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10 Immigration, International Trade, and the Wages of Native Workers

Peter Kuhn and Ian Wooton

The purpose of this paper is to develop and apply to U.S. data a theoretical model with the following features. First, it should yield a set of predictions regarding the effects of international factor movements, such as immigration, on the rewards of all factors employed in the country, including labor disaggregated by skill level. Second, it should be consistent with the following stylized facts: (i) the U.S. economy is "partially open" in the sense that it produces both internationally traded and nontraded goods; and (ii) international trade in goods has apparently not equalized factor prices between the United States and the rest of the world.

These requirements play an important role in this paper because few of the existing models that consider general-equilibrium effects of factor endowments on factor prices satisfy them. For example, Hicks's (1932, chap. 6) classic analysis assumes that no goods are traded internationally. This work predicted that the effect of factor quantities on factor prices was determined by a set of within-industry elasticities of substitution as well as substitution elasticities in consumption, and it stimulated several empirical attempts to estimate these parameters (e.g., Fallon and Layard 1975). On the other hand, the basic two-good, two-factor (2 × 2) trade model (Samuelson 1948) assumes that all produced goods are traded. It predicts, unrealistically, that trade alone should eliminate all factor price differentials between countries and thus that factor endowments should have no effect on factor prices. Finally, among the trade models that do allow for international factor movements to affect factor prices (e.g., the 2 × 2 models of Kemp 1966; Markusen and Melvin 1979; Brecher and Choudhri 1982; and Rivera-Batiz 1982; the two-good, three-factor (2 × 3) models of Batra and Casas 1976; Ruffin 1981; and Jones

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and Easton 1983; as well as the higher-dimensional treatments of Jones and Scheinkman 1977; or Chang 1979), the only one that includes any nontraded goods is Rivera-Batiz (1982).

The model in this paper can be thought of as an extension of Rivera-Batiz (1982), which adds an extra traded good and an extra factor. We thus have three factors, two traded goods, and one nontraded good. The additional traded good allows us to have both an exporting and an import-competing industry in the analysis and to compare how these two sectors are affected by changes in factor endowments. The additional factor allows us to distinguish between workers with different investments in human capital. Specifically, we subdivide the labor force into skilled workers and unskilled workers. Immigrants of a particular type are considered to be perfect substitutes for native workers of that same category. Our model may also be thought of as the addition of a nontraded sector to Ruffin's (1981) 2 × 3 model.

The paper's main theoretical results are twofold. First, we find that the directions of the effects of factor endowments on factor prices, while not zero as in the "standard" trade model, are still independent of the within-industry technical substitution elasticities between inputs in production. This independence property (which incidentally also holds in Rivera-Batiz's lower-dimensional model) dramatically illustrates the effects of allowing international trade in even a subset of commodities on models of the functional distribution of income. It arises because, contrary to the closed-economy model, the fundamental determinants of factor price changes are *not* the ability to substitute factors in production; they are, instead, the tendency for factor prices to change in such a way as to maintain the international competitiveness of the country's exporting and import-competing industries, as long as those industries continue to operate.

Second, providing that a relatively weak "normality" condition holds, the directions of all the factor quantity–factor price effects in our model can be deduced directly from the relative intensities of factor use within the traded sector of the economy only, as follows. First, an increase in the supply of any factor lowers its own price. Second, with three factors, one will be "extremely" intensively used in exports, another in imports, and the third will be the "middle" factor in the traded sector of the economy. Our model predicts that an increase in the supply of either extreme factor lowers the price of the other extreme factor and raises the price of the middle factor. Third, an increase in the supply of the middle factor benefits owners of both extreme factors. Interestingly, the results given above are identical to those obtained by Ruffin (1981) without a nontraded sector.

The paper's main empirical result, based on factor intensities in 430 four-digit U.S. manufacturing industries for the years 1960, 1970, 1980, and 1984, is the following. For all definitions of traded versus nontraded goods considered, and for all years except 1960, skilled labor is extreme in exports and unskilled labor is extreme in imports, with capital as the middle factor. Thus, our model predicts that, in the long run, the interests of both types of labor in immigration issues should coincide and should conflict with those of capital. Workers of both types should oppose all immigration but favor foreign investment in the United States, while owners of capital should favor immigration of both types of workers.

Section 10.1 of the paper outlines the structure of the model. Section 10.2 solves the model for the effect of factor endowment changes on factor prices. Section 10.3 characterizes the properties of that solution. Section 10.4 presents our empirical estimates of factor intensities for the United States and their implications, while section 10.5 concludes.

10.1 The Model

Each of the three goods X_1, X_2, and X_3 is produced using the services of the three factors of production, V_1, V_2, and V_3, according to linearly homogeneous production functions. We adopt the convention that good 3 is nontraded and that, of the two traded goods, X_1 is imported and X_2 exported. Let a_{ij} be the quantity of factor i required to produce a unit of good j, where a_{ij} depends on the prices of the three factors w_1, w_2, and w_3. Without loss of generality, we number factors in such a way that

$$a_{11}/a_{12} \geq a_{21}/a_{22} \geq a_{31}/a_{32}$$

in the initial equilibrium and assume the inequalities are strict. Thus, in Ruffin's (1981) terminology, when comparing factor intensities of the two traded sectors, factor 1 is extreme in imports (X_1), factor 2 in exports (X_2), and factor 3 is the middle factor in the traded sector.

If the nominal prices of the three goods are p_1, p_2, and p_3, then the zero-profit conditions for production are

(1) $$a_{11}w_1 + a_{21}w_2 + a_{31}w_3 = p_1,$$

(2) $$a_{12}w_1 + a_{22}w_2 + a_{32}w_3 = p_2,$$

(3) $$a_{13}w_1 + a_{23}w_2 + a_{33}w_3 = p_3.$$

It is assumed that all three goods are produced in positive amounts, so the market prices exactly reflect the costs per unit of output.

