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Testing two trade models in Latin American agriculture

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Abstract

The Heckscher–Ohlin and Markusen models state that countries export the goods intensive in the use of their relatively abundant factor. Latin American agricultural trade is consistent with both models. The paper then shows that Latin American agricultural trade is primarily explained by country differences in relative factor abundance between countries rather than differences in technology. This finding does not reject the Heckscher–Ohlin model but rejects one of Markusen's models.

1. Introduction

The two-factor, two-good, two-region Heckscher–Ohlin model has been a point of departure for a great amount of trade theory research. A key feature of the Heckscher–Ohlin model is that differences in the relative abundance of factors between trading regions determines the pattern of trade. Specifically, the Heckscher–Ohlin model predicts that a country will export the commodity that uses intensively its relatively abundant factor. This three-way linkage between the factor abundance of trading regions, the factor content of products, and the pattern of trade can be empirically tested.[1]

Baldwin (1971), Stern and Maskus (1981) and Leontief (1956) tested the Heckscher–Ohlin proposition that relative factor abundance determines trade patterns and obtained mixed results. Leontief (1956) aggregated over many commodities and factors and calculated the capital per man embodied in a million dollars of exports and imports of the United States. Stern and Maskus (1981) regressed U.S. trade of individual products on input requirements of those factors. These studies, focused on the United States, did not relate the revealed factor content of exports with observed factor endowment data, and raised more questions than they answered.

Leamer (1974, 1980) tested the Heckscher–Ohlin proposition by regressing net exports of commodities on measures of factor supplies. Leamer included data from many countries in his studies and explicitly dealt with observed factor endowments (which Leontief did not measure) but did not measure factor intensities of commodities. Bowen, Leamer and Sveikauskas (1987) connected all three links between factor endow-

[1] The Heckscher–Ohlin model and the assumptions underlying it are reviewed by Abbott and Haley (1988) and Coyle et al. (1987) and is presented in most economic textbooks on trade.

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ments, factor content, and trade. Using data for 27 countries they ranked the factor content of exports with factor endowments and found a fairly strong relationship.

Lee et al. (1988) used agricultural data to test the link between factor content and trade. These authors broke U.S. agriculture production into 16 sectors and agricultural processing into 14 sectors, and calculated the factor content of a million dollars worth of agricultural exports and compared this with the factor content of a millions dollars worth of domestically consumed agricultural goods.

Except Bowen et al. (1987) each of the above studies examines only two of the three links in the Heckscher–Ohlin model. Also, most of the studies expanded beyond the two dimensions allowed by the original Heckscher–Ohlin model. Jones (1979) demonstrates that theoretically it is difficult to expand beyond two sectors. Vanek (1968) did extend the model but had to amend the Heckscher–Ohlin proposition.[2] Furthermore, all of the above studies ignore factor trade, which is a significant component of world trade, and was incorporated into the Heckscher–Ohlin model by Mundell (1957).

The results of the above studies also have been mixed. These mixed results along with the high levels of intra-industry trade among developed countries have led some economists to say that the Heckscher–Ohlin model better applies to trade between developed and developing countries (see Markusen and Wigle, 1990). Yet no study exclusively has used developing country data to test the relationship between relative factor abundance and the factor content of exports.

The present paper demonstrates that Latin American agricultural exports are correlated with the relative factor abundance of Latin America's agricultural economies. The paper then investigates if relative factor abundance is the *only* determinant of exports. This paper is unique in three ways: (1) It does not focus on exports of developed economies. (2) It defines the agricultural sector as a trading unit. Previous literature limited trading regions to politically established borders. (3) It develops an empirical test to distinguish between the Heckscher–Ohlin model and a related general equilibrium model that recognizes the importance of factor trade.

2. Markusen model

The Heckscher–Ohlin model allows factors to move between sectors of a country but does not allow factors to be traded between countries or trading regions. Mundell amended the Heckscher–Ohlin model and showed that the gains from trade are equivalent if factors are traded instead of goods (1983).[3] Perhaps, because of this equivalence between factor trade and output trade, economists have ignored factor trade when testing the Heckscher–Ohlin model. Markusen showed that factor trade should not be ignored.

