Sources of International Comparative Advantage
Theory and Evidence

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General Notation

A	$m \times n$ matrix of factor input requirements with elements A_{ij}
B	$n \times n$ matrix of intermediate input requirements
C	$n \times 1$ vector of consumption of final goods
F	production function
f	output per worker
f'	first derivative of f
K	capital
L	labor
M	land
k	K/L
p	$n \times 1$ vector of commodity prices
Q	$n \times 1$ vector of production levels
s	consumption share
T	$n \times 1$ vector of net exports
X	$n \times 1$ vector of final outputs
Y	gross national product
V	$m \times 1$ vector of factor endowments
w	$m \times 1$ vector of factor prices

Subscripts

i	factor; $i = 1, \ldots, m$
j	commodity; $j = 1, \ldots, n$
c	country; $c = 1, \ldots, p$
w	world

1 Theories of International Trade

This chapter offers a review of the standard Heckscher-Ohlin model of international trade that forms a basis for later empirical analysis of the sources of comparative advantage. The two fundamental hypotheses of this model are (1) there are factors of production that are immobile between countries, and (2) these factors are used in different combinations to produce different goods. A country will then possess a comparative advantage in good X if the country is relatively well endowed with factors that are used intensively in the production of X. Although a long list of restrictive assumptions is necessary to make this proposition a precisely defined mathematical truth, it nonetheless is hard to imagine a model in which the possession of immobile factors of production is not a source of comparative advantage. Moreover, with a broad definition of factors it becomes evident that the proposition that endowments are the source of comparative advantage is tautological. For example, the technological differences in the Ricardian model can be thought to arise from differing endowments of knowledge capital.

The way in which endowments confer comparative advantage is not tautological, however. In the simple traditional model with assumptions including constant returns to scale and equal numbers of factors and goods, trade is a linear function of the endowments. If the list of assumptions is altered, the relation between trade and endowments becomes nonlinear in ways that depend on the assumption that is altered. A linear relation between net exports and factor endowments serves as the working hypothesis for the empirical work subsequently presented. This choice is dictated by reasons of convenience and conceptual clarity, since, among the many convenient functional forms that could be used in the data analysis, only the linear form can be derived formally from a fully described general equilibrium model. An important purpose of this chapter is to alert the reader that there is a myriad of assumptions that could be made—and to discuss the kind of nonlinearities that might consequently be expected in the data set. Though overall the impression that is likely to be created is that the linear model is very fragile, it will be shown that linearity is preserved if there are nontraded goods, if there are more goods than factors, if consumption shares are income dependent, and even if there are certain kinds of transportation costs and tariff charges.

The traditional assumptions underlying the 2×2 textbook trade model are listed in section 1.1; the resulting theorems are derived in section 1.2; and the effects of departures from the assumptions are discussed

in section 1.3. This chapter is meant to be a fairly complete statement of international trade theory as it relates to the determinants of the composition of trade and provided it seems useful in studying empirical data. Hypotheticals, such as "autarky prices," that have no observable counterparts are excluded from discussion, as are models that do not produce adequately clear descriptions of the relation between the composition of trade and its observable determinants.[1] The discussion in this chapter is detailed when a specific relation between trade and factors endowments can be derived, but the discussion is brief when the theory can provide only an impression. The subsequent empirical work rests primarily on the simplest model and its extension to high dimensions. It is therefore sufficient to read sections 1.1 and 1.2 and the part of section 1.3 dealing with dimensionality.

1.1 Assumptions

There are six classes of assumptions that are used to produce trade theory's sharpest results.

1. *Dimensionality*. The number of goods n and the number of productive factors m are equal to 2: $n = m = 2$.

2. *Mobility*. (a) Factors of production move costlessly between industries within a country, but are completely immobile between countries. (b) Commodities move internationally at zero cost of transport and there are no other impediments to trade.

3. *Competition*. Both commodity and factor markets clear competitively, in the sense that all agents act as if they could buy or sell unlimited quantities at the prevailing market prices.

4. *Technology*. The same technological knowledge about the production of goods is costlessly available to all countries. The production functions exhibit constant returns to scale and diminishing marginal products.

5. *Factor Endowment Similarity*. The variability of factor endowment ratios among countries is less than the variability of factor input intensities across industries. (A precise definition of "less variability" is given below.)