Full employment of the stocks of the three factors of production would entail

(4) $$a_{11}X_1 + a_{12}X_2 + a_{13}X_3 = V_1,$$

(5) $$a_{21}X_1 + a_{22}X_2 + a_{23}X_3 = V_2,$$

(6) $$a_{31}X_1 + a_{32}X_2 + a_{33}X_3 = V_3.$$

Were all three goods prices exogenously determined, then equations (1), (2), and (3) would uniquely determine the factor-price vector, and factor prices would be independent of the factor endowments. However, while goods 1 and 2 are considered to be traded internationally at exogenously given world prices, it is assumed that good 3 is nontraded, its price being endogenously determined by domestic demand. In consequence, changes in factor endowments, through immigration, may influence the returns to factors in the economy.

Let domestic demand for good 3 be represented by a Hicksian compensated demand function, that is,

$$C_3 = D[p_1, p_2, p_3; U].$$

Equilibrium in the market for the nontraded good occurs when domestic supply exactly meets domestic demand,

$$X_3 = D[p_1, p_2, p_3; U], \tag{7}$$

and "national' utility is a function of the quantities of goods consumed in the country by native and immigrant factors together:

$$U = U[C_1, C_2, C_3]. \tag{8}$$

National utility is maximized subject both to the balanced trade constraint,[1]

$$p_1 C_1 + p_2 C_2 = p_1 X_1 + p_1 X_2, \tag{9}$$

and to the constraints of technology and endowments,

$$X_3 = g[X_1, X_2; V_1, V_2, V_3]. \tag{10}$$

Equations (1)–(10) provide a complete description of the static general equilibrium of the economy.

10.2 Factor Migration

Consider a change in the domestic supply of a factor of production as a result of migration. This will directly affect production activity through the change in the total factor supplies available for production. It will also affect the (endogenous) price of the nontraded good, with consequent further changes in output and induced changes in factor rewards.

Differentiating equations (1), (2), and (3) reveals the way in which the equilibrium is disturbed by small changes in commodity prices:

$$\theta_{11}\hat{w}_1 + \theta_{21}\hat{w}_2 + \theta_{31}\hat{w}_3 = \hat{p}_1, \tag{1'}$$

$$\theta_{12}\hat{w}_1 + \theta_{22}\hat{w}_2 + \theta_{32}\hat{w}_3 = \hat{p}_2, \tag{2'}$$

$$\theta_{13}\hat{w}_1 + \theta_{23}\hat{w}_2 + \theta_{33}\hat{w}_3 = \hat{p}_3, \tag{3'}$$

where $\theta_{ij} \equiv a_{ij}w_i/p_j$, the distributive share of factor i in industry j, and a "hat" (ˆ) over a variable denotes a relative change (e.g., $\hat{w} \equiv dw/w$). Similarly, by differentiating equations (4), (5), and (6), the response to changes in factor endowments can be determined:

$$(4') \quad \lambda_{11}\hat{X}_1 + \lambda_{12}\hat{X}_1 + \lambda_{13}\hat{X}_3 = \hat{V}_1 - \{\sigma_1^1 \hat{w}_1 + \sigma_1^2 \hat{w}_2 + \sigma_1^3 \hat{w}_3\},$$

$$(5') \quad \lambda_{21}\hat{X}_1 + \lambda_{22}\hat{X}_2 + \lambda_{23}\hat{X}_3 = \hat{V}_2 - \{\sigma_2^1 \hat{w}_1 + \sigma_2^2 \hat{w}_2 + \sigma_2^3 \hat{w}_3\},$$

$$(6') \quad \lambda_{31}\hat{X}_1 + \lambda_{32}\hat{X}_2 + \lambda_{33}\hat{X}_3 = \hat{V}_1 - \{\sigma_3^1 \hat{w}_1 + \sigma_3^2 \hat{w}_2 + \sigma_3^3 \hat{w}_3\},$$

where $\lambda_{ij} \equiv a_{ij}X_j/V_i$, the fraction of the total supply of factor i used in the jth industry, and σ_i^k denotes the economy-wide substitution toward or away from the use of factor i when factor k becomes more expensive, under the assumption that each industry's output is held constant. That is, $\sigma_i^k \equiv \Sigma_j \lambda_{ij} E_{ij}^k$, where E_{ij}^k is the elasticity of demand for factor i with respect to w_k in industry j, holding output and other factor prices constant.

Were commodity prices to remain unchanged after the factor movement (as would occur if all goods were traded at exogenously given world prices), then, from equations (1′), (2′), and (3′), factor earnings would also remain constant, and hence the bracketed terms of equations (4′), (5′), and (6′) would all be zero, as there would be no substitution between factors in production. Output change in response to changes in factor endowments would be influenced only by the relative intensities with which factors are used in each of the three industries. This behavior results from a higher dimensional analogue of the familiar Rybczynski theorem (which was derived for a model with two factors and two goods), and we shall call it a "pure Rybczynski effect."

Good 3 is, however, not traded internationally, and the inflow of factors will induce changes in both the demand for and the supply of that good. Differentiating equation (8), and using equations (9) and (10) to determine the change in utility resulting from factor immigration at constant commodity prices,

$$(11) \qquad dU = \rho \sum_i \left\{ \frac{dI}{dV_i} dV_i \right\},$$

where ρ is the marginal utility of money income, and I is national income:

$$I \equiv \sum_i w_i V_i = \sum_j p_i X_i.$$

Rewriting equation (11) in terms of relative changes yields

$$(11') \qquad \hat{U} = \omega \sum_i \theta^i \hat{V}_i,$$

where $\omega \equiv \rho I/U$, and θ^i is the share of factor i in national income,

$$\theta^i \equiv \frac{w_i V_i}{I}.$$

By the appropriate choice of utility scale, let $\omega \equiv 1$ locally. Then equation (11′) becomes

$$(12) \qquad \hat{U} = \theta^1\hat{V}_1 + \theta^2\hat{V}_2 + \theta^3\hat{V}_3.$$

