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Carlos A. Arnade

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Abstract

Latin American agricultural trade is consistent with both the Heckscher-Ohlin and Markusen propositions, which hold that countries export goods intensive in the use of their relatively abundant factor. This paper further shows that Latin American agricultural trade is primarily driven by country differences in relative factor abundance rather than by technology differences. This finding does not counter the Heckscher-Ohlin model, but counters one of Markusen's models, which allows for factor trade.

Keywords: Latin America, agricultural output trade, agricultural input trade, Heckscher-Ohlin, Markusen, factor abundance, factor content, relative exports, productivity

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Testing Two Trade Models in Latin American Agriculture

Carlos A. Arnade

Introduction

Econometric models have a poor record of predicting the major changes in the world's agricultural economies (14)[1]. Poor forecasting, combined with the high cost of building econometric models, may lead government or international agencies to rely on intuition and extrapolation of existing trends to make economic predictions. Unfortunately, this practice imposes little structure upon economic analysis, does not use forecasters' ability as economists, and often does not improve forecasting performance.

Models that provide qualitative forecasts may be more useful predictors of agricultural change in a volatile world economy. A well-known qualitative model is the general equilibrium Heckscher-Ohlin model (1, 7). Theorems derived from the Heckscher-Ohlin model can predict the impacts of broad structural changes in economies. For example, the Rybczynski (23) theorem predicts the impact of relative input growth on relative commodity production. The Stolper and Samuelson theorem (26) predicts the effect of output price changes on relative input prices. This, in turn, can predict patterns of trade.

Latin American countries are reforming their economic policies in the wake of the 1980's debt crisis. Rapid population growth and widespread technical and social change characterize many of these economies. These changes are so sweeping that their impact on agriculture may be difficult to capture in an econometric model. The best forecast of agricultural change in Latin America may come from using the theorems of the Heckscher-Ohlin model, or one of several similar general equilibrium models. These predictions would be convincing if Latin American agricultural trade were shown to follow a pattern predicted by the Heckscher-Ohlin model or related general equilibrium models.

This paper tests if the Heckscher-Ohlin Model explains Latin American agricultural trade. The paper emphasizes the difference between the Heckscher-Ohlin model and a related general

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[1] Underscored numbers refer to sources listed in the References section.

equilibrium model developed by Markusen. This paper is unique in three ways: (1) It investigates Latin American agricultural trade. Previous empirical testing of the Heckscher-Ohlin model focused on trade in northern countries.[2] (2) It defines the agricultural sector as a trading unit. Previous literature limited trading regions to politically established borders. Thus, the concept of trade is generalized. (3) It develops an empirical test to distinguish between the Heckscher-Ohlin model and a related general equilibrium model developed by Markusen. Previous literature focused on testing only the Heckscher-Ohlin proposition that countries export goods intensive in the use of their abundant factor. This paper goes one step further to investigate if relative factor abundance is the only determinant of trade.

The Heckscher-Ohlin Model

The Heckscher-Ohlin model is a two-factor, two-good, two-region general equilibrium model that is often used to explain trade patterns in the modern world. The model assumes that there are two inputs subject to diminishing returns and that countries have identical constant returns-to-scale production functions. Inputs are perfectly mobile across two sectors within a country but do not move across countries. These and other assumptions are reviewed by Abbott and Haley (1), Coyle and others (7), and most economic textbooks on trade.

In the Heckscher-Ohlin model, trade is driven by differences in relative factor abundance between trading regions.[3] The model predicts a country will export the commodity that uses intensively its relatively abundant factor. This prediction establishes a three-way linkage between the factor abundance of a country, the factor content of products, and the pattern of trade. For example, the Heckscher-Ohlin model would predict that a relatively labor-abundant country such as El Salvador would export labor-intensive goods such as coffee.

Leontief (18) tried to verify the Heckscher-Ohlin proposition that relative factor abundance determines trade patterns. He calculated the capital per man embodied in a million dollars of exports and imports of the United States. Leontief aggregated

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[2] Widespread intra-industry trade in the north has led many economists to believe that trade of less developed countries may better fit the Heckscher-Ohlin model than trade of developed countries (21).

[3] In constrast, Ricardo assumed countries traded because of differences in relative technology between countries.

his data over many commodities (and factors), investigated only one country, and did not compare the factor content of U.S. exports with U.S. factor endowments. Leontief's finding that labor is the primary content of U.S. exports was controversial.

Baldwin (2) and Stern and Maskus (25) regressed U.S. trade of individual products on each product's input requirements. If the coefficient were positive, a country would be inferred to be abundant in a resource. Neither of the above studies took the final step of relating this result to factor endowment data. Thus, there was little basis for verification of the Heckscher-Ohlin claim that relative factor abundance is the basis of trade. Both studies were limited to one country.

Leamer (15), critical of Leontief's study, tested the relationship between factor content of exports and relative factor abundance. Leamer (16, 17) regressed net exports of commodities on measures of factor supplies. Leamer included data from many countries in his studies, calculated factor endowments (which Leontief did not measure), but did not measure input intensities of commodities.

Bowen, Leamer, and Sveikauskas (4) connected all three links between factor endowments, factor content, and trade. They linked the factor content of exports with relative factor endowments by using a full employment condition. Using data for 27 countries, they ranked the factor content of exports with factor endowments and found a strong connection between the two.

Lee and others (19) is the only study that used agricultural data exclusively to test the link between factor abundance, factor content, and trade. These authors broke U.S. agriculture into 16 sectors and agricultural processing into 14 sectors. They calculated the factor content of a million dollars worth of agricultural exports and compared this with the factor content of a million dollars worth of domestically consumed agricultural goods. They found the ratio of the factor content of agricultural exports to domestically consumed agricultural goods to be highest for land, followed by agricultural capital. The ratio of the labor content of exports to labor content of domestically consumed goods was the lowest. These authors did not, however, explicitly relate the revealed relative factor content of U.S. exports with relative factor abundance in U.S. agriculture.

