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# Resource supplies and changing world agricultural comparative advantage

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**Abstract**

This paper advances consideration of the Heckscher–Ohlin (H-O) theory of comparative advantage to agriculture in a dynamic setting. The dynamic relationship among trade flows, resource supplies, and factor contents is studied. The view that special circumstances in the agricultural sector render the H-O theory inapplicable as a guide to agricultural trade is challenged. Consistent with the H-O theory, the results suggest that changing world patterns of resource abundance are an important explanation of the evolving structure of world trade in agriculture commodities.

## 1. Introduction

The purpose of this study is to determine if changes in U.S. trade reflect changes in agricultural factor endowments, in accordance with the Heckscher–Ohlin (H-O) theory of international trade. Ricardo's theory of comparative advantage originally explained international trading patterns based on labor productivity across nations. Haberler (1936) modified Ricardo's theory by focusing on relative costs of production, rather than the labor theory of value. The nation with the lower relative cost of producing a good will specialize in production and export to its trading partner, importing goods for which the trading partner has a lower relative cost of production. The theory of comparative advantage predicts trade patterns on the basis of relative costs, but does not explain why one nation has lower relative costs than its trading partner. A nation's production possibilities frontier is determined by the factors that affect relative production costs.

The H-O theory of international trade explains the differences in relative costs (comparative advantage) by focusing on initial factor endowments. The H-O theory states that a country has comparative advantage in products that use a higher ratio of abundant to nonabundant factors

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than products that have a lower abundant to nonabundant factor ratio. The more abundant (relatively cheaper) factor will be used more intensively in exported products. This can be illustrated with the following relationship:

$$\frac{F_{11}}{F_{21}} > \frac{F_{12}}{F_{22}}$$

where $F_{ij}$ is factor $i$ used to produce good $j$.

In the above example, if factor $i = 1$ is the abundant factor, the nation will produce and export good $j = 1$, while importing good 2. If the nation is capital-rich (technology, infrastructure, human capital) relative to its trading partner, the H-O theorem predicts that exported products will have a higher capital to other factor ratio than imported products.

Due to the nature of developing nations' relatively abundant factors (natural resources, low-skill labor), relative to industrial nation trading partners, developing nations perceive that comparative advantage traps them by their initial endowments into never-ending cycles of exploitation by industrialized nations. This conclusion requires a static interpretation of comparative advantage. Nations can alter their comparative advantage in a dynamic setting through investment in infrastructure, education, and technology. It is possible to observe changing comparative advantage, as has been illustrated by the dynamically growing economy of South Korea.

The H-O theory has been frequently tested; however, most of the early empirical efforts concentrate on the determinants of comparative advantage in manufactured goods in a single year (Baldwin, 1971; Branson and Monoyios, 1977; Harkness, 1978; Harkness and Kyle, 1975; Leontief, 1954). More recently, studies have extended the H-O model to a dynamic setting and have examined how changes over time in resource supplies alter trade structure (Stern and Maskus, 1981; Bowen, 1983).

The H-O theory of international trade is based on several key assumptions. These assumptions include: (1) identical production functions across countries; (2) identical and homothetic consumer preferences for all countries; and (3) perfect competition in all markets and full employment of resources. Agricultural products are a special challenge for applications of the H-O theorem due to special circumstances in the agricultural sector that lead to violations of several key assumptions of the model. Special circumstances in the agricultural sector that have been particularly noted include: (a) non-uniform technology across countries; (b) pervasive government intervention; (c) nonhomothetic demand patterns; and (d) the unique importance of natural resource endowments that are often difficult to measure. All but the last point involve violations of assumptions of the H-O model.

For these reasons, Haley and Abbott (1986b) suggest that sector-specific Ricardian models are more appropriate for both applied and theoretical work on agricultural comparative advantage. Several observers have argued that agricultural and manufactured processes are sufficiently different to render the H-O theory inapplicable as a guide to agricultural trade (Ball, 1966; Leontief, 1956; Abbott and Thompson, 1987). Due to the above mentioned difficulties, few efforts have attempted to explain agricultural trade patterns on the basis of the H-O theory of comparative advantage. Notable exceptions include Leamer (1984), Haley and Abbott (1986a) and Vollrath and Vo (1988).

The importance of the special circumstances shaping long-run agricultural comparative advantage is far from resolved. It may be possible to use the H-O theorem to measure dynamic changes in factor endowments used in agricultural products. A large empirical study of world agricultural competitiveness undertaken at the U.S. Department of Agriculture (Vollrath and Vo, 1988) provides support for both the Ricardian and H-O theories. The study finds that relative labor and land productivities are directly related to export shares, suggesting a technological (Ricardian) explanation of trade. The study also provides support for the H-O viewpoint, however finding that resource supplies including human capital, research and development, and capital endowments contribute significantly to export performance. These real economic variables are found to be much more important in determining trade performance than are government interventions which support domestic prices and shifts in monetary policy. Leamer (1984) has also empirically applied the H-O model and finds that trade patterns of three agricultural commodity aggregates are explained surprisingly well by a relatively small list of resource endowments.

This paper does not attempt to determine which trade theory is most appropriate for agriculture, but it does advance consideration of the H-O theory to agriculture in a dynamic setting. In particular, the dynamic relationship between trade flows, resource supplies, and factor contents is studied. Unlike the Leamer (1984) estimates of agricultural trade patterns using economy-wide resource endowments, we report a substantial data effort directed at studying the relationship of agricultural trade to resource supplies specific to the agricultural sector. The first section examines changing patterns of resource supply among a select group of 59 countries studied over the period 1966–86. The second section investigates several key relationships between these resource changes and observed changes in agricultural trade.

