the wage ratio $w^*/w \in (\underline{\omega}, \bar{\omega})$. In the limit, we must have $w^*/w = \bar{\omega} \equiv (1 - t)^{1/\varepsilon}$, and the wage ratio depends only on the tax/transport cost and on production technology (which determines ε). The wage ratio achieves its upper bound because with perfect information the maximum transfer of labor demand from the home to the foreign country occurs.

III. Information and Labor Market Integration

As stated in the introduction, we expect the elasticity of substitution between national labor forces to increase as informational barriers to trade fall. We can now demonstrate this result formally. Define the relevant elasticity as $\sigma^{GE} \equiv d[\ln(L/L^*)]/d[\ln(w^*/w)]$, where the superscript GE reminds us that this is a general-equilibrium elasticity of substitution in which the endowment ratio varies exogenously. Combining equations (8) and (8'), we have

$$\frac{k - 2(\frac{1}{2} - z)}{k + 4z(\frac{1}{2} - z)} (w^*/w)^{\varepsilon+1} = L/L^*.$$

Using this expression, we can immediately see that suppressing the dependence of z on w^*/w yields $\sigma^{GE} = \varepsilon + 1$: eliminating the impact of the wage ratio on the probability of forming a successful international partnership, and thus on the transfer of labor demand between countries, yields a "base" value of the elasticity of substitution that must rise when that impact is factored in. Proposition 4 shows that the extent to which the substitutability of national labor forces exceeds this base value increases as first-cut quality improves, and that this substitutability becomes perfect as information becomes perfect.

PROPOSITION 4: $\sigma^{GE} > \varepsilon + 1$, σ^{GE} decreases with k, and $\sigma^{GE} \to \infty$ as $k \to 0$.

PROOF:

The equilibrium wage ratio w^*/w is calculated with the help of equation (9), which we repeat here:

(9)

$$\frac{2(1 - t)[(w^*/w)^\varepsilon - \underline{\omega}^\varepsilon]}{(1 + 4k)\bar{\omega}^{2\varepsilon} - (w^*/w)^{2\varepsilon}} (w^*/w)^{\varepsilon+1} = L/L^*.$$

This equation implicitly defines w^*/w as a function of L/L^*. Taking derivatives and substituting the equation back in, we get:

$$\sigma^{GE} = \varepsilon + 1 + \frac{\varepsilon}{1 - \underline{\omega}^\varepsilon/(w^*/w)^\varepsilon}$$

$$+ \frac{2\varepsilon}{(1 + 4k)\bar{\omega}^{2\varepsilon}/(w^*/w)^{2\varepsilon} - 1}.$$

It is trivial by inspection to see that $\sigma^{GE} > \varepsilon + 1$, given the limits for w^*/w.

Next, we prove that σ^{GE} decreases with k. The fourth term on the right-hand side clearly decreases with k, since w^*/w decreases with k (see Proposition 2) and $\bar{\omega}$ does not depend on k. It then suffices to prove that the third term also decreases with k. We can show that $1 - \underline{\omega}^\varepsilon / (w^*/w)^\varepsilon$ increases with k by using the definition of P [equation (6)]. We have:

$$1 - P = \frac{(w^*/w)^\varepsilon - \underline{\omega}^\varepsilon}{2k(1 - t)}.$$

Since $1 - P$ increases when k increases (by the Lemma), it must be that $(w^*/w)^\varepsilon - \underline{\omega}^\varepsilon = (w^*/w)^\varepsilon[1 - \underline{\omega}^\varepsilon / (w^*/w)^\varepsilon]$ increases as well. Since $(w^*/w)^\varepsilon$ decreases with k, $1 - \underline{\omega}^\varepsilon / (w^*/w)^\varepsilon$ must increase with k, and the result follows.

Finally, we showed at the end of Section II that in the limit as k approaches zero $w^*/w = \underline{\omega}$ ($= \bar{\omega}$). The third term of the expression for σ^{GE} thus tends to infinity as k tends to zero, completing the proof.

Since the value of the elasticity of substitution between national labor forces is infinite in the 2×2 Heckscher-Ohlin-Samuelson model and in the standard one-good, two-factor model of trade in factor services, Proposition 4 contains our second convergence result.