Each of the above tests for the Heckscher-Ohlin model has advantages. Only the Bowen, Leamer, and Sveikauskas study looks at each of the three links between factor abundance, factor content, and trade.[4] Many of the models generalized beyond the two dimensions allowed by the original Heckscher-Ohlin model.[5] Most of the studies examined only one country. All the above studies ignored input trade, which is a significant component of world trade, and was incorporated into the Heckscher-Ohlin model by Mundell (22).

Economists may have neglected input trade and Mundell's amendment to the Heckscher-Ohlin model since Mundell argued that the gains from trade are equivalent if inputs instead of goods are traded (22). However, another general equilibrium model, by Markusen (20), indicates that input trade may be important.

The Markusen Model

Markusen's (20) two-factor, two-sector model also predicts that countries export goods intensive in the use of their relatively abundant factor. Markusen presents many versions of his model but the key feature of each is that, prior to trade, the relative factor abundance of trading units is equivalent. Thus, the driving force for trade in the Heckscher-Ohlin model is eliminated.

In the Markusen model, differences in technology, economies of scale, or government distortions create trade. These differences exist because Markusen does away with other assumptions of the Heckscher-Ohlin model. In one model, he assumes countries do **not** have identical technologies. In another he assumes production is **not** characterized by constant returns to scale (20). In yet another, domestic distortions are introduced.

In each case, Markusen shows that the initial trading equilibrium is characterized by "a country having the relatively high price for the factor used intensively in the production of the export good" (20 p. 342). Markusen allows factors to be traded across borders and claims: "Factor mobility must lead to an inflow (outflow) of the factor used intensively in the production of the (import) export good. This allows a factor-proportion basis for trade which complements the other basis for trade" (20 p. 342).

In Markusen's model, countries become relatively well endowed with the factors intensive in their export products as a **result** of trade. In contrast, relative factor abundance is the **cause** of trade in the Heckscher-Ohlin model. The difference between both

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[4] The final study is the only study that tests the assumption that the factor content of a product is not the same for all countries.

[5] Jones (13) discusses the limitations of a two-sector model.

models is not trivial. Factor trade **complements** goods trade in Markusen's model. In contrast, Mundell (22), who amended the Heckscher-Ohlin model by allowing inputs to be traded, showed that trade in factors **substitute** for trade in goods.

Testing Both Models in Latin American Agriculture

Neither the Heckscher-Ohlin nor Markusen models perfectly explain real world trading patterns, which violate assumptions underlying both models (1, 5). However, one model may better explain Latin American agricultural trade than another. Violations of Heckscher-Ohlin model assumptions, such as a worldwide trade in capital, did not prevent economists from testing the factor content of U.S. exports (2, 16, 18, 19, 25). Similarly, real world considerations should not prevent testing propositions from the Heckscher-Ohlin and Markusen models in Latin America.

The test in this paper most closely follows Leamer (16, 17). He regresses net exports of a single commodity for many countries on measures of factor supplies. This paper does the same but aggregates all agricultural commodities into one of two sectors: a land/capital-intensive sector or a labor-intensive sector. Thus, the binary dimensions of the original Heckscher-Ohlin model are maintained.

A positive correlation between relative exports of Latin America's agricultural sectors and the relative abundance of production factors shows that either the Heckscher-Ohlin or Markusen model may be valid. Additional factors must be accounted for to distinguish between the two models. The Heckscher-Ohlin and Markusen models differ in three ways:

> In the Heckscher-Ohlin model, relative factor proportions form the basis for trade. In the Markusen model, differences in technology, scale, or government distortions form the basis for trade.
>
> In the Heckscher-Ohlin model, factor endowments are exogenous. In the Markusen model, factor proportions emerge endogenously and are a result of trade.
>
> In the Heckscher-Ohlin model, input and output trade substitute for each other. In the Markusen model, input and output trade complement each other.[6]

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[6] In the Markusen model, increased exports (imports) of a good should increase imports (exports) of the inputs intensively used by that good. In the Heckscher-Ohlin-Mundell model, increased exports (imports) of a good should decrease exports (imports) of the input used intensively by that good. The

In two of Markusen's models, the production function is written as:

$$\phi_r F(X_{r1}\ X_{r2}) = Y_{r1}; \quad (1)$$

where X_1 is labor, X_2 is capital, r denotes a subscript that is distinct for each country or trading unit, ϕ_r is a Hicks-neutral output-augmenting parameter for country r. This parameter represents technological differences between countries or, when written as $\phi_r(Y_{r1})$, represents differences in external returns to scale between countries. Y_{r1} is the output of good 1 in country r. A similar production function is written for the other good.

In Markusen's models, countries export goods with higher technology or returns-to-scale parameters. In the Heckscher-Ohlin model, countries export goods intensive in the use of their relatively abundant factor. Using agricultural data, Markusen's models can be tested against the Heckscher-Ohlin model by estimating the following cross-section equation:

$$REX^* = \beta_0 + \beta_1 RA + \beta_2 RTFP; \quad (2)$$

where: REX = the ratio of capital-intensive to labor-intensive agricultural exports (for each agricultural sector),

RA = the ratio of the stock of agricultural land and agricultural capital to the stock of agricultural labor (in the agricultural sector of each country), and

RTFP = the relative technology (scale) parameters in capital-intensive and labor-intensive agricultural crops.