6. *Demand Similarity*. Individuals consume as if each were maximizing an identical homothetic utility function.

1.2 The Basic Trade Theorems

The core of general equilibrium trade theory consists of four theorems that describe the responsiveness of outputs and factor prices to changes in output prices and factor supplies and a fifth that identifies which commodities are exported and which are imported. The factor price equalization theorem deals with the responsiveness of factor prices to factor supplies, holding fixed output prices. The Stolper-Samuelson theorem describes the relation between factor prices and output prices, holding fixed factor supplies. The Rybczynski theorem links outputs to factor supplies, given output prices. And the Samuelson reciprocity relations describe the correspondence between the Stolper-Samuelson effects and the Rybczynski effects. The fifth theorem, the Heckscher-Ohlin theorem, identifies the structure of trade as a function of either (a) the difference between autarky (pretrade) prices and posttrade prices or (b) factor supplies. Since autarky prices are generally unobservable, this book will make use of only the quantity version of the Heckscher-Ohlin theorem.[2]

THE FACTOR PRICE EQUALIZATION THEOREM All countries have identical factor prices.

Proof Let the goods be labeled X_1 and X_2 and let the factors be labor (L) and capital (K). A *unit-value isoquant* for commodity X_1 is depicted in figure 1.1. This is the set of combinations of capital and labor minimally

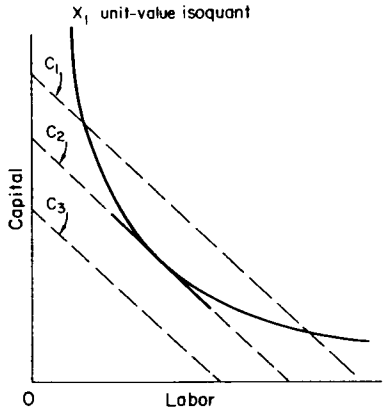

Figure 1.1
Unit-value isoquant and isocost lines.

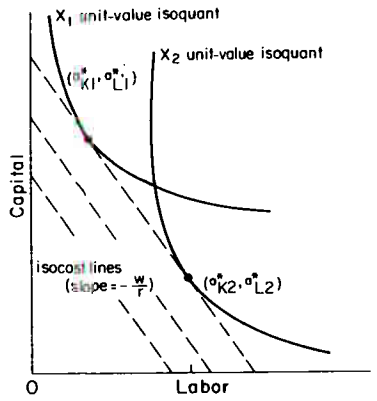

Figure 1.2
Equilibrium factor costs.

required to produce a unit value of output. Because commodity prices are assumed equalized by trade and because technologies are assumed identical, all countries have the same unit-value isoquant. The three straight lines labeled C_1, C_2, and C_3 in figure 1.1 are three hypothetical unit *isocost lines* defined as combinations of capital and labor that cost a unit value. A unit isocost line is defined algebraically as $1 = w_K K + w_L L$, where w_K and w_L are the rental rates for capital and labor services, respectively. Each isocost line has slope equal to $-w_L/w_K$, and from the fact that the three isocost lines in figure 1.1 are parallel we may infer that the ratio of w_L to w_K is the same in each case. Of these three unit isocost lines, only line C_2, which is tangent to the unit-value isoquant, is consistent with competitive equilibrium. If line C_1 were the unit-cost line, producers could hire a unit value of inputs and produce more than a unit value of output. In an attempt to exploit this profit opportunity by hiring inputs, producers would drive up the input costs, thereby shifting the unit-cost line downward, a process that continues until profit opportunities are exhausted, that is, until the unit-value isoquant and the unit-cost line are tangent. Likewise, if the isocost line were C_3, there would be no way for producers even to break even, and either factor costs would have to fall or the commodity would not be produced.