Differentiating the market-clearing condition, equation (7), to determine the equilibrium responses to disturbances in the market for good 3,

$$(13) \qquad X_3 = \nu_1\hat{p}_1 + \nu_2\hat{p}_2 + \nu_3\hat{p}_3 + \mu\hat{U},$$

where ν_1, ν_2, and ν_3 are the compensated price elasticities of demand for X_3, and μ is the income elasticity of demand for X_3. It will be convenient to rewrite (13), using (12), as

$$(13') \qquad \hat{p}_3 = \beta_1\hat{p}_1 + \beta_2\hat{p}_2 + \beta_3\hat{X}_3 + \phi\{\theta^1\hat{V}_1 + \theta^2\hat{V}_2 + \theta^3\hat{V}_3\},$$

where $\beta_1 \equiv -\nu_1/\nu_3$, $\beta_2 \equiv -\nu_2/\nu_3$, $\beta_3 \equiv 1/\nu_3 < 0$, and (if good 3 is normal) $\phi \equiv -\mu/\nu_3 > 0$.

Rewriting the output-response equations (4′)–(6′) in matrix form,

$$\begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} \end{bmatrix} \begin{bmatrix} \hat{X}_1 \\ \hat{X}_2 \\ \hat{X}_3 \end{bmatrix} = \begin{bmatrix} \hat{V}_1 \\ \hat{V}_2 \\ \hat{V}_3 \end{bmatrix} - \begin{bmatrix} \sigma_1^1 & \sigma_1^2 & \sigma_1^3 \\ \sigma_2^1 & \sigma_2^2 & \sigma_2^3 \\ \sigma_3^1 & \sigma_3^2 & \sigma_3^3 \end{bmatrix} \begin{bmatrix} \hat{w}_1 \\ \hat{w}_2 \\ \hat{w}_3 \end{bmatrix}.$$

Solving this for $\hat{X}_3$,

$$(14) \qquad \hat{X}_3 = \delta_1\hat{V}_1 + \delta_2\hat{V}_2 + \delta_3\hat{V}_3 + \gamma_1\hat{w}_1 + \gamma_2\hat{w}_2 + \gamma_3\hat{w}_3,$$

where

$$(15) \qquad \gamma_k = -\{\delta_1\sigma_1^k + \delta_2\sigma_2^k + \delta_3\sigma_3^k\},$$

for $k = 1, 2, 3$; $\delta_k \equiv |\Lambda_k|/|\Lambda|$, for $k = 1, 2, 3$; $|\Lambda|$ is the determinant of the lambda matrix

$$\Lambda \equiv \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} \end{bmatrix};$$

and

$$|\Lambda_1| \equiv \begin{vmatrix} \lambda_{21} & \lambda_{22} \\ \lambda_{31} & \lambda_{32} \end{vmatrix} < 0, \quad |\Lambda_2| \equiv -\begin{vmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{31} & \lambda_{32} \end{vmatrix} < 0 \quad |\Lambda_3| \equiv \begin{vmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \end{vmatrix} > 0$$

from the definitions of the "extreme" and "middle" factors. Note that the pure Rybczynski effect (i.e., when factor prices are constant) of factor endowment changes on output of good 3 is then

$$(16) \qquad \hat{X}_3 = \sum_i \delta_i\hat{V}_i.$$

Substituting equations (3′) and (14) into (13), and solving, yields

(17) $$A_1\hat{w}_1 + A_2\hat{w}_2 + A_3\hat{w}_3 = \beta_1\hat{p}_1 + \beta_2\hat{p}_2 + Z_1\hat{V}_1 + Z_2\hat{V}_2 + Z_3\hat{V}_3,$$

where

(18) $$A_i \equiv (\theta_{i3} - \beta_3\gamma_i),$$

for $i = 1, 2, 3$; and

(19) $$Z_i \equiv \beta_3(\delta_i - \mu\theta^i),$$

for $i = 1, 2, 3$. The comparative statics of factor rewards in this economy are now completely determined by equations (1′), (2′), and (17):

(20) $$\begin{bmatrix} \theta_{11} & \theta_{21} & \theta_{31} \\ \theta_{12} & \theta_{22} & \theta_{32} \\ A_1 & A_2 & A_3 \end{bmatrix} \begin{bmatrix} \hat{w}_1 \\ \hat{w}_2 \\ \hat{w}_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ \beta_1 & \beta_2 \end{bmatrix} \begin{bmatrix} \hat{p}_1 \\ \hat{p}_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \sum_i Z_i\hat{V}_i \end{bmatrix},$$

which is easily solved for $\hat{w}_1$, $\hat{w}_2$, and $\hat{w}_3$.

Since, in this paper, we focus on the effects of factor endowments on factor prices, we henceforth set $\hat{p} = \hat{p} = 0$ and solve (20) for $\hat{w}_k$ in terms of $\hat{V}_i$, for $i, k = 1, 2, 3$. The induced change in factor rewards when factor endowments change is then given by

(21) $$\hat{w}_k = \frac{|\Theta_k|}{\Delta} \sum_i Z_i\hat{V}_i,$$

for $i, k = 1, 2, 3$,

$$\Delta \equiv \begin{vmatrix} \theta_{11} & \theta_{21} & \theta_{31} \\ \theta_{12} & \theta_{22} & \theta_{32} \\ A_1 & A_2 & A_3 \end{vmatrix}, \quad |\Theta_1| \equiv \begin{vmatrix} \theta_{21} & \theta_{31} \\ \theta_{22} & \theta_{32} \end{vmatrix} < 0,$$

$$|\Theta_2| \equiv - \begin{vmatrix} \theta_{11} & \theta_{31} \\ \theta_{12} & \theta_{32} \end{vmatrix} < 0, \quad |\Theta_3| \equiv \begin{vmatrix} \theta_{11} & \theta_{21} \\ \theta_{12} & \theta_{22} \end{vmatrix} > 0.$$

The properties of equation (21) are analyzed in the following section.