A higher elasticity of substitution means that firms are able to transfer labor demand more effectively between countries in response to the opportunities presented by wage differentials, thereby reducing the extent to which relative wages need to change when relative labor supplies change in order for national labor markets to clear. Figure 3 illustrates this aspect of increasing labor market integration as information improves. As k falls from 1 to 0.01, home producers begin unable to rule out any foreign types in advance and end able to rule out the worst 99 percent in advance. We see that for minimum first-cut quality the home wage falls by less than 1 percent and the foreign wage falls by more than 4 percent in response to a 10-percent increase in foreign labor supply, but as first-cut quality increases these changes both converge towards the perfectly integrated world labor market value and the
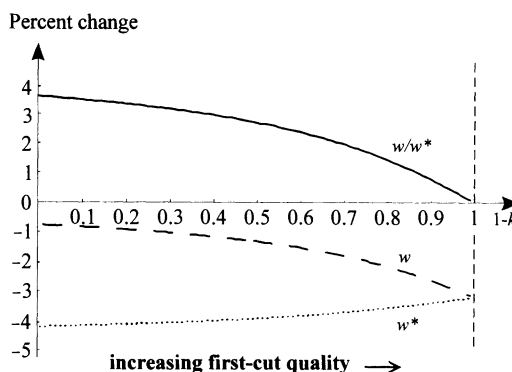

Percent change

FIGURE 3. RELATIVE WAGE RESPONSE TO A 10-PERCENT INCREASE IN FOREIGN LABOR SUPPLY

change in the wage ratio converges towards zero.[14] An interesting feature of this simulation and those reported in Figures 4 and 5 below is that the pace of convergence to the perfect information result accelerates as k shrinks: only when information has dramatically improved does its impact on globalization become really noticeable.

In a recent book, Dani Rodrik (1997) argues that globalization increases the insecurity felt by workers in high-wage countries. An important part of his argument is that globalization increases the elasticity of national labor demand. We have just shown that an increase in first-cut quality increases the substitutability of national labor forces, so we can expect it to increase the elasticity of national labor demand as well. Following Rodrik, we consider the elasticity of national labor demand for the high-wage country ignoring any effect of the change in domestic wages on wages in the rest of the world, i.e., holding w^* constant. Denote that elasticity by $e(L^d, w) \equiv d[\ln(L^d)]/d[\ln(w)]$, where L^d is the demand for home labor [the left-hand side of equation (8)]. We can think of this elasticity as a partial-equilibrium magnitude, as would be typical in labor economics, or

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[14] The initial value of L/L^* in this simulation is ½, so the world labor supply increases by 6 ⅔ percent. The value of ε is 1, yielding an autarky labor demand elasticity of -2, so in a perfectly integrated world labor market the world wage should fall by 3 ⅓ percent (actually about 3.175 percent once we correct for linear approximation error). The value of t in this simulation is zero.
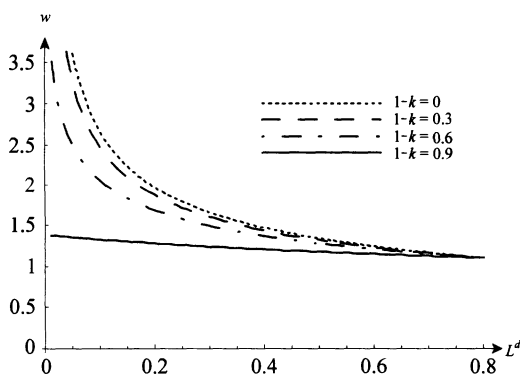
FIGURE 4. CHANGES IN THE HOME LABOR DEMAND CURVE
AS FIRST-CUT QUALITY INCREASES (w^* FIXED)

we can think of it as a general-equilibrium mag-
nitude, in which case the home country must be
"small" relative to the foreign country.[15] In
either case, it is easily shown (Rauch and
Trindade, 2000, Proposition 6) that in absolute
value $e(L^d, w) > \varepsilon + 1$, $e(L^d, w)$ decreases
with k, and $e(L^d, w) \to \infty$ as $k \to 0$. With
infinitely elastic domestic labor demand, the
results of our model again converge to the re-
sults of standard trade models as information
becomes perfect.

Figure 4 illustrates these results. The home
wage and the home labor demand are expressed
in proportion to the foreign wage and foreign
labor supply, respectively.[16] The home labor
demand curve tends towards a horizontal line as
k approaches zero.[17] Again this tendency man-

ifests itself clearly only when information has
dramatically improved.