Markusen (1983) introduces several two-factor, two-sector general equilibrium models. In each model, factor trade plays a major role in establishing the pattern of output trade. Markusen's (1983) model also predicts that countries export goods intensive in the use of their relatively abundant factor. Therefore the results of traditional studies of the Heckscher–Ohlin model cannot distinguish between a Heckscher–Ohlin–Mundell model and Markusen's models. If factor trade is important, there needs to be a way to distinguish between the Markusen model and the Heckscher–Ohlin–Mundell model.

Markusen presents many versions of his model but the key feature of each of his models is that, previous to trade, the relative factor abundance of trading units are equivalent. Thus the driving force for trade in the Heckscher–Ohlin model is eliminated. In one model, Markusen assumes

[2] Vanek proposed that a country will export the services of abundant factors and import the services of scarce factors. This proposition is related to, but weaker than the original H–O proposition. It may be extremely difficult to adapt the Rybczynski and Samuel–Stolper theorems to higher-dimension models (see Leamer, 1984).

[3] Space does not permit a review of Mundell's well known and often cited paper (1957).

countries do *not* have identical technologies. In another, Markusen assumes production is *not* characterized by constant returns to scale. In yet another, domestic distortions are introduced. Differences in technologies, or returns to scale in production, or domestic distortions create trade.

In each of these cases 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." Markusen lets 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."

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 models is not trivial. Factor trade *complements* goods trade in Markusen's model. In contrast, Mundell (1957) showed that trade in factors will *substitute* for trade in goods.

In sum there are three distinctions between the Heckscher–Ohlin and Markusen models: (A) 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. (B) In the Heckscher–Ohlin model, factor endowments are exogenous. In the Markusen model, factor proportions emerge in endogenously as a result of trade. (C) In the Heckscher–Ohlin–Mundell model, factor and output trade substitute for each other. In the Markusen models, factor and output trade complement each other.[4]

3. Testing both models in Latin American agriculture

There are many violations of the assumptions underlying the Heckscher–Ohlin model in the real world (see Coyle et al., 1987). Real-world complexities did not prevent economists from testing the factor content of U.S. exports and should not prevent testing the Heckscher–Ohlin and Markusen models in Latin America. The complexities of the real world also mean that neither the Heckscher–Ohlin or Markusen models can explain trading patterns of the real world perfectly. However, one model may better explain Latin American agricultural trade than the other.

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

$$\phi_{ri} \mathrm{F}_i(X_{ri1} X_{ri2}) = Y_{r1} \quad \text{for} \quad i = 1, 2 \tag{1}$$

where X_1 is labor, X_2 is capital, r denotes a subscript which is distinct for each country or trading unit, i denotes one of the two sectors, ϕ_r is a Hicks-neutral output-augmenting parameter representing the total factor productivity of the ith sector in country r. Total factor productivity differences could represent technological differences between countries or when written as $\phi_r(Y_{r1})$ represent differences in external returns to scale between countries. Y_{r1} is output of good 1 in country r. A similar production function is written for the other good.

In Markusen's models, exports are determined by relative productivity between sectors. Using agricultural data, this point can be tested against the Hecksher–Ohlin proposition that relative factor abundance determines exports by estimating the following cross-section equation:

$$\text{REX}^* = \beta_0 + \beta_1 \text{RA} + \beta_2 \text{RTFP} \tag{2}$$

where REX equals an index of the ratio of capital-intensive to labor-intensive agricultural exports for each agricultural sector, RA is an the

[4] When the real world contains a mix of both models, point (C) is difficult to test. In Markusen's model, increased exports (imports) of a good, say good 1, should increase imports (exports) of the inputs intensively used by that good. In the Heckscher–Mundell model increase exports (imports) of a good 1 should decrease exports (imports) of the input used intensively by that good. The direction of growth in input trade is the same in both models. The difference between models lies in the starting point for input trade. Mundell shows there is a positive level of input trade when trade in goods is prohibited. There is no input trade before there is trade in goods in Markusen's model. In the real world goods *are* traded so these two differences can be compared.

index of 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 represents the ratio of the two-factor productivity estimates of the capital-intensive sector to the two-factor productivity estimate of the labor-intensive sector.