10.3 Consequences for Factor Rewards

The consequences of (21) for the effects of factor endowment changes on both nominal factor prices and the welfare of factor owners are analyzed in turn below. We begin with properties of price changes that are independent of a certain "normality" condition and then consider the additional restrictions imposed by that condition. Finally, welfare effects are considered.

10.3.1 General Results

To develop an intuition for the effects of endowment changes on factor rewards, consider the effect of a change in the endowment of factor i on the rewards paid to factor k in equation (21). The Z_i term gives the effect of immigration ($\hat{V}_i > 0$) or emigration ($\hat{V}_i < 0$) on the price of the nontraded good X_3. Recalling equation (19),

$$Z_i \equiv \beta_3(\delta_i - \mu\theta^i). \tag{19}$$

The first term in the parentheses is the supply effect of the change in output of good X_3 resulting from the immigration of factor i, that is, the pure Rybczynski effect of equation (16). The second term is a demand effect, reflecting the increased demand for good X_3 resulting from a higher level of national income created by the increase in the economy's endowment. We call the difference between the terms the "modified Rybczynski effect." Should this be positive, then an excess supply of the nontraded good has been induced by the migration, triggering a fall in its price, p_3 (because $\beta_3 < 0$), and vice versa.

The other component of the effect of $\hat{V}_i$ on w_k in (21) is the ratio of the two determinants. Changes in commodity prices in the traditional two-factor, two-good trade model induce changes in factor prices according to the Stolper-Samuelson Theorem. Were all three commodities in our model traded internationally, then the response of factor prices to a change in p_3 would be a higher dimensional analogue to these familiar magnification effects. We shall call it the "pure Stolper-Samuelson effect." The magnitude of this response can be measured by solving equations (1′)–(3′) (letting $\hat{p}_1 = \hat{p}_2 = 0$), yielding

$$\hat{w}_k = \frac{|\Theta_k|}{|\Theta|}\hat{p}_3, \tag{22}$$

for $k = 1, 2, 3$, where $|\Theta|$ is the determinant of the theta matrix,

$$\Theta = \begin{bmatrix} \theta_{11} & \theta_{21} & \theta_{31} \\ \theta_{12} & \theta_{22} & \theta_{32} \\ \theta_{13} & \theta_{23} & \theta_{33} \end{bmatrix}.$$

Good 3 is not traded, however, and faces a less than infinitely elastic demand. As a result, changes in factor earnings have repercussions on the amount of X_3 supplied, through within-sector substitution among factors, and this will induce a further change in the commodity price. This effect is captured by the $\beta_3\gamma_i$ terms that modify the denominator from $|\Theta|$, in the pure Stolper-Samuelson effect of equation (22), to Δ in equation (21). We therefore call the ratio of determinants in (22) a "modified Stolper-Samuelson effect" of p_3 on w_k. It can be shown, for any negative semidefinite economy-wide substitution matrix, that

$$\text{sign}(\Delta) = \text{sign}(|\Theta|), \tag{23}$$

and so the modified Stolper-Samuelson effect will be *qualitatively* identical to the pure Stolper-Samuelson effect.[2]

The entire effect of a change in the endowment of factor i on the earnings of factor k is thus simply the product of the modified Rybczynski effect of V_i on p_3 and the modified Stolper-Samuelson effect of p_3 on w_k. This interpretation and decomposition of (21) emphasizes a major feature of the model that is independent of any assumptions regarding the structure of demand and factor-intensity rankings and is true for changes in the rewards to all factors. The only way that factor endowment changes can affect factor prices is through inducing changes in price of the nontraded good, p_3; that is, factor prices cannot change unless p_3 changes. Otherwise, were p_3 fixed, because either the good was traded internationally or domestic demand was infinitely elastic ($\beta_3 = 0$), then factor prices would be uniquely determined by equations (1)–(3), independently of the endowment.[3]

10.3.2 The Normality Condition

Consider more closely the excess supply of X_3 induced by immigration of factor i ($\delta_i - \mu\theta^i$). The level of national income will always rise with factor inflows, and, if this is compounded by a negative Rybczynski effect ($\delta_i < 0$) lowering the supply of X_3, then there will undoubtedly be excess demand for the nontraded good, inducing an increase in its price. However, suppose immigration of factor V_i induces an expansion of X_3 production because $\delta_i > 0$. The change in factor endowment has then raised both the demand for and the supply of the nontradable. Thus, the potential exists for what we shall call a "perverse demand" result that, with a sufficiently high national income elasticity of demand for the nontraded good, an increase in the output of good 3 induced by a change in endowment will be accompanied by an increase in its price.[4]

In this subsection, we develop a pair of sufficient conditions, together called the "normality condition," that rule this out. One of these is a fairly weak restriction on the structure of demand, while the other is a constraint on supply effects that, as we shall see, is clearly satisfied by our empirical evidence on factor intensities. Together they ensure that

(24) $$\text{sign}(\delta_i - \mu\theta^i) = \text{sign}(\delta_i);$$

thus, the modified Rybczynski effect, like the Stolper-Samuelson effect, is qualitatively the same as the "pure" effect.

First, rewrite the expression for δ_i in equation (16) in terms of distributive shares:

(25) $$\delta_i = \frac{\theta^i|\Theta_i|}{\theta_3|\Theta|},$$

where $\theta_j \equiv p_jX_j/I$, the share of good j in national expenditure. From our numbering of factors in terms of relative intensity of their use in the traded sector, we know that

(26) $$\text{sign}(\hat{w}_1) = \text{sign}(\hat{w}_2) = -\text{sign}(\hat{w}_3).$$

Thus, immigration of either of the two "extreme" factors will have opposite effects to immigration of the "middle" factor on the production of the nontraded good.