IV. Information and the Impact of Trade Liberalization

One of the most important aspects of infor-
mational barriers to international trade is their
interaction with conventional trade barriers. We
can expect that, just as informational barriers
interfere with the ability of firms to transfer
labor demand across borders in response to the
incentive of international wage differentials,
they would also blunt their shifting of labor
demand in response to the disincentive of trade
taxes or transport costs. As information im-
proves, decisions by firms whether to demand
domestic or foreign labor will become more
responsive not only to changes in the wage
differential w^*/w but also to changes in the
tax/transport cost t. With labor supplies given by
endowments in our simple general-equilibrium
trade model, all of the adjustment to the greater
responsiveness to changes in t is borne by
wages. We thus expect the elasticity of the wage
ratio with respect to the tax/transport cost to
increase as first-cut quality increases.

We saw in Proposition 4 that the elasticity of
substitution between national labor forces tends
to infinity as k tends to 0, hence the elasticity of
the wage ratio with respect to the labor endow-
ment ratio tends to 0 as k tends to 0. Towards
what quantity should we expect the elasticity of
the wage ratio with respect to the tax/transport
cost to tend as k tends to 0? At the end of
Section II we showed that w^*/w tends to $\bar{\omega} \equiv$
$(1 - t)^{1/\varepsilon}$ as k tends to 0, and it is easily shown
that the equation $w^*/w = \bar{\omega}$ yields an elasticity
of the wage ratio with respect to t equal to
$-t/[\varepsilon(1 - t)]$. The dependence on t is awk-
ward, so we make the change of variable $T \equiv$
$1 - t$, in which case the equation $w^*/w = \bar{\omega} \equiv$
$T^{1/\varepsilon}$ yields an elasticity of the wage ratio with
respect to T equal to $1/\varepsilon$, which we expect to
be the limiting elasticity as k tends to 0. An

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[15] We can implement the small country assumption rig-
orously in our model by allowing the foreign producer
cylinder to become infinitely tall, while at the same time
allowing the foreign labor endowment to grow proportion-
ately so that the foreign zero-trade equilibrium wage is
unchanged. In this way the measure of foreign producers
that match with home producers goes to zero, permitting us
to treat the foreign wage w^* as a constant when the home
wage varies. The home labor market clearing condition does
not change because with one-shot random matching the
probability of formation of successful partnerships by home
producers does not change.

[16] In the case where the home country is small relative to
the foreign country, we must instead state that the home
labor demand *per producer* is expressed in proportion to the
foreign labor supply *per producer*.

[17] The value of ε in Figure 4 is 1, as in Figure 3, but the
value of t is 0.1, its (initial) value in Figure 5 below. It
follows that when w/w^* falls to 1/0.9 (w^*/w rises to 0.9 =

$(1 - t)^{1/\varepsilon}$) the home country is in zero-trade equilibrium,
so that labor demand is the same regardless of the value of
k. The reader can easily compute that, for $\varepsilon = 1$, the value
of L/L^* for which $t = 0.1$ is a "prohibitive" tax/transport
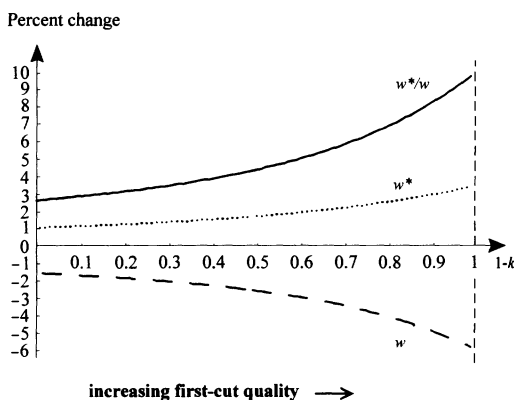cost is $(0.9)^{1 + 1/\varepsilon} = 0.81$.

Percent change

FIGURE 5. RELATIVE WAGE RESPONSE TO A
10-PERCENT TRADE LIBERALIZATION
(10-PERCENT INCREASE IN $T = 1 - t$)

increase in T corresponds to trade liberalization or to an increase in the proportion of the traded good that "arrives" in the ice transport cost model. We denote the elasticity of w^*/w with respect to trade liberalization by $e(w^*/w, T) \equiv d[\ln(w^*/w)]/d[\ln(T)]$. Note that we know from Proposition 2 that $e(w^*/w, T)$ is positive.