The unit-value isoquants for both commodities are depicted in the "Lerner diagram," figure 1.2 (Lerner, 1952). Only one unit-cost line is consistent with the production of both goods in equilibrium, since only

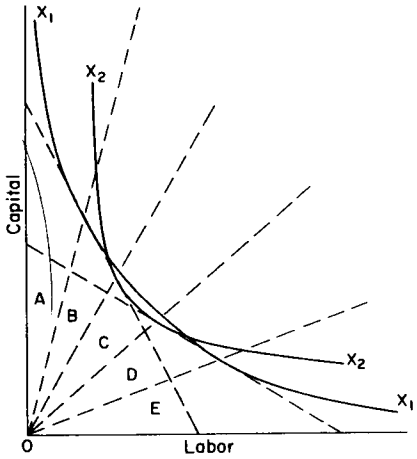

Figure 1.3
Factor intensity reversal.

one line is tangent to both unit-value isoquants. This line determines unique values for the factor rental rates w_K and w_L. Hence factor prices are equalized. Though this argument has referred to unit-value isoquants, the assumption of constant returns makes it apply to any level of output. ■

This argument is deficient in one respect. There is no assurance that the unit-value isoquants admit only a single tangent isocost line. An example to the contrary is illustrated in figure 1.3, in which there is a high wage equilibrium with X_1 produced with a capital intensive technique and a low wage equilibrium with X_1 produced with a labor intensive technique. The commodities X_1 and X_2 are said in this case to exhibit a *factor intensity reversal*, since one of the commodities can be produced efficiently with capital/labor ratios either more or less than the capital/labor ratio of the other, depending on the relative factor returns.

When there is more than one possible equilibrium set of factor returns, the choice among them depends on the factor endowment of the country. The allocation of a given endowment of capital and labor between the industries is illustrated in figure 1.4, where the vector V_1 indicates the factors allocated to industry 1 and the vector V_2 indicates the factors allocated to industry 2. These two vectors must lie along the expansion paths of the two industries and they must sum to the endowment vector (K, L). If the endowment vector (K, L) lies outside the cone between the

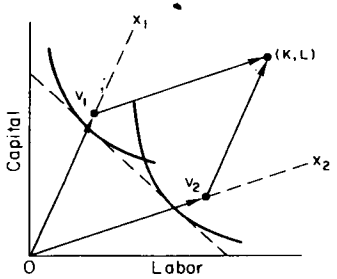

Figure 1.4
Allocation of factors between industries.

two expansion vectors, it is impossible to find two vectors along the expansion vectors that sum to the endowment vector, and consequently the factor prices associated with that cone are inconsistent with equilibrium. Return again to figure 1.3; this implies that the choice between the two factor price ratios depends on the endowment ratio. If the endowment is in a cone B with relative capital abundance, high wages are selected. If the endowment is in cone D with relative labor abundance, low wages are selected. If labor is even more abundant, and the endowment vector lies in region E, then the country specializes in X_1, and wages are still lower. Relative factor prices may then be found by placing an isocost line tangent to the X_1 isoquant at the endowment point.

The regions B and D in figure 1.3 are called *cones of diversification*. Countries with endowments in the same cone of diversification produce both goods using the same techniques and also have the same factor prices. Countries with endowments in different cones use different techniques and have different factor prices. Countries with endowments in none of the cones specialize in the production of one of the goods.

In order to ensure factor price equalization it is therefore necessary to invoke the following.

FACTOR ENDOWMENT SIMILARITY CONDITION Given the equilibrium commodity prices and the consequent family of cones of diversification, all countries either have factor endowments in the same cone or identical factor endowment ratios.

The cones of diversification will be wider, the more dissimilar are the productive techniques, and this condition can be stated as above that endowments must be more similar than (equilibrium) input intensities.

It may be noted in passing that this demonstration has made use of assumptions 1–5 with the exception of the part of 2a describing the immobility of factors between countries. Because factor prices are equalized, the economic incentive for migration is eliminated, and international mobility of factors is immaterial, provided such mobility does not affect the assumption about factor endowment similarity. Assumption 6 is used only in the limited sense that the production side of the economy maximizes the value of output.

From the internationally determined prices of goods, we have been able to derive the factor prices and the factor input intensities (defined precisely below). These intensities are depicted in figure 1.2, where (a^*_{K1}, a^*_{L1}) and (a^*_{K2}, a^*_{L2}) are the amounts of capital and labor required to produce a unit value of X_1 and X_2, respectively. The input requirements a^*_{ij} per *unit value* of output can be transformed into input requirements a_{ij} per *unit* of output by multiplying by product prices: $a_{ij} = a^*_{ij}p_j$, where p_j is the product price. The input requirements a_{ij} are called *factor input intensities*, and can be collected into a *factor intensity matrix* symbolized by A.

The following definitions refer to relative factor intensities and relative factor abundance.