If resource endowments explain relative agricultural exports (Heckscher–Ohlin), the index of factor abundance variable should be significant in Eq. (2). If technology (Markusen) or scale effects or other reasons for total factor productivity differences between countries explains relative agricultural exports, then the RTFP indices should be significant in Eq. (2).

Another distinction between the Heckscher–Ohlin and Markusen models invite comparison. In the Markusen model relative factor abundance emerges endogenously as a result of trade. This can be tested against the Heckscher–Ohlin assumption that relative factor abundance is exogenous by estimating the following equation:

$$\text{RA} = \beta_0 + \beta_1 \text{REX}_{-1} + \beta_2 \text{PDN} \quad (3)$$

where PDN represents the population density in the country at large, and a lagged REX_{-1} is the relative agricultural export index. In this paper cross-sectional export data represent a five-year average so allowing a one-period lag gives at least 5 years for relative exports to influence relative factor abundance.

If the lagged relative exports variable in Eq. (3) is significant then relative factor abundance emerges endogenously as a result of trade.[5] If the lagged REX variable is insignificant, then the relative factor abundance is primarily exogenous.

In order to estimate Eq. (2) and (3) a measure of relative agricultural exports, a measure of relative factor abundance, and a measure of the relative technology (scale) parameters had to be calculated. The following sections describe how agriculture in 16 Latin American countries was classified into two sectors, the data used in calculating relative exports, the data used in calculating relative factor abundance of the agricultural sectors, and how the parameter (ϕ) was calculated for each agricultural sector in 16 Latin American countries.

4. Two-sector production classification

Economists typically let trading regions be defined by political boundaries, such as national borders. Nothing prevents applying the Heckscher–Ohlin and Markusen models to regions consisting of a group of countries or subregions within a country. This paper classifies the agricultural sector of each country as a trading unit.[6] Sales of agricultural goods to urban regions of a country are counted as exports. The advantage of this approach is: (1) The dimensions of the model are kept to two sectors without forcing all of agriculture into one sector. (2) Problems of aggregating non-homogeneous goods are reduced since, relative to industrial goods, agricultural goods are homogenous products.

Agricultural production and trade of 16 Latin American countries was broken into two sectors: a labor-intensive sector and a sector intensive in both land and/or capital. Agricultural products were classified into either sector with the help of budget and wage data obtained from the Brazilian government and the Getulio Vargas foundation.[7] Table 1 lists the labor requirements per

[5] Note only the agricultural capital component of the land–capital factor can be traded. This would limit the capacity of a country with no capital to export land-capital. It is obvious that if agricultural capital is present in each country, factor prices equalize. A three-factor model would be required to determine if land prices themselves would equalize across countries.

[6] 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.

[7] This study follows the tradition established by Baldwin (1971), Leamer (1980), Leontief (1956) and Stern and Maskus (1981) who take the factor content of products from the United States and assume the same content holds for other countries. This paper uses the factor content of products in Brazil rather than products of the United States. This approach is consistent with Markusen's model since he writes technological differences between countries as a Hicks-neutral parameter that does not influence the relative factor content of a product.

hectare, and the labor to capital spending ratios of available Brazilian crops. Clearly, production of coffee, fruits, and vegetables is more labor-intensive than grains and oilseeds and sugar requires a large capital investment relative to labor. Therefore, 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.

5. Exports of the agricultural sector

Since storage of agricultural products is practically negligible in Latin America, exports of the agricultural sector were defined as agricultural production minus the value of rural consumption. Rural consumption was calculated by multiplying domestic consumption by the share consumed in rural areas. Average domestic consumption from 1975 to 1985 of each commodity equaled the average 1975–85 value of each country's production minus the average 1975–85 value of *international* sales. Production and export data was obtained from published reports of the United Nations Food and Agricultural Organization.