We demonstrate in Proposition 5 that the extent to which trade liberalization equalizes wages across countries increases with first-cut quality, and $e(w^*/w, T)$ approaches $1/\varepsilon$ as information becomes perfect.

PROPOSITION 5: $e(w^*/w, T)$ decreases with k, and $e(w^*/w, T) \to 1/\varepsilon$ as $k \to 0$.

PROOF:
The proof of this proposition is more involved than the proofs of our other propositions, and is confined to the Appendix.

Figure 5 shows Proposition 5 in action. The value of ε is 1, so the increase in w^*/w in response to a 10-percent increase in T must approach 10 percent as k approaches 0. We also see in Figure 5 that for minimum first-cut quality the wage ratio only increases by about 2 ½ percent. This equalization of wages in response to trade liberalization is brought about more by a fall in the home wage than by an increase in the foreign wage, reflecting the larger size of the foreign labor force.[18]

Since from Proposition 5 we already know that w^*/w changes less in response to a change in T as k increases, we can expect that if we hold w^* constant w will change less in response to a change in T as k increases. Just as in our analysis of the elasticity of domestic labor demand $e(L^d, w)$, we can hold w^* constant by making the home country "small" relative to the foreign country, or consider our analysis to be of the partial- rather than general-equilibrium variety. Rauch and Trindade (2000, Proposition 8) show that in either case $e(w, T)$ decreases (in absolute value) with k and $e(w, T) \to -1/\varepsilon$ as $k \to 0$, where $e(w, T) \equiv d[\ln(w)]/d[\ln(T)]$ holding w^* constant. The reduction in home wages in response to trade liberalization increases as first-cut quality increases.

Standard small-country analysis of ad valorem trade taxes/transport costs, in both the 2 × 2 Heckscher-Ohlin-Samuelson model and the one-good, two-factor model of trade in factor services that our model generalizes, demonstrates that the percentage change in domestic wages equals the percentage change in T multiplied by a coefficient that is determined only by the underlying production technology.[19] The fact that this property holds in our model as information becomes perfect is our final "convergence" result.

We know from Proposition 3 that the volume of trade increases with first-cut quality. Our result on $e(w, T)$ therefore implies that the impact of trade liberalization on domestic wages will be greater, the greater is the initial volume of trade, holding constant all parameters other than first-cut quality, including the initial level of the tax/transport cost and all characteristics of the trading partner.

V. The Armington Elasticity of Substitution

The elasticity of substitution between domestic and imported outputs, known as the Armington elasticity of substitution, is a key parameter in both econometric and simulation models that are used to assess the likely effects of various trade policies (see, e.g., Rajesh Chadha et al., 1998). It also plays an important role in inter-

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[18] The value of L/L^* in this simulation is ½ and the initial value of T is 0.9 ($t = 0.1$).

[19] In the 2 × 2 Heckscher-Ohlin-Samuelson model we would define T as $1 + t$ rather than $1 - t$.

national macroeconomics, as it influences the "expenditure-switching" impact of exchange rate changes, and can even determine the sign of the welfare effect of a domestic monetary shock (Cédric Tille, 2001). If domestic and imported outputs are identical, then in standard trade models with ad valorem trade barriers the Armington elasticity must be infinite, or there must be complete specialization in production. This creates a problem because estimated Armington elasticities are not especially large (e.g., Bruce A. Blonigen and Wesley W. Wilson, 1999), and the world does not typically display complete specialization. The generally adopted solution to this problem is that proposed by Paul S. Armington (1969), which is to differentiate goods by place of production. Following Armington, this has been taken to mean that chemicals produced in the United States and chemicals produced in Canada are "imperfect substitutes in demand" (Armington, 1969, p. 159), meaning imperfect substitutes in the representative consumer's utility function or producer's production function.

We propose a different approach to this problem. We assume that imported and domestic outputs are distinguished *only* by place of production, i.e., they are perfect substitutes in consumer or producer demand. Finite Armington elasticities of substitution nevertheless obtain because of matching friction with foreign suppliers. Complete specialization in production can arise, but only if the price differential between imported and domestic outputs is great enough to overcome the "natural protection" offered by the informational barrier to trade. With incomplete specialization, we expect Armington elasticities of substitution to rise as first-cut quality (information) improves.