FACTOR INTENSITY DEFINITION Commodity X_1 is said to be the relatively capital intensive commodity if

$$a_{K1}/a_{L1} > a_{K2}/a_{L2}.$$

FACTOR ABUNDANCE DEFINITION A country endowed with capital K and labor L is said to be relatively abundant in capital if its share of the world's capital stock exceeds its share of the world's labor force:

$$K/K_w > L/L_w,$$

or equivalently if the country is more capital abundant than the world as a whole:

$$K/L > K_w/L_w,$$

where the w subscript refers to world totals. ■

Having established factor price equalization, we may now demonstrate the Heckscher-Ohlin theorem.

THE HECKSCHER-OHLIN THEOREM A country with balanced trade will export the commodity that uses intensively its relatively abundant factor and will import the commodity that uses intensively its relatively scarce factor.

Proof Denoting the output levels by X_1 and X_2, we may set factor supply equal to factor demand to obtain

$$K = a_{K1}X_1 + a_{K2}X_2,$$

$$L = a_{L1}X_1 + a_{L2}X_2,$$

which is a system that can be solved for outputs as a function of the endowments. If V represents the vector of endowments (K, L) and X the vector of outputs (X_1, X_2), then these equations may be written in matrix form as $V = AX$, or inverted as

$$X = A^{-1}V, \tag{1.1}$$

where the inverse exists provided the relative input intensities are unequal: $a_{K1}/a_{L1} \neq a_{K2}/a_{L2}$. Because of the linearity of these equations (and the consequent unresponsiveness of total world outputs to factor migration), we can also write total world outputs X_w as a function of total world endowments V_w:

$$X_w = A^{-1}V_w.$$

Since the relative prices of goods are given in world markets and hence are the same for all countries, assumption 6 implies that each country consumes commodities in the same proportions, that is,

$$C = sX_w,$$

where s is the country's consumption share of world output and C is its consumption vector.

Trade balance requires that the value of production equal the value of consumption, that is, $p'X = p'C = sp'X_w$, where p is the price vector (p_1, p_2). Thus if trade is balanced, the consumption share is the ratio of own GNP to world GNP:

$$s = p'X/p'X_w. \tag{1.2}$$

The vector of *net exports* is the difference between production and consumption:

$$\begin{aligned} T &= X - C \\ &= A^{-1}V - sA^{-1}V_w \\ &= A^{-1}(V - sV_w), \end{aligned} \tag{1.3}$$

which is A^{-1} times the vector of *excess factor supplies*:

$$V - sV_w = \begin{bmatrix} K - sK_w \\ L - sL_w \end{bmatrix} = \begin{bmatrix} K_w\left(\dfrac{K}{K_w} - s\right) \\ L_w\left(\dfrac{L}{L_w} - s\right) \end{bmatrix}.$$

It will now be demonstrated that if the country in question is relatively capital abundant, $K/K_w > L/L_w$, then this excess factor supply vector has signs $(+, -)$. This follows from the fact that the consumption share is a weighted average of the capital share and the labor share

$$s = \frac{p'X}{p'X_w} = \frac{p'A^{-1}V}{p'A^{-1}V_w} = \frac{w'V}{w'V_w} = \frac{[w_K K_w(K/K_w) + w_L L_w(L/L_w)]}{w_K K_w + w_L L_w},$$

where w is the factor reward vector: $w = (A')^{-1}p$. Thus s must fall between K/K_w and L/L_w, and consequently $K/K_w > s$ is equivalent to $K/K_w > L/L_w$.

To determine the sign of the net export vector of a capital abundant country, we need to determine the effect of premultiplying a vector with signs $(+, -)$ by the inverse of the matrix A:

$$A^{-1} = \begin{bmatrix} a_{K1} & a_{K2} \\ a_{L1} & a_{L2} \end{bmatrix}^{-1} = \begin{bmatrix} a_{L2} & -a_{K2} \\ -a_{L1} & a_{K1} \end{bmatrix} / |A|,$$

where the determinant is

$$|A| = (a_{K1}a_{L2} - a_{L1}a_{K2}) = a_{L1}a_{L2}\left(\frac{a_{K1}}{a_{L1}} - \frac{a_{K2}}{a_{L2}}\right).$$

If X_1 is the capital intensive industry, then $|A| > 0$, and A^{-1} has the sign pattern

$$A^{-1} = \begin{bmatrix} + & - \\ - & + \end{bmatrix}.$$

If the country is abundant in capital, the vector of excess factor supplies has sign pattern $(+, -)$, and trade therefore has sign pattern

$$T = \begin{bmatrix} + & - \\ - & + \end{bmatrix} \begin{bmatrix} + \\ - \end{bmatrix} = \begin{bmatrix} + \\ - \end{bmatrix},$$

meaning the capital abundant country exports the capital intensive commodity X_1 and imports the labor intensive commodity X_2. All other cases of the Heckscher-Ohlin theorem follow similarly.[3] ■

The primary intent of this book is to study the linkages between trade and factor endowments, but for completeness I will briefly state the other basic trade theorems.