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. 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.

Rural consumption figures were adjusted by differences in the rural population between the base country and base period (Brazil, Peru) and the country and time of interest. Suppose the rural sector in Brazil, for example, comprised 50% of the population and consumed 40% of Brazilian grains. Suppose in 1980 the rural sector of another country comprised 25% of its population. That country's rural sector was estimated to have consumed 20% of that country's grain crop.[8]

Rural sector exports of each commodity were computed by subtracting rural consumption from production. Then using the labor-capital classification of each commodity from the previous section, 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 normal-

Table 1
Ranking of Brazilian crops (1975–1985 average)

Labor days per ha		Ratio of labor to machinery cost	
Column 1		Column 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	0.9	Rice
18.2	Beans	0.8	Sorghum
10.9	Corn	0.8	Sugar
7.3	Sorghum	0.7	Soybeans
5.8	Soybeans	0.6	Corn
3.0	Wheat	0.2	Wheat

Source: Derived from 1975–1985 budgets published in successive issues of the Brazilian publication *Prognostico* and from wage and price data from the Getulio Vargas foundation.
[1] *Prognostico* often publishes more than one budget per crop, reflecting the region of the country or the level of technology. These data were taken from an average of all budgets expect for the potato budget. The potato budget that does not use 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 wet and dry rice cultivation. The latter is the primary manner of growing rice in Brazil.

[8] The above approach takes limited account of differences in rural consumption habits across countries and assumes the marginal propensity to consume food products is equal in the rural and urban regions of each country. However, Brazil and Peru were the only Latin American countries where available estimates of rural and urban consumption were considered credible.

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

Ratio of land-capital to labor-intensive agricultural exports		Agricultural capital-land to agricultural 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	Dominican 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	Dominican Rep.	3.8	Dominican Rep.
9.4	El Salvador	3.8	El Salvador	2.3	Guatemala
7.6	Ecuador	3.7	Guatemala	2.2	El Salvador

Column 1 ranks each country's agricultural sector by an index of the relative exports (land-capital-intensive to labor-intensive agricultural exports). The divergence between the agricultural sectors was so large the index was normalized so that the second to the top country index equaled 100. The indices were calculated from average 1975–85 data.
Column 2 ranks countries by land-capital to agricultural labor ratios. Indices are based on 1975–1985 data.
The land-capital factor was created by obtaining a weighted sum of the three types of land, harvesters, and tractors. Prices of these inputs were used to obtain the weights. Agricultural land, machine and labor data were obtained from FAO.

ized so the second to the top country equaled 100. Argentina's and Uruguay's, agricultural sectors, which export grains and beef but export little coffee, fruits, or vegetables lead the list. The agricultural sectors of El Salvador and Ecuador who are primarily coffee exporters, are on the bottom.

6. Relative factor abundance

The agricultural sectors of Latin American countries were ranked by their agricultural land-capital to agricultural labor ratios. Five items served as a proxy for measuring agricultural land-capital: non-irrigated crop land, 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.

Agricultural land data in all categories were obtained from FAO. Annual FAO estimates of the number of harvesters and tractors were converted into non-depreciated equivalents by depreciating machines 5% a year from their purchase date. The final measure of the agricultural land-capital factor represented a weighted sum of non-depreciated harvester equivalents, non-depreciated tractor equivalents, and the three types of agricultural land. Prices of the factors were used as weights.[9]

Land prices are not available in Latin American countries. De Janvry used the difference between revenues and operating costs to get an estimate of land rents in developing countries (1989, p. 379). A similar approach was used to calculate land rents in this paper. The value of agricultural land was calculated by applying standard present value formulas to returns to land.

[9] International sale prices were used for harvesters and tractors.

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 agricultural land to labor ratio is included in Table 2. The agricultural sector of Argentina and Uruguay, who have much land but little rural labor, lead the list while the agricultural sector of Guatemala and El Salvador, which have little land are at the bottom.