Furthermore, it is helpful to note that

$$\text{sign}(\delta_3) = \text{sign}|\Theta|, \tag{27}$$

since $|\theta_3| > 0$. A sufficient condition for $\delta_3 > 0$ is then that

$$\frac{\theta_{32}}{\theta_{33}} < \frac{\theta_{12}}{\theta_{13}}, \frac{\theta_{22}}{\theta_{23}} \text{ or } \frac{\theta_{31}}{\theta_{33}} < \frac{\theta_{11}}{\theta_{13}}, \frac{\theta_{21}}{\theta_{23}}.$$

In other words, an increase in the supply of the middle factor in the traded sector (V_3) raises the supply of the nontraded good if, relative to *either* one of the traded goods, nontraded goods are extremely intensive in V_3. Conversely, if nontraded goods are extremely unintensive in V_3 relative to either X_1 or X_2, the supply of X_3 will fall when V_3 rises. Thus, through (27) and (26), the signs of all the Rybczynski effects hinge on whether the nontraded sector uses the middle "traded" factor intensively or unintensively.

Now assume that the two traded goods, X_1 and X_2, are not, as a bundle, inferior in demand, in the sense that the total expenditure on the two goods ($p_1X_1 + p_2X_2$) does not decline when national income increases, at constant prices. Differentiating the national income identity yields

$$\hat{I} = \theta_1\hat{X}_1 + \theta_2\hat{X}_2 + \theta_3\hat{X}_3.$$

X_1 and X_2 then are not inferior as a bundle if and only if

$$\hat{I} - \theta_3\hat{X}_3 > 0.$$

Noting that $\mu \equiv \hat{X}_3/\hat{I}$, this may be rewritten as

$$1 > \mu\theta_3.$$

Multiplying by θ^i and rewriting yields

$$\frac{\theta^i}{\theta_3} > \mu\theta^i. \tag{28}$$

Thus, the noninferiority of goods 1 and 2 ensures that the demand term modifying the Rybczynski effect is less than the wage bill of the immigrant factor relative to the value of output of X_3. We can therefore rule out the perverse demand result if, when $\delta_i > 0$, $\delta_i > \theta^i/\theta_3$. Using equation (25), this may be rewritten to state:

$$\text{sign}\,\frac{|\Theta_i|}{|\Theta|} = \text{sign}\left\{\frac{|\Theta_i|}{|\Theta|} - 1\right\}. \tag{29}$$

Suppose that factor 3 has a positive Rybczynski effect, that is, $\delta_3 > 0$. As noted earlier, this means that $|\Theta|$ is positive. As both $|\Theta_1|$ and $|\Theta_2|$ are negative, we are assured that $|\Theta_3|$ exceeds $|\Theta|$, and, hence, the perverse demand result cannot occur if goods 1 and 2 are noninferior.

If, instead, immigration of factor 3 directly reduces the production of the nontraded good, that is, $\delta_3 < 0$, then the potential for a perverse demand result arises with immigration of either factor 1 or factor 2. Now, as $|\Theta| < 0$ and only $|\Theta_3| > 0$, it is not possible to rule out $|\Theta_j|/|\Theta| < 1$ for $j = 1$ or 2 without recourse to the data.[5] Our normality condition therefore in general requires *both* $\mu\theta_3 < 1$, which ensures a small enough effect of V_i on the demand for good 3, and $|\Theta_j|/|\Theta| > 1$ for $|\Theta| < 0$ and $j = 1$ or 2, which ensures a large enough supply effect in the cases where the nontraded sector is extremely unintensive in the middle "traded" factor. The latter condition is clearly satisfied by the data on factor intensities that we consider below.

10.3.3 Effects of Factor Endowments on Factor Prices under the Normality Condition

Under the normality condition, modified Rybczynski effects are qualitatively the same as the pure effects, as is also true for modified Stolper-Samuelson effects. Furthermore, it is straightforward to show that the Rybczynski effect of V_i on X_3 is always the same sign as the Stolper-Samuelson effect of p_3 on w_i. This can be seen by manipulating (25) and substituting into (23), yielding

$$\text{sign}(\delta_i) = \text{sign}\left[\frac{|\Theta_i|}{\Delta}\right]. \tag{30}$$

Substituting (24) and (30) into (21), and noting that $\beta_3 < 0$, we have

$$\text{sign}(\hat{w}_k) = \text{sign}(-\delta_k\delta_i\hat{V}_i), \tag{31}$$

for $i, k = 1, 2, 3$. Irrespective of whether $|\Theta| \gtreqless 0$, it is clear from (31) that any factor is its own "enemy," in that immigration of a factor will always lower its own nominal wage, while emigration raises its earnings. Further, as w_1 and w_2 have the same sign, the extreme factors, 1 and 2, will be mutual enemies while being friends with the middle factor, 3. The qualitative effects of factor quantities on factor prices thus depend only on which factors are extreme in the traded sector of the economy, not on the relative factor intensities of the traded versus nontraded sector. The reason is that, whenever a factor supply shift raises the price of nontraded goods (by lowering supply), higher nontraded goods prices lower the equilibrium price of that factor, and conversely.

10.3.4 Welfare Effects

The effect of the above nominal changes in returns on the welfare of a factor depends on the induced changes in p_3 (p_1 and p_2 being fixed, by assumption). Assessment of welfare effects is, however, made easy if we note that, by substituting (22) into (21),

(32) $$\hat{p}_3 = \beta_3 \frac{|\Theta|}{\Delta} (\delta_i - \mu\theta^i)\hat{V}_i.$$

Since the ratio of determinants is always positive, the general equilibrium effects of V_i on p_3 are always the same sign as when factor prices are held fixed. In more detail, immigration of factor V_i whose $\delta_i > 0$ will result in a fall in p_3, raising the real income of those factors whose nominal earnings have increased. The other factors are faced with both reduced nominal earnings and lower prices, with apparently ambiguous consequences for their welfare. However, consider the relative change in the ratio of earnings of factor k to the price of good 3,

(33) $$\left[\frac{\hat{w}_k}{p_3}\right] = w - \hat{p}_3.$$

Substitute equations (21) and (32) into this expression and rearrange to find

(34) $$\left[\frac{\hat{w}_k}{p_3}\right] = \hat{p}_3 \left\{\frac{|\Theta_k|}{|\Theta|} - 1\right\}.$$

Using (29), (31), and (32), equation (34) implies that sign $[\hat{w}_k/p_3]$ = sign $\hat{w}_k$. Thus, under the normality condition, changes in nominal earnings will outweigh changes in the price of the nontraded good, ensuring that changes in welfare will have the same signs as the changes in factors' nominal returns.