THE RYBCZYNSKI THEOREM At constant commodity prices, an increase in the supply of a factor will lead to an increase in the output of the commodity that uses that factor intensively and a reduction in the output of the other commodity.

This follows directly from equation (1.1) and the sign patterns for A^{-1}. A somewhat more precise version of the theorem can be stated in terms of the percentage changes in outputs induced by percentage changes in inputs. From equation (1.1) we have

$$\hat{X}_1 = (dX_1)/X_1 = (a_{L2}dK - a_{K2}dL)/(a_{L2}K - a_{K2}L).$$

Thus

$$(a_{L2}K - a_{K2}L)\hat{X}_1 = a_{L2}K\hat{K} - a_{K2}L\hat{L},$$

$$a_{L2}K(\hat{X}_1 - \hat{K}) = a_{K2}L(\hat{X}_1 - \hat{L}),$$

or

$$(\hat{X}_1 - \hat{K}) = (\hat{X}_1 - \hat{L})(a_{K2}/a_{L2})/(K/L).$$

Thus if commodity one is the capital intensive commodity, $a_{K1}/a_{L1} > K/L > a_{K2}/a_{L2}$, we must have $|\hat{X}_1 - \hat{K}| < |\hat{X}_1 - \hat{L}|$, that is, X_1 must grow at a rate more similar to K than to L, and we must have $\text{sign}(\hat{X}_1 - \hat{K}) = \text{sign}(\hat{X}_1 - \hat{L})$. This implies that either $\hat{L} < \hat{K} < \hat{X}_1$ or $\hat{X}_1 < \hat{K} < \hat{L}$, which establishes.

JONES'S MAGNIFICATION RESULT At constant commodity prices, $a_{K1}/a_{L1} > a_{K2}/a_{L2}$ and $\hat{K} > \hat{L}$ imply $\hat{X}_1 > \hat{K} > \hat{L} > \hat{X}_2$.

The next result links factor prices to commodity prices. This linkage is implied by the zero-profit conditions

$$A'w = p, \tag{1.4}$$

where p is the vector of prices (p_1, p_2) and w the vector of factor rewards. This condition asserts that the price of a commodity is equal to the cost of producing it. Differentiating this expression produces $A'(dw) = dp$, since $(dA')w = 0$ by cost minimization.[4] Writing this as

$$dw = (A')^{-1}\,dp, \tag{1.5}$$

and again referring to the sign pattern of the inverse of a 2×2 positive matrix, we obtain.

THE STOLPER SAMUELSON THEOREM An increase in the price of the import good leads to an increase in the return to the scarce factor and a reduction in the return to the abundant factor.

Finally, by comparing (1.5) with (1.1) we obtain a result due to Samuelson (1953/1954):

THE RECIPROCITY RELATIONS

$$\partial X_j/\partial V_i = \partial w_i/\partial p_j, \qquad i = K, L, \quad j = 1, 2.$$

In words, the partial derivative of the supply of commodity j with respect to the total availability of factor i is equal to the partial derivative of the wage of factor i with respect to the price of commodity j. These reciprocity relations are used in chapter 7 to obtain indirect estimates of the effects of tariffs on factor returns from direct observation of the responsiveness of output to factor supplies.

1.3 The Effects of Departures from Assumptions

It takes neither great observational skills nor keen inquisitiveness to make one question the six assumptions and to make one wonder whether the results hold up if these assumptions are relaxed. A particularly troubling observation is the great international disparity in wage rates. For example, the agricultural wage rates reported in table 1.1 vary from a low of \$.046 per hour in India to a high of \$2.04 per hour in Denmark. Part of these differences might be explained by skill differences, but agricultural wages seem unlikely to include a reward for skills that is