Fig. 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 of Fig. 1 has been adjusted to exaggerate the dispersion of countries that crowd into the South West corner. As would be predicted by both the Heckscher–Ohlin and Markusen model, the agricultural sectors of Latin American countries fall along a north east to south west diagonal, with the exceptions of those of Chile and the Dominican Republic.

7. Productivity indices

Two factor productivity indices provide a measure of the country specific Hicks-neutral output augmenting parameter (ϕ_r) in Markusen's production functions. These indices were calculated for each agriculture sector in the 16 Latin American countries by using the formula:

$$\text{TFP}^{n1}/\text{TFP}^{n0} = \left[Y^{n1}/Y^{n0}\right]/\left[X^{n1}/X^{n0}\right] \qquad (4)$$

where Y^{n1} is aggregate output in country $n1$, and X^{n1} is aggregate factor in country $n1$. Relative

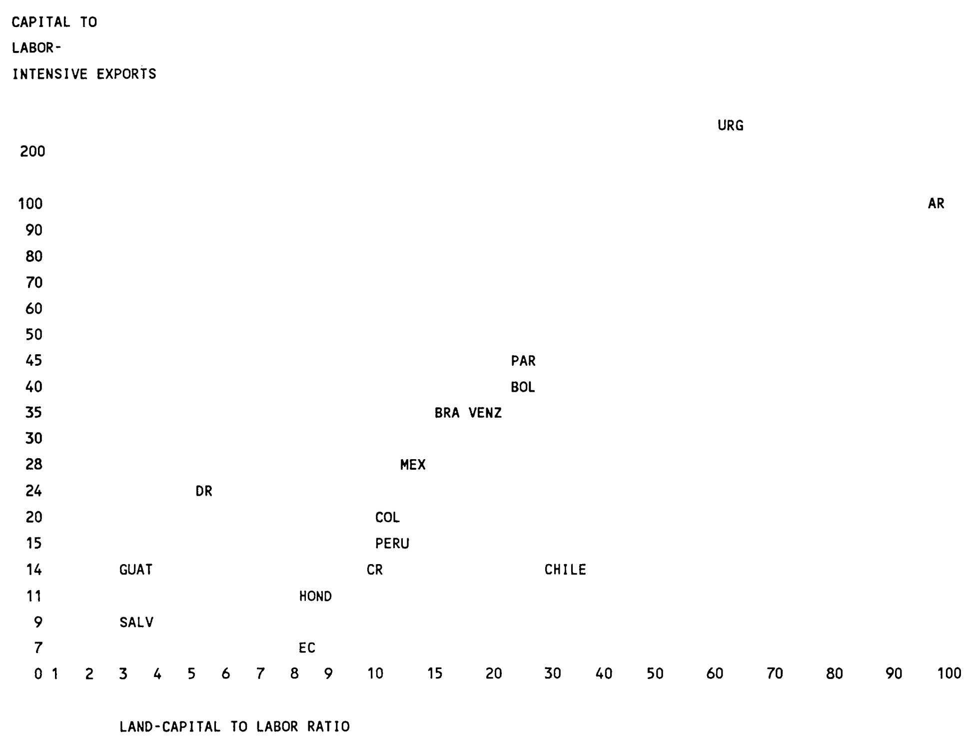

Fig. 1. Breakout of countries by capital to labor-intensive agricultural exports and by relative factor intensities of their rural sectors. Countries are abbreviated by their initials: AR represents Argentina, BRA Brazil, BOL Bolivia, COL Colombia, CR Costa Rica, DR the Dominican Republic, EC Ecuador, HOND Honduras, GUAT Guatemala, MEX Mexico, PAR Paraguay, SALV El Salvador, URG Uruguay and VENZ Venezuela.

outputs and inputs are calculated from the following formulas:

$$\ln(Y^{n1}/Y^{n0}) = \sum_{i=1}^{I} \tfrac{1}{2}\left[s_1^{n1} + s_i^{n0}\right] \ln(y_i^{n1})/y_i^{n0} \tag{5}$$

$$\ln(X^{n1}/X^{n0}) = \sum_{j=1}^{J} \tfrac{1}{2}\left[c_i^{n1} + c_i^{n0}\right] \ln(x_i^{n1})/x_i^{n0} \tag{6}$$

where ln represents the natural log function, 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 revenues. The weights on the inputs allow for Markusen's point that production may not be constant returns to scale (see Chambers, 1988, p. 247).