Table 10.1 gives a complete listing of the predicted responses of variables to changes in migration.

10.4 Empirical Estimates of Factor Intensities

Our estimates of U.S. factor intensities are based on an analysis of 430 four-digit manufacturing industries during the period 1960–84. These indus-

Table 10.1 Predicted Effects of Factor Endowment Changes under the "Normality" Condition

	Endowment Change		
	$\hat{V}_1 > 0$	$\hat{V}_2 > 0$	$\hat{V}_3 > 0$
Effect on:			
$\hat{w}_1$	−	−	+
$\hat{w}_2$	−	−	+
$\hat{w}_3$	+	+	−
Welfare of:			
V_1	−	−	+
V_2	−	−	+
V_3	+	+	−

tries constitute all the industries in the NBER Data Set on Trade, Immigration, and Foreign Direct Investments (450 in all) with data on both exports and imports.[6] This data set has the advantages of being at a finer level of aggregation than most existing empirical studies of factor intensities and trade and of being available for a long series of years, as recently as 1984.[7] It has the disadvantage of being limited to manufacturing industries only. Thus, we view our results here as (*a*) likely to be quite accurate for the manufacturing sector relative to other studies but (*b*) relevant to the whole economy only to the extent that the pattern we identify in manufacturing generalizes to other industries.

Our basic procedure begins by allocating the total value added in each four-digit industry into payments to one of the three factors in the model. Total income of "unskilled" workers was defined as the industry's total production-worker payroll for the year. Income of "skilled" workers is the difference between this and the industry's total payroll.[8] Finally, subtracting total payroll from total value added yielded the payments to "capital" in the industry. Thus, in keeping with our model's assumptions, we ignore indirect factor inputs and assume no intermediate inputs in production.[9]

Next, the 430 four-digit industries were aggregated into three as follows. First, nontraded goods were defined as those industries whose level of "openness" to international trade, measured by the sum of exports plus imports divided by total industry output, was under k%, where k took on alternative values of 0, 5, 10, and 20. Then the remaining, traded goods were divided into import-competing goods and exports, depending on whether the net imports of the industry (imports less exports) were positive or negative, respectively. This yielded 3 × 3 table of factor incomes, from which it was then straightforward to calculate the matrix of factor intensities, Θ.

Table 10.2 shows the factor intensities calculated in this manner for the year 1984 and with $k = 10\%$. This criterion yielded a nontraded sector producing $351 billion of value added, which is 36.6% of the total value added of $959

Table 10.2 **Estimated Factor Intensities for U.S. Manufacturing, 1984**

	V_1, Unskilled Labor	V_2, Skilled Labor	V_3, Capital
1. "Absolute" factor intensities (θ_{ij}):			
a. X_1 (import competing)	.2615	.1504	.5881
b. X_2 (exporting)	.2092	.1858	.6051
c. X_3 (nontraded)	.2205	.1408	.6387
2. Relative factor intensities (θ_{ij}/θ_{ik}):			
a. θ_{i1}/θ_{i2} (imports vs. exports)	1.2502	.8096	.9719
b. θ_{i1}/θ_{i3} (imports vs. nontradeds)	1.1861	1.0681	.9208
c. θ_{i2}/θ_{i3} (exports vs. nontradeds)	.9487	1.3192	.9473

Sources: NBER Data Set on Trade, Immigration, and Foreign Direct Capital Investments.
Note: Nontraded sector is defined as industries with (exports + imports)/output under 10%. Determinant of θ equals .0019528.

billion in the sample. Import-competing and exporting industries, respectively, produced \$361 billion (37.6%) and \$247 billion (25.7%) of value added. A list of industries producing more than \$10 billion of value added, by trade category, is given in table 10.3.

Row 2a of table 10.2 clearly indicates that, within the traded sector, unskilled labor is extremely intensive in imports and skilled labor is extreme in exports, with capital as the middle factor. This accords well with the widely held notion that the United States is well endowed with skilled labor and poorly endowed with unskilled labor, relative to the rest of the world (e.g., Baldwin 1971).[10] The list of industries in table 10.3 supports this notion, with what are commonly considered "low-technology" industries such as paper and steel appearing only in the import category and "high-technology" industries like computers dominating in exports.

Finally, row 2b of table 10.2 indicates that the middle "traded" factor, V_3, is used extremely intensively in the nontraded sector relative to imports. Thus, in a well-defined sense, the nontraded sector is intensive in capital and unintensive in both types of labor, relative to the traded sector. By previous results, this means that $|\Theta| > 0$ and that the "perverse demand" result cannot occur as long as X_1 and X_2 are normal goods (either individually or as a bundle). Thus, in combination with the results in table 10.2, *our model predicts that immigration of either type of labor will, in the long run, hurt do-*

Table 10.3 Four-Digit Industries with over \$10 Billion of Value Added, by Trade Category, 1984

1. Exports:	
2869	Industrial organic chemicals, n.e.c.
3573	Electronic computing equipment
3721	Aircraft
2. Imports:	
2621	Paper mills
2911	Petroleum refining
3312	Blast furnaces
3662	Radio and TV transmitting, signaling and detection equipment
3674	Semiconductors and related devices
3679	Electronic components, n.e.c.
3711	Motor vehicles and passenger car bodies
3714	Motor vehicle parts and accessories
3861	Photographic equipment and supplies
3. Nontraded goods:	
2711	Newspapers, publishing
2752	Commercial printing, lithographic
2834	Pharmaceutical products
3079	Miscellaneous plastics products
3761	Guided missiles and space vehicles

Note: Nontraded goods defined as (exports + imports)/output < 10%. N.e.c. means "not elsewhere classified."

mestic owners of both types of labor. The reason is that immigration raises the price of nontraded goods, which in turn benefits owners of capital. This higher return to capital must be compensated for by a reduction in wages of both types of workers if U.S. exports and import-competing industries are to remain internationally competitive.