If resource endowments explain relative agricultural exports (Heckscher-Ohlin), the factor abundance variable (RA) should be significant in equation 2. If technology or the external returns-to-scale parameter (Markusen) explain relative agricultural exports, then the RTFP indices should be significant in equation 2.

In Markusen models, relative factor abundance emerges

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direction of growth in input trade is the same in both models. The difference lies in the starting point. Mundell shows that there is a positive level of input trade when trade in goods is prohibited. Markusen assumes there is no input trade when trade in goods is prohibited. In the real world, goods <u>are</u> traded, so a starting point cannot be isolated to determine the initial level of input trade.

endogenously as a result of trade. In the Heckscher-Ohlin model, relative factor abundance is exogenous. Thus, the origin of factor endowments can be tested by estimating the following equation:

$$RA = \beta_0 + \beta_1 REX_{-1} + \beta_2 PDN; \qquad (3)$$

where PDN represents the population density and REX_{-1} is the relative agricultural export index lagged one time period.

If the lagged relative export variable in equation 3 is significant, then relative factor abundance emerges endogenously as a result of trade. If the lagged REX variable is insignificant, then the relative factor abundance is primarily exogenous.

To estimate equations 2 and 3, a measure of relative agricultural exports, a measure of relative factor abundance, and a measure of the relative technology (scale) parameters must be calculated. The following sections detail the classification of agriculture in 16 Latin American countries into two sectors and describe the data used in calculating relative exports, relative factor abundance, and the parameter (ϕ_r) for each agricultural sector in 16 Latin American countries.

Two-Sector Product Classification

Economists typically let trading regions be defined by political boundaries, such as national borders. The Heckscher-Ohlin-Mundell or Markusen models deal exclusively with real commodities. Therefore, nothing prevents these models from being applied to regions consisting of a group of countries or subregions within a country. For example, the agricultural sector of each country can be classified as a trading unit. Sales of agricultural goods to urban regions of a country can be considered a component of exports. The advantages of defining the trading region as the agricultural sector are: (1) the dimensions of the model can be kept to two sectors without forcing all of agriculture into one sector and (2) problems of aggregating nonhomogeneous goods (as faced by Leontief) are reduced since, relative to industrial goods, agricultural goods are more homogeneous products.

In the following sections, the agricultural sectors of Latin American countries are each considered a trading region.[7]

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[7] The large outflow of labor from the agricultural sectors of Latin America means that input trade cannot be ignored. This underscores the importance of testing the Heckscher-Ohlin-Mundell model against the Markusen model.

Sales of agricultural goods to urban areas and international exports are classified as exports. Agricultural production and trade of 16 Latin American countries are broken into two sectors: a labor-intensive sector, and a sector intensive in both land and/or capital.[8]

Brazilian budget and wage data helped classify agricultural products into either labor-intensive or land/capital-intensive categories (9, 11). Budgets from other Latin American countries were not used because of their unreliability.[9] Table 1 lists the labor requirements per hectare, and the labor-to-capital spending ratios of available Brazilian crops. Later, land and capital are aggregated into one input category (land/capital) to preserve the two-factor requirement of the Heckscher-Ohlin and Markusen models.[10]

Clearly, production of coffee, fruits, and vegetables is more labor intensive than production of grains and oilseeds. Rice is the most labor intensive of the grain crops but ranks below most fruits and vegetables in column 1. Furthermore, column 2 indicates that rice has a noticeably lower labor-to-capital ratio than all fruit and vegetable crops, but not a noticeably higher ratio than other grain crops.

Column 2 also indicates that sugar requires a large capital investment relative to labor. Sugar is unique in that its large bulk ensures that it is processed at rural mills located near sugar-growing centers and only then is sold to the urban areas or exported.

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[8] In a two-input world, a product X is considered to be relatively more labor intensive than another product Y if the labor/capital ratio used in the production of X is greater than the labor/capital ratio used in the production of Y.

[9] This study follows the tradition established by Baldwin (2), Leontief (18), and Stern and Maskus (25), who take the input requirements of goods from the United States and assume the same input requirements hold for other countries. This paper uses the factor content in Brazil rather than the United States. This approach is consistent with Markusen's model, which represents technological differences between countries as a Hicks-neutral parameter that does not influence the relative factor content of a product.

[10] A weighted average of land and agricultural capital are aggregated into one input category called land/capital. For measuring stocks of land/capital, prices of the two inputs are used as weights. For measuring flows of both inputs, cost shares are used as weights.

Coffee, cocoa, fruits, melons, pulses (beans not included in oilseeds), root and tuber crops, and vegetables were classified as labor-intensive crops, and grains, oilseeds, and sugar were classified as land/capital-intensive crops.

Table 1--Ranking of Brazilian crops (1975-85 average)

Labor days per hectare	Commodity	Ratio of labor to machinery cost	Commodity
	1		2
772.0	Tomatoes	396.6	Manioc
404.0	Grapes	26.3	Bananas
132.0	Onions	17.5	Grapes
129.0	Tea	8.6	Potatoes
120.0	Coffee	8.2	Tomatoes
92.3	Bananas	7.0	Tea
80.0	Potatoes [1]	5.9	Beans (Pulses)
58.9	Oranges	5.1	Onions
44.4	Manioc	3.3	Cotton
26.6	Sugar	2.4	Peanuts
21.7	Cotton	2.3	Coffee
21.0	Rice [2]	1.7	Oranges
18.6	Peanuts	.9	Rice
18.2	Beans	.8	Sorghum
10.9	Corn	.8	Sugar
7.3	Sorghum	.7	Soybeans
5.8	Soybeans	.6	Corn
3.0	Wheat	.2	Wheat

[1] Prognostico often publishes more than one budget per crop, reflecting the region of the country or the level of technology. This data was taken from an average of all budgets except for the potato budget. The potato budget without mechanical harvesting was used. The assumption is that this more accurately reflects the technology used for growing potatoes in the rest of Latin America.