Discussion of the multifactor Tornqvist index is provided in Ball (1984) and Chambers (1988). The present paper is restricted to a two-factor model so all available inputs were aggregated into two factors.[10] The two-factor productivity indices represent one point in time (using average 1975–85 data), but compares this measure across 16 countries.

Separate productivity indices were calculated for the labor-intensive sector and the land-capital-intensive sector. The estimated allocation of the capital–land factor between the capital-intensive and labor-intensive sectors was determined from the relative acreage planted to each sector. Allocation of labor 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 in Table 1. For example suppose a country had only two crops; grains which used 75% of the agricultural land and fruits which used 25% of the agricultural land. Suppose also that grains used 10 hours of labor per hectare and fruits used 40 hours per hectare. Then it can be determined that 43% of the labor was used in grain crops and 57% were used in fruit crops.

To measure the quantity of service flows of land-capital a price index of the service flows of land-capital was divided into the total value of service flows of crop land, pasture land, irrigated land, tractors, and harvesters. The price index of service flows of the land–capital factor was represented by a weighted average of rental prices of crop land, pasture land, irrigated land, and calculated service prices of harvesters, and tractors. Tractor and harvester rents were calculated from the Jorgenson rental price (see Ball, 1984).

Table 3 reports Tornqvist productivity indices for each agricultural sector. The productivity of Central American countries is relatively high since the rest of Latin America has a large amount of low productive pasture land.

Table 3
Estimates of two-factor productivity of agriculture

Country	Labor-intensive sector index	Capital-intensive sector index
Argentina	1.00	1.00
Bolivia	0.40	0.64
Brazil	0.73	0.51
Chile	0.50	0.50
Colombia	0.84	0.52
Costa rica	1.74	1.18
Dominican Rep.	0.54	0.62
Ecuador	0.60	0.42
El Salvador	1.53	1.25
Guatemala	0.84	0.73
Honduras	0.70	0.63
Mexico	0.34	0.14
Peru	0.83	1.05
Paraguay	1.36	2.14
Uruguay	0.29	1.61
Venezuela	1.07	1.31

Capital-intensive crops consist of beef, grains, oilseeds, and sugar crops, Labor-intensive crops consist of coffee, cocoa, fruit, melons, pulses, roots and tubers, tea and vegetable crops. The revenue share of each of these categories represent the weights on the output component of the productivity indices.

Since constant returns to scale was not assumed the shares of expenditures of each input relative to revenues represented the weights on the input components of the productivity index.

[10] 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.

8. Productivity versus factor abundance

Table 4 reports the results from estimating Eq. (2). This equation specified relative exports to be a function of relative factor abundance and relative productivity. Two models are reported. Both are significant at the 0.01 confidence level as given by the equation F statistic. The model in column 1 is an estimate of Eq. (2) using data from all 16 Latin American agricultural economies. The model in column 2 drops Uruguay from the regression. Uruguay was an outlier in the relative productivity data set. The difference in the results in Table 4 indicates a high sensitivity of the model to this outlier.

Table 4 reports statistics called FR1 and FR2. FR1 is an F statistic which tests the hypothesis that the estimators on the relative factor abundance variable are not significantly different from zero. FR2 is an F statistic that tests the restriction that the estimators on the relative productivity variable are not significantly different from zero. In both models the F statistic on the relative factor abundance variable (FR1) is significant at the 99% confidence level. It is clear that relative factor abundance is a significant factor in determining the exports of Latin America's agricultural sectors.