We can demonstrate these results using the model of Sections I and II after some reinterpretation of the agents and variables. We begin by reinterpreting "producers" as wholesalers engaged in both domestic distribution and import-export activities. Instead of purchasing "labor," wholesalers purchase goods from manufacturers, and "wages" can then be interpreted as producer prices and relabeled p and p^*, respectively. Wholesaler "types" can be interpreted as reflecting their (possibly contractual) affiliations with certain manufacturers and end users (retailers or purchasers of intermediate

goods). Match quality is then increasing in the suitability of the product varieties supplied by the underlying manufacturers for the end users the wholesalers wish to serve. Equation (1) now gives the production function for wholesale services for a given industry. The assumption that product varieties are identical across countries (perfect substitutes in demand) is reflected by the fact that the location of any wholesaler's best match is identical across countries and yields an identical match quality. The model can implicitly allow for variation in the degree of product differentiation within an industry by changing the exponent on z_{ij} in a Cobb-Douglas specification of the production function F: the greater is this exponent, the more important is match quality as a component of wholesale services, indicating a greater level of product differentiation in the industry. It is easily shown that this implies a smaller elasticity of the profit function in equation (2) with respect to the producer price p, leading to a smaller "base" elasticity of substitution. Conversely, the more "commodified" is the industry, the more price sensitive are the profits of the wholesalers that work in it.

We will assume that all product varieties within an industry are symmetric, hence p and p^* represent the producer prices of every product variety in the respective countries.[20] Aggregating units across all goods within the industry, equations (7) and (7') then give the demands for domestic industry output and foreign industry output, respectively. Let us define imports M as that part of demand for foreign industry output generated by international matches, i.e., goods purchases of internationally matched foreign wholesalers from their affiliated manufacturers for resale by their partner home wholesalers to their affiliated end users.[21] We also denote demand for domestic industry output by D. Following Blonigen and Wilson (1999), we then define the Armington elasticity of substitution as $\sigma^A \equiv d[\ln(D/M)]/d[\ln(p^*/p)]$.

From equation (5), we know that σ^A is only defined for $p^*/p \in (\max(0, \underline{\omega}), \bar{\omega})$: for $p^*/p \leq \underline{\omega} \equiv [(1 - 2k)(1 - t)]^{1/\varepsilon}$, all international

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[20] In empirical work p and p^* would be producer price indices.

[21] This is equivalent to $-\partial Q/\partial w^*$ in equation (7').

matches are accepted and $D = 0$, and for $p^*/p \geq \bar{\omega} \equiv (1 - t)^{1/\varepsilon}$, all international matches are rejected and $M = 0$.[22] For $t = 0$ and $k < \frac{1}{2}$, $\underline{\omega} = (1 - 2k)^{1/\varepsilon}$ is a measure of "natural protection": it tells us how much cheaper importable output must be than domestic output in the absence of conventional trade barriers before domestic production is eliminated and complete specialization prevails. Natural protection increases with k, as expected, and decreases with ε: as product differentiation measured by the importance of match quality to wholesalers declines, matching friction caused by incomplete information in the foreign market provides less protection to domestic producers.

To compute σ^A for $p^*/p \in (\max(0, \underline{\omega}), \bar{\omega})$, we first compute the values of D and M. We have $D = [\frac{1}{4} - (\frac{1}{2} - \zeta)/2k](-\pi'(p))$ and $M = [(\frac{1}{4} - \zeta^2)/k](-\pi'(p^*))$.[23] We can then show that the extent to which the Armington elasticity of substitution exceeds its base value increases as information improves:

PROPOSITION 6: $\sigma^A > \varepsilon + 1$ and σ^A decreases with k for $p^*/p \in (\max(0, \underline{\omega}), \bar{\omega})$.

PROOF:
Dividing D by M and substituting in the definition of ζ, we have

$$D/M = \frac{2\bar{\omega}^\varepsilon[(p^*/p)^\varepsilon - \underline{\omega}^\varepsilon]}{4\bar{\omega}^{2\varepsilon} - [\bar{\omega}^\varepsilon + (p^*/p)^\varepsilon]^2} (p^*/p)^{\varepsilon + 1}.$$

Logarithmic differentiation yields

$$\sigma^A = \varepsilon + 1 + \frac{\varepsilon(p^*/p)^\varepsilon}{(p^*/p)^\varepsilon - \underline{\omega}^\varepsilon}$$

$$+ \frac{2[\bar{\omega}^\varepsilon + (p^*/p)^\varepsilon]\varepsilon(p^*/p)^\varepsilon}{4\bar{\omega}^{2\varepsilon} - [\bar{\omega}^\varepsilon + (p^*/p)^\varepsilon]^2}.$$

Since $\underline{\omega} < p^*/p < \bar{\omega}$, we have $\sigma^A > \varepsilon + 1$.