[2] The labor requirements for rice represent an average of irrigated and nonirrigated rice cultivation. Dry cultivation is the primary manner of growing rice in Brazil.

Source: (9, 11)

Exports of the Agricultural Sector

Agricultural exports include sales to the urban sector in each country as well as sales outside the country. Storage of agricultural products is negligible in Latin America. Therefore, the value of aggregate rural agricultural consumption was subtracted from the value of agricultural production to get agricultural exports.[11]

Published data from Brazilian surveys of consumption of 22 agricultural commodities by rural and urban sectors served as a base for calculating rural consumption in 13 of the 16 Latin American countries (10). Since the Andean countries in Latin America have a distinct topography and racial composition, Peruvian surveys of consumption of 22 agricultural commodities by rural and urban sectors served as a base for calculating rural consumption in Bolivia, Ecuador, and Peru (31).

Rural consumption figures were adjusted by differences in the rural population between the base country (Brazil, Peru) and the country and time of interest. Suppose the rural sector in Brazil, for example, comprised 50 percent of the population and consumed 40 percent of Brazilian grains. Suppose in 1980 the rural sector of another country comprised 25 percent of its population. That country's rural sector then was estimated to have consumed 20 percent of that country's grain crop.

The above approach generalizes consumption habits across countries. However, Brazil and Peru were the only Latin American countries where available estimates of rural and urban consumption of agricultural commodities had been verified by domestic and international reviewers (11, 31).

Rural sector exports of each commodity were computed by subtracting rural consumption from production. Then, using the labor-capital classification of each commodity, an index of the ratio of land/capital-intensive agricultural exports to labor-intensive agricultural exports was created. The first column in table 2 ranks the agricultural sectors of 16 countries by this index which, for clarity, was normalized so the second highest country equaled 100. Argentina's and Uruguay's agricultural sectors, which export grains and beef but export little coffee, fruits, or vegetables, top the list. The agricultural sectors of

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[11] International exports and production for each agricultural commodity were represented by 1975-85 averages (27, 28). Aggregate rural consumption was calculated by multiplying domestic consumption by the share consumed in rural areas. Domestic consumption of each commodity equaled the value of each country's production minus international sales.

El Salvador and Ecuador, which are primarily coffee exporters, are on the bottom.

Relative Factor Abundance

The agricultural sectors of Latin American countries were ranked by their ratios of agricultural land/capital to agricultural labor. Due to limited data, only five items served as a proxy for measuring agricultural land/capital: nonirrigated cropland, irrigated land, pasture land, harvesters, and tractors. Livestock herds were not included as capital to avoid the obvious correlation between herd size and beef and live cattle exports. This obvious relationship could mask more subtle relationships between relative exports and relative factor abundance.

Agricultural land data in all categories were obtained from the United Nations Food and Agriculture Organization (FAO). Annual FAO estimates of the number of harvesters and tractors were converted into nondepreciated equivalents by depreciating machines 5 percent a year from their purchase date.[12] The final measure of the agricultural land/capital factor represented a sum of nondepreciated harvester equivalents, nondepreciated tractor equivalents, and the three types of agricultural land, each weighted by its average price. Prices for harvesters and tractors were obtained from USDA estimates of international sales prices. Where land prices were not available, the value of agricultural land was calculated by applying standard present value formulas to current and projected returns to land. Discount rates were assumed to equal 12 percent.[13]

The second column of table 2 ranks the agricultural sector of Latin American countries by their agricultural land/capital to agricultural labor ratios. For comparison, a ranking by the ratio of agricultural land to labor is included in table 2. The agricultural sectors of Argentina and Uruguay, which have much land but little rural labor, lead the list while the agricultural sectors of Guatemala and El Salvador, which have little land but a large rural workforce, are at the bottom.

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[12] Harvesters and tractors are imported by many Latin American countries, which is consistent with the Markusen model and the Mundell amendment to the Heckscher-Ohlin model.

[13] In countries where land prices are not available, economists often use the difference between revenues and operating costs as an estimate of land rents (8). Discount and interest payments reflect the interest forgone by not investing in dollar-denominated money markets.

Table 2--Ranking of agricultural sectors of 16 Latin American countries by relative exports and factor abundance[1]