The significance of the relative productivity variable is quite different between models. In the first model, which includes Uruguay, the F statistic on the relative factor productivity variable (FR2) is significant at the 99% confidence level. However, in the model which does not include Uruguay, the F statistic on the relative factor productivity variable (FR2) is not significant.

The discrepancy in results is quite illuminating. It is a reminder that outliers can dramatically alter the inferences drawn from a sample. Sample choice is important in testing theory. This point is particularly important in this case since Leontief (1956), Baldwin (1971) and Stern and Maskus (1981) focused their studies on one country.

Table 5 reports the results of estimating Eq. (3). This equation specified relative factor abundance of the agricultural sector to be a function of lagged relative exports and population density of the country at large. Lagged relative exports were represented by the ratio of the 1970–1975 average of capital-intensive agricultural exports to the 1970–1975 average of labor-intensive agricultural exports. The Markusen model predicts this variable should determine relative factor abundance. The results in Table 6 indicate that

Table 4
Estimates from Eq. (2)

The endogenous variable is an index of relative exports

Exogenous variable	Model 1	Model 2
Constant	−17.72	4.50
	(−3.44)	(1.29)
Relative factor abundance	0.84	0.87
	(5.67)	(7.71)
Relative productivity	30.3	6.20
	(9.67)	(0.79)
	RBAR = 0.93	RBAR = 0.81
	F(2,13) = 103.5 **	F(2,12) = 32.49 **
	FR1(1,12) = 32.17 **	F(1,11) = 59.4 **
	FR2(1,13) = 93.3.05 **	F(1,12) = 0.62

Model 1 reports the results of agriculture sectors of all 16 countries. Model 2 drops Uruguay's agricultural sector from the equation. T statistics are in parenthesis. F statistics test the restriction that all estimators except the constant are zero. FR1 tests the restriction that estimators on the relative factor abundance variables is zero. FR2 tests the same restriction on the relative productivty variable. Two asterisks notes significance of F statistic at the 0.01 confidence level. One asterisk notes significance at the 0.05 level.

Table 5
Estimates from Eq. (3)

The endogenous variable is an index of relative factor abundance (1975–1985)

Exogenous variable	Model 1
Constant	23.72
	(2.41)
Relative factor abundance	0.08
	(0.845)
Relative productivity	−0.014
	(−1.22)
	RBAR = 0.06
	F(2,13) = 1.54

The 1975–85 average of relative factor abundance of the agricultural sector is regress of relative agricultural exports from the 1970–1975 average of relative agricultural exports and population density of the country at large.
T statistics are in parenthesis. F statistics test the restriction that all estimators except the constant are zero.

this variable, as well as the population density variable of the country at large, does not influence the relative factor abundance of the agricultural sector.

The combined information in Tables 4 and 5 imply that the Heckscher–Ohlin model better explains Latin American agricultural trade than the Markusen model. Differences in relative factor abundance between Latin America's rural sectors explain much of Latin America's agricultural exports. However, Uruguay's agricultural exports may be partially explained by the relatively large differences between 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.

9. Conclusion

The rural economies of Latin America export agricultural goods intensive in the use of their relatively abundant agricultural factor. This evidence supporting the Heckscher–Ohlin and Markusen model appears despite violations of the more extreme assumptions underlying both models in the real world. Differences in relative factor abundance between countries better explain the trading patterns of Latin America's agricultural sectors than differences in technology. These results support the Heckscher–Ohlin model.

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. For further research, the factor intensity of crops needs to be calculated in *each* country. Also, more detailed estimates of a land–capital factor are required. If Markusen's model applies to a certain region then the time it would take for factor abundance to emerge endogenously as a response to trade needs to be further explored. Currently lack of data limits exploration of these issues.

For future study, economists should ask why there is empirical evidence of the Heckscher–Ohlin model in Latin America even when many of its underlying assumptions are violated. Perhaps the assumption that factors (or outputs in the Mundell model) are not traded is unnecessarily restrictive. There may exist a less restrictive general equilibrium model which leads to the same conclusions of the Heckscher–Ohlin model.

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