Moreover, $\underline{\omega}$ decreases with k and p^*/p is given exogenously, so σ^A decreases with k.

Blonigen and Wilson (1999) examine the determinants of estimated Armington elasticities between U.S. domestic and imported goods across over 100 industrial sectors from 1980–1988. They find evidence in support of their hypothesis that "more efficient distribution of the import good makes it easier for the consumer to substitute to these products" (p. 9). This is also consistent with our Proposition 6.[24]

VI. Conclusions

We modeled a reduction in informational barriers to trade as allowing investors from a labor-scarce country to rule out, in advance of attempting to form a match, more of the potential partners in a labor-abundant country with which they can enter into productive joint ventures. We found that this increased first-cut quality leads to a greater general-equilibrium elasticity of substitution between national labor forces, hence greater integration of national labor markets in the sense that an increase in one country's labor supply has more nearly equal proportionate effects on its wages and those in its trading partner. A related result is that, unlike reductions in conventional trade barriers (at least in standard models), improved information has the effect predicted by Rodrik (1997) of increasing the elasticity of national labor demands.

In our model conventional trade barriers took the form of ad valorem tax/transport costs. We found that the extent to which reductions in conventional trade barriers equalize national wages increases with first-cut quality. Since in our model the volume of trade is increasing in first-cut quality, trade tax changes have a greater impact on wages when the initial volume of trade is greater, all else equal. Our model thus has implications for the effects of trade liberalization on wages, both over time and in cross-section. If information is in fact improving with time, past impacts of trade lib-

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[22] For the general-equilibrium elasticity of substitution, the wage ratio is determined endogenously and $\max(0, \underline{\omega})$, $\bar{\omega}$ respectively give the lower and upper bounds for the equilibrium value of w^*/w. Here it is the price ratio rather than the endowment ratio that varies exogenously, so p^*/p can take on values above $\bar{\omega}$ or below $\underline{\omega}$ (when $\underline{\omega} > 0$).

[23] Substituting in $\zeta = \frac{1}{4} + [(p^*/p)^\varepsilon]/[4(1 - t)]$, we can easily confirm that $p^*/p = \underline{\omega}$ yields $D = 0$ and $p^*/p = \bar{\omega}$ yields $M = 0$.

[24] Blonigen and Wilson use import price indices rather than indices of producer prices in the source country. Our model is useful for interpreting their results to the extent that variation in the former is driven by variation in the latter.

eralization on wages may underestimate the impacts of future liberalization, at least if the liberalization involves reductions in trade taxes.[25] In cross section, our model suggests that trade liberalization with countries with which the initial volume of trade is greater, all else equal, will have greater impact on domestic wages.

Once it is adapted to apply to trade in goods, our model also predicts that elasticities of substitution between domestic and foreign outputs will increase as information improves. Though our results have yet to be integrated with an international macroeconomic model, we can speculate about what cross-sectional or time-series implications they might have in this area as well. For example, if at present distance between countries is still a useful proxy for quality of information (Portes and Rey, 1999), the expenditure-switching effects of exchange rate changes may be smaller for countries that are more distant from their major trading partners.[26]

Our model conceives of international trade as a business-to-business enterprise, conducted between manufacturers of consumer goods and distributor-wholesalers, between assemblers and component suppliers, and so on with individual consumers in the background. Gene M. Grossman and Elhanan Helpman (2002) have applied a business-to-business matching model to determination of the level of international outsourcing in general equilibrium. The business-to-business matching approach may prove to be a useful vehicle for many new insights in international economics.