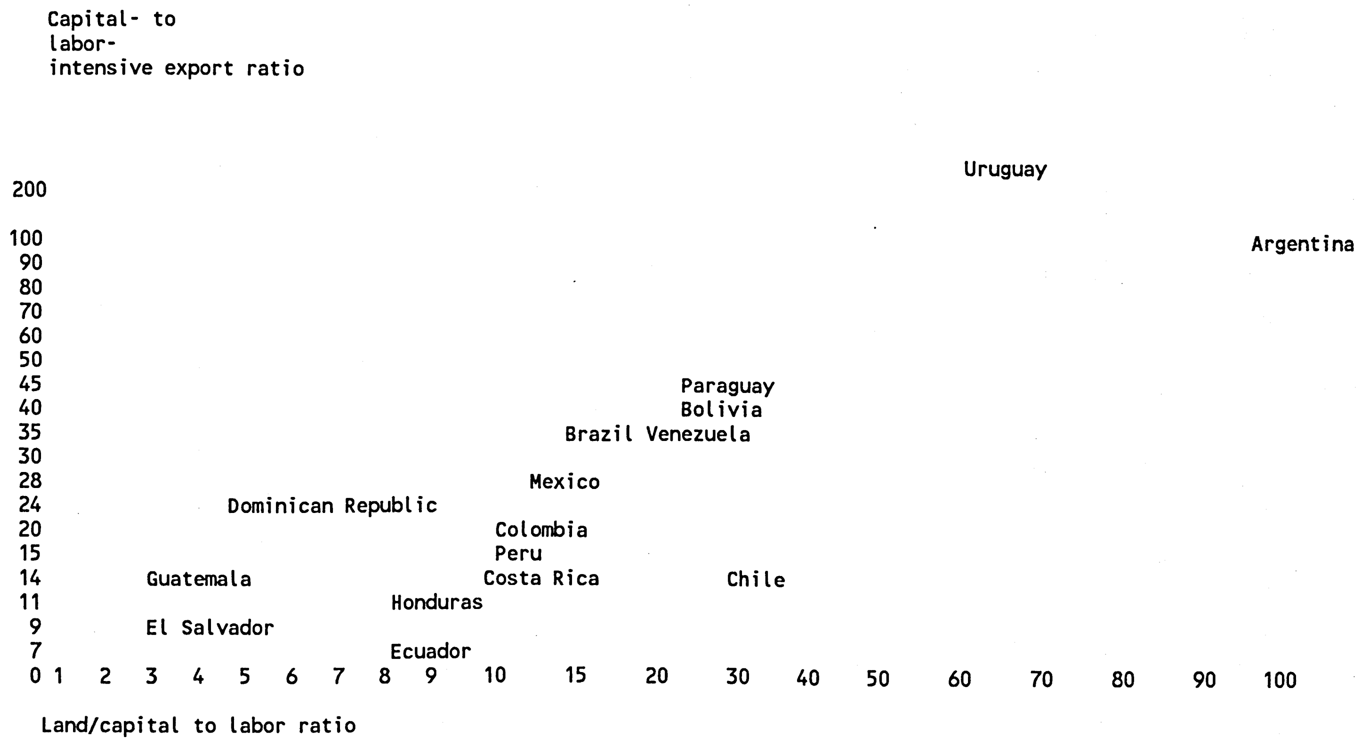
Ratio of land/capital- to labor-intensive agricultural exports		Agricultural land/capital to labor ratio		Agricultural land to agricultural labor ratio	
205.0	Uruguay	100.0	Argentina	100.0	Argentina
100.0	Argentina	57.0	Uruguay	63.9	Uruguay
43.7	Paraguay	31.1	Chile	30.1	Bolivia
37.3	Bolivia	24.3	Paraguay	29.0	Paraguay
36.8	Brazil	24.1	Bolivia	24.6	Venezuela
33.7	Venezuela	20.8	Venezuela	22.0	Chile
27.9	Mexico	16.1	Brazil	13.3	Brazil
23.1	Dom. Rep.	11.7	Mexico	12.1	Peru
20.4	Colombia	11.2	Peru	10.8	Colombia
16.6	Peru	11.1	Colombia	9.8	Mexico
14.2	Chile	10.8	Costa Rica	9.4	Costa Rica
14.2	Costa Rica	8.3	Ecuador	6.8	Honduras
14.1	Guatemala	8.0	Honduras	5.8	Ecuador
11.4	Honduras	5.6	Dom. Rep.	3.8	Dom. Rep.
9.4	El Salvador	3.8	El Salvador	2.3	Guatemala
7.6	Ecuador	3.7	Guatemala	2.2	El Salvador

[1] Indices are based on 1975-85 data.

Relative Exports and Relative Factor Abundance

Figure 1 breaks out the agricultural sector of each country according to its rankings in both the relative trade and relative factor intensity categories. On the vertical axis is an index of the ratio of land/capital-intensive agricultural exports to labor-intensive agricultural exports. On the horizontal axis is an index of the agricultural land/capital to labor ratio. The horizontal axis has been adjusted to exaggerate the dispersion of countries that crowd into the lower left corner. The agricultural sectors of Latin American countries, with the exceptions of Chile and the Dominican Republic, fall along a northeast to southwest diagonal, signifying a positive relationship between the factor content of exports and relative factor abundance. This pattern fits <u>both</u> the Heckscher-Ohlin and Markusen models.

Figure 1
Breakout of countries by capital- to labor-intensive agricultural exports and by relative factor intensities of their rural sectors



Productivity Indices

Markusen (21) includes in his production functions a Hicks-neutral output-augmenting parameter (ϕ_r). Differences in this parameter between countries can lead to trade. A Hicks-neutral parameter external to a production function shows up as country differences in productivity. Productivity estimates contain differences in technology, differences in efficiency, and the effect of scale on production. A measure of two-factor productivity represents the parameter (ϕ_r), which determines relative exports in Markusen's model.

Two-factor productivity indices were calculated for each agricultural sector in the 16 Latin American countries. Productivity indices were calculated for the labor-intensive sector (coffee, cocoa, fruit, pulses, melons, roots and tubers, tea, and vegetables) and for the land/capital-intensive sector (beef, live cattle, grains, oilseeds, and sugar).

The aggregate output of each sector was defined two ways, leading to two different productivity indices. In the first index, output was defined as a weighted average of the value of output of each commodity. For the second index, output was defined as a weighted average of the quantity of output of each commodity. The shares of sector revenues contributed by each commodity were used as weights (appendix).

The aggregate input for each sector was defined as a weighted average of the service flows of land/capital and labor.[14] The possibility that the production process was not constant returns to scale (as in one of Markusen's models) was allowed for when aggregating inputs. This was done by weighting inputs by the ratio of expenditures on each input to revenues. Typically, constant returns to scale are assumed and cost shares are used as the factor weights (6 p. 247).