How robust are these conclusions to changes in the definition of traded versus nontraded sectors and to changes in factor intensities over time in the U.S. economy? This question is explored in table 10.4, which summarizes our estimates of factor intensities for various levels of k and for other years. What is most striking about this table is that, for every year but 1960 and for every level of k, the factor intensity rankings in the traded sector are the same as in table 10.2. Also, $|\Theta|$ is the same sign, indicating that the relative factor intensities of the traded versus nontraded sectors are unchanged and that normality of X_1 and X_2 in demand continues to be sufficient to rule out perverse factor-demand results. Only in 1960 are the results mixed; we feel that this is connected with changes in the U.S. economy over time that produced "Leontief paradox"–type results in earlier years but no longer do so, as the United States specializes more and more in knowledge-intensive industries. We conclude that our estimates of direct relative factor intensities (and the resulting predictions about the effects of immigration) reliably summarize a broad underlying pattern that has persisted in manufacturing since 1970 or even somewhat earlier.

Table 10.4 **Factor-Intensity Rankings for Various Definitions of the Nontraded Sector, 1960, 1970, 1980, and 1984**

	Maximum Level of (Exports + Imports)/ Output in the Nontraded Sector			
	.0	.05	.10	.20
1960:				
Extreme factors in imports and exports, respectively (within traded sector)	U, S	K, S	U, S	K, S
Sign $\mid\theta\mid$	NA	−	+	+
1970:				
Extreme factors in imports and exports, respectively (within traded sector)	U, S	U, S	U, S	U, S
Sign $\mid\theta\mid$	NA	+	+	+
1980:				
Extreme factors in imports and exports, respectively (within traded sector)	U, S	U, S	U, S	U, S
Sign $\mid\theta\mid$	NA	+	+	+
1984:				
Extreme factors in imports and exports, respectively (within traded sector)	U, S	U, S	U, S	U, S
Sign $\mid\theta\mid$	NA	+	+	+

Note: K = capital, S = "skilled" (nonproduction) labor, and U = "unskilled" (production) labor.

How robust are our estimates to the inclusion of nonmanufacturing industries in the analysis? This question cannot be answered with the NBER data but is explored using two-digit industry data from another source in the Appendix. Interestingly, this analysis indicates that the basic results *do* generalize. The basic reason for this is that services (which constitute the bulk of the excluded, nonmanufacturing industries), contrary to widespread beliefs, are not always nontraded and not always labor intensive. For example, real estate (a very important nontraded service) is highly capital intensive, while education (which is very intensive in skilled labor) is a substantial U.S. net export. Still, owing to the considerable practical and conceptual problems involved in estimating service trade (see the data sources listed in the Appendix), we view this finding with considerable caution. Clearly, there is an outstanding need for careful empirical analysis based on better-quality trade data for service industries. The consistency of our results across definitions of sectors and years is, however, suggestive and proves a useful illustration of the ease with which our theoretical model can be implemented.

10.5 Conclusion

This paper has developed a simple, general equilibrium model of how factor endowments affect factor prices when a subset of the goods produced in the economy is traded at internationally fixed prices. The result is a model that makes unambiguous predictions that are independent of estimated elasticities of substitution among factors in production.

Our empirical analysis, based on 430 four-digit manufacturing industries in the years 1960, 1970, 1980, and 1984, indicated that, at least since 1970, factor intensities in U.S. manufacturing follow a very consistent pattern: skilled labor is used extremely intensively in exports, while unskilled labor is extremely intensive in import-competing industries. Furthermore, the middle factor in the traded sector, capital, is used intensively in the nontraded sector relative to the traded sector. Thus, to the extent that the relative factor intensities we find in manufacturing generalize to the whole economy, our model predicts the following. Increased immigration of either skilled or unskilled workers to the United States will, in the long run, hurt U.S. workers of both types and benefit owners of capital. These effects should be associated with an increase in nontraded goods prices, which, by reducing the international competitiveness of the country's traded goods, causes the reduction in wages. They are also independent of the technical substitution elasticities in production that so many analysts have attempted to estimate (for a recent summary, see Hamermesh and Grant 1979).

Our model can, of course, be extended and improved on in various ways. These include incorporating intermediate inputs (as is done in empirical work by Baldwin 1971; and Stern and Maskus 1981), allowing for capital mobility (as in Gerking and Mutti 1983), considering shorter run effects (as in Rivera-

Batiz 1987), relaxing the extreme assumption that U.S. consumption and production have no effect on the prices of traded goods, and considering nonbalanced trade. In addition, better data, which consider nonmanufacturing industries as well, may also be available in the relatively near future as more trade statistics on services are collected. All these extensions could, of course, change our specific predictions about the directions of factor price changes here, which we view as suggestive but tentative. It is clear that they will not, however, change what we view as the fundamental lesson of this paper. This lesson is that the effects of immigration in a partially open economy may be determined by a fundamentally different set of factors than in a closed economy, where technical substitutability between factors in production plays the key role. In the partially open economy, factor prices are constrained to change in a way that preserves the international competitiveness of its traded goods, as long as those goods continue to be produced. This places tight restrictions on the kinds of factor-price changes that can occur. These restrictions deserve, we feel, greater prominence in the work of empirical and policy-oriented researchers studying the effects of immigration to the United States.