APPENDIX

PROOF OF PROPOSITION 5:

We can rewrite equation (9) in the following way, by substituting for $\underline{\omega}$ and $\bar{\omega}$, making the change of variable $T \equiv 1 - t$, dividing the

numerator and denominator of the fraction on the left-hand side by $4kT^2$, and rearranging:

(A1)

$$\frac{1 - \dfrac{1}{2k}\left(1 - \dfrac{(w^*/w)^\varepsilon}{T}\right)}{1 + \dfrac{1}{4k}\left(1 - \dfrac{(w^*/w)^{2\varepsilon}}{T^2}\right)}\,(w^*/w)^{\varepsilon+1} = L/L^*.$$

We know from Proposition 2 that w^*/w increases with T. We can now see from equation (A1) that $(w^*/w)^\varepsilon$ must increase less than proportionately than T. If it increased proportionately the fraction on the left-hand side would remain constant and the whole left-hand side would increase, a contradiction since L/L^* is kept constant. This argument applies a fortiori to rule out a more than proportionate increase in $(w^*/w)^\varepsilon$. This then implies that $0 < \varepsilon e(w^*/w, T) < 1$.

We now show that $e(w^*/w, T)$ decreases with k. Let us denote the numerator and the denominator in equation (A1) by A and B, respectively:

$$A = 1 - \frac{1}{2k}\left(1 - \frac{(w^*/w)^\varepsilon}{T}\right) = 1 - P,$$

where use has been made of equations (4) and (6), and

$$B = 1 + \frac{1}{4k}\left(1 - \frac{(w^*/w)^{2\varepsilon}}{T^2}\right).$$

Differentiating the logarithm of equation (A1) with respect to T, we obtain:

(A2)

$$\frac{1}{A}\frac{\partial A}{\partial T} - \frac{1}{B}\frac{\partial B}{\partial T} + \frac{\varepsilon + 1}{w^*/w}\frac{\partial(w^*/w)}{\partial T} = 0$$

It is straightforward to calculate:

$$\frac{\partial A}{\partial T} = -\frac{1}{2k}\frac{(w^*/w)^\varepsilon}{T^2}\left[1 - \varepsilon e(w^*/w, T)\right] \text{ and}$$

$$\frac{\partial B}{\partial T} = \frac{1}{2k}\frac{(w^*/w)^{2\varepsilon}}{T^3}\left[1 - \varepsilon e(w^*/w, T)\right].$$

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[25] We leave analysis of the interaction of informational barriers to trade with quantitative restrictions to future research. One way to handle quantitative restrictions in our model would be to allow only a subset of domestic producers who have licenses to engage in international joint ventures to match with producers abroad.

[26] We are grateful to Maury Obstfeld for this suggestion.

Therefore, given that $0 < \varepsilon e(w^*/w, T) < 1$, the first two terms in equation (A2) are both negative.

Suppose now that when k increases, $(1 - \varepsilon e(w^*/w, T))$ is either constant or decreases, implying that $e(w^*/w, T)$ does not decrease, as we wish to prove. Because w^*/w is decreasing in k, we can deduce that:

(i) $\partial A/\partial T$ decreases (in absolute value) with k;

(ii) A increases with k, because the Lemma tells us that P decreases with k; and

(iii) $\dfrac{1}{B}\dfrac{\partial B}{\partial T} = \dfrac{2[1 - \varepsilon e(w^*/w, T)](w^*/w)^{2\varepsilon}/T^3}{4k + 1 - (w^*/w)^{2\varepsilon}/T^2}$ decreases with k.

These three results imply that the last term in equation (A2), which is positive, also decreases with k. But that term is simply proportional to $e(w^*/w, T)$, so we arrive at a contradiction. Therefore it must be that $(1 - \varepsilon e(w^*/w, T))$ increases and $e(w^*/w, T)$ decreases with k, as we wished to prove.

Let us now prove that $e(w^*/w, T) \to 1/\varepsilon$ as $k \to 0$. If this is not true, $(1 - \varepsilon e(w^*/w, T))$ does not tend to zero as $k \to 0$. Recalling that $w^*/w \to T^{1/\varepsilon} = \bar{\omega}$ when $k \to 0$, this implies that both

$$\frac{1}{A}\frac{\partial A}{\partial T} = -\frac{[1 - \varepsilon e(w^*/w, T)](w^*/w)^{\varepsilon}/T^2}{2k - 1 + (w^*/w)^{\varepsilon}/T},$$

and $-(\partial B/\partial T)/B$ go to $-\infty$ as $k \to 0$. It then follows from equation (A2) that $e(w^*/w, T) \to +\infty$, which contradicts $\varepsilon e(w^*/w, T) < 1$, thus establishing the result.

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