Allocation of the land/capital input between the capital-intensive and labor-intensive sectors was determined from land data. Allocation of the labor input between the capital-intensive and labor-intensive sectors was determined from the share of land in each sector and the per-hectare labor requirements of products (table 1). For example, suppose a country had only two crops: grains, which used 75 percent of the agricultural land, and fruits, which used 25 percent of the agricultural land. Suppose also that grains used 10 hours of labor per hectare and fruits used 40 hours per hectare. It can

[14] An earlier section of this paper was concerned with measuring the stock of land/capital and labor. For productivity indices, the flows from this stock must be estimated.

be determined that 43 percent of the labor was used in grain crops and 57 percent was used in fruit crops.

To measure the quantity of service flows of the land/capital input, a price index of the service flows of land/capital was divided into the total value of service flows of cropland, pasture land, irrigated land, tractors, and harvesters. The price index of land/capital service flows was represented by a weighted average of rental prices of cropland, pasture land, irrigated land, and calculated service prices of harvesters and tractors. Tractor and harvester rents were calculated from the Jorgenson rental price (3). The appendix discusses this procedure.

Table 3 reports two Tornqvist productivity indices for each agricultural sector. The first (second) index was calculated from a weighted average of the value (quantity) of output. The productivity of Central American countries is relatively high since the rest of Latin America has a large amount of low-productivity pasture land.

Table 3--Two-factor productivity indices of agricultural sectors

Country	Labor-intensive sector: Value Index	Labor-intensive sector: Quantity Index	Capital-intensive sector: Value Index	Capital-intensive sector: Quantity Index
Argentina	1.00	1.00	1.00	1.00
Bolivia	0.40	0.49	0.64	0.44
Brazil	0.73	1.20	0.51	0.57
Chile	0.50	2.16	0.50	2.01
Colombia	0.84	1.57	0.52	0.54
Costa Rica	1.74	3.69	1.18	1.92
Dom. Rep.	0.54	1.78	0.62	1.29
Ecuador	0.60	3.13	0.42	1.27
El Salvador	1.53	5.69	1.25	2.62
Guatemala	0.84	4.32	0.73	2.12
Honduras	0.70	2.50	0.63	1.32
Mexico	0.34	0.56	0.14	0.15
Peru	0.83	0.72	1.05	0.69
Paraguay	1.36	0.79	2.14	0.95
Uruguay	0.29	0.29	1.61	1.15
Venezuela	1.07	2.01	1.31	1.69

Productivity Versus Factor Abundance

Equation 2 can determine whether relative factor abundance or relative productivity is the primary determinant of relative exports. Tables 4 and 5 report the results from estimating equation 2.[15] Two models are reported in each table. In both tables, column 1 reports the estimators from an equation that uses the "value" productivity indices as exogenous variables while column 2 reports the estimators from an equation that uses the "output" (tons) productivity indices as exogenous variables. All estimated equations are significant at the 0.01 confidence level.

Table 4 estimates equation 2 using all countries. Table 5 drops Uruguay from the regression. The calculated productivity of Uruguay's land/capital-intensive crops is higher than that of most countries, while the productivity of Uruguay's labor-intensive sector is one of the lowest. Relative productivity numbers of Uruguay were an outlier in the relative productivity data set. The difference in the results between table 4 and table 5 indicates a high sensitivity of the model to this outlier.

Tables 4 and 5 report F statistics called FR1 and FR2. A significant FR1 indicates that the estimator on the relative factor abundance variable is not significantly different from zero. A significant FR2 indicates that the estimator on the relative productivity variable is not significantly different from zero.

In table 4, FR1 is significant at the 99-percent confidence level in model 1 and at the 95-percent confidence level in model 2. In table 5, FR1 is significant at the 99-percent confidence level. Either way, as proposed by the Heckscher-Ohlin model, relative factor abundance is a significant factor in determining the exports of Latin America's agricultural sectors.

The significance of the relative productivity measure is quite different between models. In table 4, which includes Uruguay, FR2 is significant at the 99-percent confidence level. However, in table 5, which does not include Uruguay, FR2 is not significant.

The discrepancy in results illuminates the fact that outliers can dramatically alter the inferences drawn from a sample. In the equation that includes Uruguay, both the Heckscher-Ohlin and Markusen explanations for trade are validated. In the equation that

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[15] Equation 2 was written as:

$$REX^* = \beta_0 + \beta_1 RA + \beta_2 RTFP$$

where REX is relative exports, RA is relative factor abundance, and RTFP is relative productivity of the two agricultural sectors.

does not include Uruguay, only the Heckscher-Ohlin explanation for trade is validated. This point is important since Leontief (18), Baldwin (2), and Stern and Maskus (25) focused their studies on one country.

Table 6 reports the results of estimating equation 3. This equation regresses relative factor abundance of the agricultural sector on lagged relative exports and population density of the country. Lagged relative exports are represented by the ratio of the 1970-75 average of capital-intensive agricultural exports to the 1970-1975 average of labor-intensive agricultural exports. The Markusen model predicts that this variable should determine relative factor abundance. The results in table 6 indicate that this variable, as well as the country's population density variable, does not influence the relative factor abundance of the agricultural sector.

The combined information in tables 4, 5, and 6 imply that the Heckscher-Ohlin model better explains Latin American agricultural trade than does the Markusen model. Differences in relative factor abundance between Latin America's rural sectors drive much of Latin America's agricultural trade. However, Uruguay's agricultural exports may be driven by a relatively large difference in the productivity of its labor-intensive crops and its land/capital-intensive crops. Relative agricultural exports do not seem to influence relative factor abundance of Latin America's agricultural sectors.