Appendix

Factor Intensity Estimates for the Entire U.S. Economy from Two-Digit Industry Data, 1983

This appendix explores the generalizability of our results based on manufacturing only to the entire U.S. economy by constructing a factor-intensity matrix for the entire U.S. economy from two-digit data for 1983. These data were obtained from the following sources: total value added and compensation of employees from the *Survey of Current Business* (66 [July 1986]: 1986, table 6); merchandise trade data from the 1985 *Statistical Abstract of the United States* (tables 1448, 1449); and rough estimates of service trade from the Office of Technology Assessment (1986, table 2, using midpoints of intervals). Thus, some services are classified as exports (e.g., education), others as imports (e.g., insurance), and still others as nontraded (e.g., retailing). Skilled workers were defined as those who completed high school; the percentage of the work force that was skilled was then taken from a 1980 Census tabulation of occupation by industry (U.S. Department of Commerce series PC-80-2-70, pp. 1–80) and their relative wage rates in 1983 from U.S. Department of Commerce series *Money Income of Husbands, Families and Persons in the United States* (P-10, no. 146, table 48). Payments to land as an input are included by definition with capital, which functions as a kind of "residual" factor here. Because of the small number of industries, we chose criteria of openness to trade and a critical balance-of-trade level that yielded nontraded, exporting, and importing sectors of roughly equal sizes (this meant that some industries with low trade deficits were classed as exports).

This procedure yielded the following factor-intensity matrix, Θ:

$$\begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \end{array} \begin{array}{c} \begin{array}{ccc} V_1 & V_2 & V_3 \end{array} \\ \begin{bmatrix} .15 & .47 & .38 \\ .12 & .51 & .37 \\ .08 & .50 & .41 \end{bmatrix} \end{array},$$

where the three factors are, respectively, unskilled labor, skilled labor, and capital, as in table 10.2. Noting that, as in table 10.2, the nontraded sector is again relatively intensive in capital, we conclude that the factor-intensity rankings we find in manufacturing may well generalize completely to the entire U.S. economy when better data on service trade are available.

Notes

1. Since this is an undistorted economy, we know that it maximizes a weighted sum of the utilities of its members subject to the balanced trade and resource constraints. Under certain conditions (see, e.g., Gorman 1953), this is equivalent to maximizing a community utility function of the type used here. We assume that such conditions are satisfied here, which does *not* necessarily imply that all agents (including immigrants) are equally endowed. This latter condition would of course make the analysis of immigration much less interesting.

2. To see this, note that the denominator can be written as

$$\Delta = |\Theta| + \beta_3 \begin{vmatrix} \theta_{11} & \theta_{21} & \theta_{31} \\ \theta_{12} & \theta_{22} & \theta_{32} \\ -\gamma_1 & -\gamma_2 & -\gamma_3 \end{vmatrix}.$$

Through algebraic manipulation, the second term can be reduced to $[\beta_3/(\theta_3|\Theta|)]\ u'Tu$, where T is a negative semidefinite matrix derived from the economy-wide substitution matrix (see Jones and Scheinkman 1977), and u is a column vector. The product $u'Tu$ is nonpositive, while β_3 is negative, and Θ_3 is positive. By simple manipulation it follows that $|\Theta|/\Delta$ is always positive.

3. It is assumed that endowment changes do not move the economy out of the "cone of diversification."

4. The national income elasticity of demand equals the national utility elasticity of demand since, locally, units of income and utility are equivalent. Also, it is easily shown that, in the "perverse demand" case, the demand curve for factor V_i in general equilibrium is upward sloping. While this might be a fortunate situation for owners of V_i, it appears quite unlikely given the fairly weak sufficient conditions needed to rule it out.

5. In the standard 2 × 2 model of international trade, the Rybczynski effect of the immigration of one factor resulted in the output of one industry increasing while production in the other industry diminished. Thus, the value of output of the expanding

industry had to increase by a greater amount than national income. If both of the goods were normal, then the increase in the value of production for the expanding industry would then necessarily be greater than the increase in the value demanded of the good, ensuring a nonperverse demand result. Our results show that, when there are three goods and three factors, nonperversity is not guaranteed. To see this, suppose that immigration of both factors 1 and 2 increases output of X_3, through the Rybczynski effect. Even with factor intensities unchanged (as product prices are constant), this need not result in a fall in the output of both of the traded goods. Indeed, the increase in the value of production of X_3 might be quite small relative to the increase in national income when output of one of the traded goods also increases. Thus, the potential does exist that the expansion in output of good 3 may be less than the increase in its demand, even when goods 1 and 2 are jointly noninferior in consumption.

6. The factor income information in the NBER data set was taken from the *Annual Survey of Manufactures* for various years. This could be matched with trade figures from the Trading Monitoring System of the Bureau of Labor Statistics for 430 of the 450 four-digit industries. The data were collected and made available to us by John Abowd and Richard Freeman.

7. See table 4.2 in Deardorff (1984). The finest level of detail used in the studies cited there is in Stern and Maskus (1981), who use 128 three-digit industries. Our sample of 430 four-digit industries contrasts very favorably with all three studies.

8. An alternative, and perhaps preferable, definition of skilled vs. unskilled workers might be based on total years of education. Unfortunately, information on years of education by industry is not available in this data set. Our experiments using high school completion rates with two-digit data, reported in the Appendix, lead us to expect that this would not change the results.

9. Ideally, our theoretical model should incorporate (both traded and nontraded) intermediate inputs and specify how these should fit into the empirical analysis. Since it appears that this extension of our model would significantly complicate our analysis, it is not undertaken here. We feel that it is, however, an important area for further research on this topic.

10. This notion has often been advanced as a possible explanation of the "Leontief paradox" of capital-intensive U.S. imports (Leontief 1953). Interestingly, this paradox does not arise in table 10.2 here (the combined labor shares in imports exceed those in exports, and the capital share is greater in exports than imports). Three possible reasons for this are the fact that we use four-digit, not two-digit, data, the fact that our focus on manufacturing excludes natural resource industries, and the later time period. Of these, the "time" explanation seems to be most convincing, for the following reason: for the four different values of k considered in the experiments of table 10.3, the capital share in exports exceeded the capital share in imports three out of four times in 1984, four times in 1980, twice in 1970, and zero times in 1960. This seems fairly strong evidence of an increasing *relative* capital intensity of U.S. exports over time.

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