Table 4--Estimators from equation 2 (all countries): The endogenous variable is an index of relative exports[1]

Exogenous variable	Model 1 (tons)	Model 2 (value)
Constant	-17.7 (-3.44)	-13.72 (-2.50)
Relative factor abundance	.84 (5.67)	.67 (3.87)
Relative productivity	30.32 (9.67)	42.9 (8.48)
	RBAR = .93 F(2,13) = 103.5 FR1(1,13) = 32.17 FR2(1,12) = 93.3	RBAR = .91 F(2,13) = 81.2 FR1(1,12) = 14.6 FR2(1,13) = 72.05

[1] T statistics are in parentheses.

Table 5--Estimators from equation 2 (excluding Uruguay): The endogenous variable is an index of relative exports[1]

Exogenous variable	Model 1 (tons)	Model 2 (value)
Constant	4.50 (.57)	9.06 (1.29)
Relative factor abundance	.87 (7.71)	.87 (6.59)
Relative productivity	6.20 (.79)	1.98 (.18)
	RBAR = .81 F(2,13) = 32.6 FR1(1,13) = 59.4 FR2(1,12) = .63	RBAR = .80 F(2,13) = 30.4 FR1(1,12) = 43.5 FR2(1,13) = 032

[1] T statistics are in parentheses.

Table 6--Estimators from equation 3: The endogenous variable is an index of relative factor abundance (1975-85)[1]

Exogenous variable	Model 1
Constant	23.72
Relative exports lagged	2.41 (.845)
Population density	-.014 (-1.22)
	RBAR = .06 F(2,13) = 1.54

[1] The 1975-85 average of relative factor abundance of the agricultural sector is regressed on relative agricultural exports from the 1970-75 average of the country's relative agricultural exports and population density.

Policy Predictions

The previous sections indicate that a mix of the Heckscher-Ohlin model and its Mundell amendment can explain the exports of Latin America's agricultural sectors. This means that agricultural input and output trade should substitute for one another. Rises in the volume of output trade should reduce input trade. This finding supports statements made by some Latin American economists concerning the impact of trade liberalization on their region.

Extensions of the Heckscher-Ohlin model may predict the effect of changes in individual Latin American agricultural economies. For example, the Rybczynski theorem states that, within the two-commodity, two-factor Heckscher-Ohlin framework, if prices are constant, an increase in the supply of one factor leads to an increase in the output of the commodity that uses that factor intensively and reduces the output of the commodity that uses it less intensively (23).

Rybczynski might predict that the Latin American agricultural economies that have fast-rising populations and little ability (in the wake of the debt crisis) to import capital will increase output of labor-intensive vegetable and fruit crops and reduce output of capital/land-intensive grain crops. In the future, these agricultural economies would be expected to export more fruit and vegetable crops and import more grain and oilseed crops.

Production of flower, fruit, and vegetable crops is increasing in Colombia, Costa Rica, Honduras, Guatemala, and Mexico. Citrus and melon production is emerging for the first time in Central America. If the Rybczynski hypothesis is correct, production of vegetable crops may increase in those countries and in Bolivia, Ecuador, and Peru, which have fast-rising rural populations and are severely constrained in their ability to import capital. Capital-intensive crops, such as grains, should decline in regions with fast-rising population, such as Mexico, Central America, and the Andean countries.

The Stolper-Samuelson theorem also states that, within the two-commodity, two-factor Heckscher-Ohlin framework, a relative output price increase raises the income share of the factor used intensively in production of the good whose price has risen (26). For example, if U.S. tariffs are reduced on labor-intensive crops coming from Mexico, then agricultural labor in Mexico will see a rise in their relative incomes.

The above predictions are far less detailed than could be provided by an econometric model. But they are superior to extrapolation and intuitive guesswork and are consistent with a well-accepted economic theory whose predictions are consistent with Latin American trade data.

Conclusions

The rural economies of Latin America export agricultural goods that intensively use their relatively abundant agricultural production factor. This evidence supports the Heckscher-Ohlin and Markusen model despite a number of violations in the real world of the more extreme assumptions underlying both models. Differences in relative factor abundance between countries better explain the trading patterns of Latin America's agricultural sectors than differences in technology or differences in the scale of production. These results support the Heckscher-Ohlin model and indicate that the theorems derived from the Heckscher-Ohlin model could be cautiously applied to forecasting the effects of agricultural policy changes in Latin America.

The technique this paper introduces for testing and distinguishing between the Heckscher-Ohlin and the Markusen models should be emphasized more than this paper's results. More detailed study of the factor intensity of crops in <u>each</u> country is needed. Better estimates of a land/capital factor are required. There needs to be a direct way to test Markusen's third model, where government distortions lead to trade, against the Heckscher-Ohlin model. Finally, economists should ask why there is empirical evidence of the Heckscher-Ohlin model even when, in the real world, many of its underlying assumptions are violated. It may be that its assumptions are unnecessarily restrictive. More general assumptions could produce a model with predictions similar to the Heckscher-Ohlin model.

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Appendix A: Calculation of Land Prices

In theory, agricultural rents should equal the returns to agricultural land. Land sale prices can be calculated from rent prices through net present value formulas. Agricultural land returns for each country's nonpasture agricultural land (1975-88) were calculated by subtracting production costs from agricultural revenue earned from nonpasture land.

To estimate agricultural revenue earned from nonpasture land in each country, FAO (29) estimates of the value of beef, hides, mutton, and wool production were subtracted from estimates of total agricultural revenues. Total agricultural revenues were represented as an average of FAO and World Bank (32) estimates. Production costs were represented by estimates of the value of fertilizers consumed, pesticides imported, the total costs of agricultural labor (11, 27), the annual depreciation costs of tractors and harvesters, the cost of seeds, and interest payments representing 12 percent of other costs.

Cropland returns were calculated on a per-hectare basis. Per-hectare land returns beyond 1988 were assumed to grow 3 percent a year. It was heartening to note that cropland prices calculated from these estimated land rents were less than 5 percent off the average cropland price reported in Brazil.[16] [17]

Agricultural land returns for each country's pasture land (1975-88)

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[16] Returns to labor were calculated by multiplying annual agricultural wages times agricultural employment. Agricultural employment data were obtained from FAO estimates (29). Agricultural wages for 9 of the 16 countries were obtained from the International Labor Organization (12). Wages for the remaining 7 countries were obtained from the relationship between International Labor Organization's estimates of mining and manufacturing wages, which were available for all countries, and agricultural wages in the 9 countries where agricultural wages were available.

[17] A weighted average of land prices across countries rather than individual country land prices provided the weight on land when calculating the land-capital factor. This reason for this is simple. If countries export a large amount of land-intensive goods, land prices may be higher. A cross-country land-capital index could be artificially related to an index of relative exports because of differences in land prices across countries.

were calculated by subtracting production costs from agricultural revenue earned from pasture land. Pasture returns were calculated by subtracting vaccination, labor, fuel costs, and machine depreciation costs from the value of production of beef, mutton, wool, and hides. Costs were derived by adapting budgets from USDA estimates of southern and eastern cow-calf and U.S. sheep operations to Latin America (30). For example, gasoline and labor expenditures in the livestock budgets of the United States were adjusted by the percent difference in fuel and labor prices in the United States and comparison country. Vaccination expenditures were based on vaccine costs in Brazil and included vaccination costs on nonsurviving animals. Estimates of Brazilian cattle survival rates were used for all livestock in all countries. Improved pasture, supplemental feeding, insurance, and overhead costs were not included as costs, reflecting livestock management practices in Latin America.

Appendix B: Productivity Indices

Multifactor productivity indices often measure changes in productivity (3, 5). Ratios of total factor productivity relative to a base time period are reported. In contrast, this paper measures two-factor productivity at one point in time (using average 1975-85 data), but compares this measure across 16 countries. This paper is also restricted to a two-factor model so all available inputs must be aggregated into two factors.

When calculating productivity, a weighted average of outputs (inputs) measures aggregate output (input). If producers are profit maximizers and production is characterized by constant returns to scale, the output (input) weights are represented by the shares of revenues (costs) each commodity (input) contributes to total revenues (costs).[18] Relative total factor productivity between nation n1 and nation n0 is measured as:

$$TFP^{n1}/TFP^{n0} = [Y^{n1}/Y^{n0}]/[X^{n1}/X^{n0}], \quad \textbf{(1a)}$$

where Y^{n1} is aggregate output in country n1 and X^{n1} is aggregate input in country n1. Relative outputs and inputs are calculated from the following formulas:

$$Ln(Y^{n1}/Y^{n0}) = (\sum_{i=1}^{I} 1/2[s_i^{n1} + s_i^{n0}]Ln(y_i^{n1})/y_i^{n0}); \quad \textbf{(2a)}$$

[18] If there are not constant returns to scale, then cost shares are not the correct weights to represent cost-minimizing producers.

$$Ln(X^{n1}/X^{n0}) = \left(\sum_{j=1}^{J} 1/2[c_i^{n1} + c_i^{n0}]Ln(x_i^{n1})/x_i^{n0}\right); \quad (3a)$$

where s_i represents the share of revenues earned by the ith good relative to total revenues from I goods and, assuming constant returns to scale, c_j represents the share of costs expended on the jth input relative to total costs on J inputs, and Ln represents the natural log function. If constant returns to scale are not imposed, then c_j represents the cost of the jth input relative to revenues. A detailed discussion of the above index is provided in Ball (3), Capalbo and others (5), and Chambers (6).

Aggregate Input

To measure an aggregate input, a weighted average of labor services and land/capital services was calculated. The model was not restricted by constant returns to scale, so the ratios of expenditures to revenues on each of the two inputs were used as weights. This two-factor aggregate input is simple relative to multifactor measures, but: (1) is consistent with the Heckscher-Ohlin and Markusen models, (2) is more indicative of technological or scale differences than a single factor measure, and (3) is the best measure given the lack of data in Latin American countries.

An aggregate measure of the service flows from the stock of the land/capital was calculated from the service flows of five components of the land/capital. First, a price of the service flows of cropland, pasture land, irrigated land, harvesters, and tractors was calculated. For all three measures of land, average per-hectare returns were used as an estimate of average per-hectare land rents. Since harvester and tractor rents were not available, the Jorgenson rental price of these factors was calculated. The calculation technique is described by Ball (3) and calculates the rental price as the sum of the opportunity cost of capital (which subtracts capital gains) plus depreciation and taxes of capital. Taxes were not used to calculate rental prices in this paper since they are rarely collected from producers in Latin America.

Second, an aggregate price index of service flows of land/capital was calculated by taking a weighted average of service flow prices of the three land types, harvesters, and tractors. Expenditure shares of each component of the land/capital input (expenditures relative to total expenditures on the land/capital input) were used as the price weights. Third, this price index was divided into the value of service flows to get an implicit quantity measure of services of the land/capital stock (3).

Aggregate Output

The indices under the label value (quantity) in table 4 were calculated using a weighted average of the value (quantity) of output as a measure of aggregate output. Theoretically, a weighted average of the quantity of outputs should be used. However, sugar is a bulky crop with a low price. For some countries, the revenue share of sugar is higher than any other crop, despite its low price, because its tonnage is a large component of output. Therefore, tonnage of a low-value crop receives a high weight.

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