## 2. Changing distribution of agricultural resource supplies

Changing resource structure in agriculture can be illustrated by observing levels of capital per worker (tractor horsepower as a proxy for capital endowment) [1], skilled labor to total labor, irrigated land to arable land, and arable land per worker over time. Data were collected on 59 countries for 1966 and 1986. Tables 1 and 2 summarize the data for selected developed and developing countries, respectively. [2]

Table 1 shows that the United States has historically been dominant in capital per farm worker, supporting the conventional wisdom that the United States is a relatively capital-abundant country. The United States has the highest level of tractor horsepower per farm worker in both 1966 and 1986. However, it had a capital growth rate of only 2.3%, well below the rest of the developed nations. Canada was approaching the United States in tractor horsepower per farm worker in 1986 following a growth of 4.7% over the previous 20 years. Among the developed nations, Japan, Spain, and Italy experienced the

Table 1
Selected developed countries, 1966 and 1986

| Country | Year | Tractor [a] | Irrigate [b] | College [c] | Arable [d] |
|---|---|---|---|---|---|
| Australia | 1966 | 21.17 | 3.4% | 17.33 | 88.82 |
| | 1986 | 46.87 | 3.8% | 37.81 | 110.15 |
| Canada | 1966 | 31.89 | 0.9% | 9.64 | 55.39 |
| | 1986 | 85.82 | 1.7% | 100.59 | 90.24 |
| France | 1966 | 9.20 | 3.8% | 2.73 | 5.20 |
| | 1986 | 47.98 | 6.6% | 21.18 | 11.33 |
| Germany | 1966 | 13.71 | 3.7% | 3.43 | 2.74 |
| | 1986 | 58.20 | 4.4% | 37.10 | 5.69 |
| Italy | 1966 | 2.90 | 19.9% | 1.07 | 2.52 |
| | 1986 | 26.26 | 33.3% | 16.82 | 4.53 |
| Japan | 1966 | 1.31 | 64.1% | 7.68 | 0.42 |
| | 1986 | 15.08 | 69.4% | 33.53 | 0.86 |
| Spain | 1966 | 1.37 | 14.7% | 0.47 | 4.05 |
| | 1986 | 15.24 | 21.0% | 4.93 | 8.57 |
| United Kingdom | 1966 | 16.65 | 1.4% | 8.72 | 8.76 |
| | 1986 | 42.08 | 2.2% | 55.24 | 11.24 |
| United States | 1966 | 53.09 | 8.7% | 26.71 | 41.91 |
| | 1986 | 86.62 | 9.6% | 92.10 | 58.01 |

highest growth rates in tractor horsepower per farm worker (11.6%, 11.5%, and 10.5%, respectively). The other developed nations listed in Table 1 had capital growth rates of 3.8% (Australia), 7.9% (France), 6.9% (Germany), and 4.4% (United Kingdom). Average tractor horsepower per worker growth rates were 6.1% and 7.6% for developed and developing countries, respectively. [3] Several newly industrialized countries (Korea, Hong Kong, Thailand, and Singapore) exhibited especially high growth rates in tractor horsepower per farm worker (29.5%, 28.9%, 17.9%, and 13.2%). Table 2 lists changes in structural variables for selected developing nations. Brazil, China, India, and Turkey have similar rates of growth in tractor horsepower (10.0%, 12.4%, 11.9%, and 11.9%, respectively). Argentina, Egypt and Mexico have relatively small growth rates (3.7%, 5.5%, and 3.3%, respectively).

Another measure of capital accumulation in agriculture is given by the percentage of arable land irrigated – a proxy for countries' endowment of improved land. The United States' rank in this variable declined from 29th to 35th from 1966 to 1986. Strength in this variable is related to the quality and quantity of domestic land resources: countries with a high percent of arable land irrigated tend to be those with a small or poor land resource base (Egypt, Israel, Japan). Growth rates in irrigated land for selected developed nations ranged from 0.5% to 2.8% (Table 1). The range was wider for developing nations, starting at 0.2% for Egypt up to 4.4% for Brazil (Table 2).

The United States was dominant in skill endowments (as measured by the number of agricultural college graduates per 10 000 farm workers) in the 1960's, but was surpassed by Canada in the 1980s. Other developed countries illustrating high investments in farm education include the European countries of France, Germany, Italy, and Spain (growth rates of 10.3%, 11.9%, 13.8%, and 11.7%, respectively). However, these countries started with substantially lower ratios in the 1960s and remained well behind the United States and

Table 2
Selected developing countries, 1966 and 1986

| Country | Year | Tractor [a] | Irrigate [b] | College [c] | Arable [d] |
|---|---|---|---|---|---|
| Argentina | 1966 | 3.05 | 5.3% | 2.75 | 13.74 |
| | 1986 | 6.58 | 6.5% | 9.43 | 21.01 |
| Brazil | 1966 | 0.28 | 1.5% | 0.55 | 3.30 |
| | 1986 | 2.27 | 3.7% | 8.66 | 4.76 |
| China | 1966 | 0.01 | 33.6% | 0.55 | 0.33 |
| | 1986 | 0.13 | 47.2% | 0.62 | 0.22 |
| Egypt | 1966 | 0.10 | 103.6% | 2.14 | 0.59 |
| | 1986 | 0.31 | 107.1% | 10.79 | 0.42 |
| India | 1966 | 0.01 | 16.8% | 0.39 | 1.04 |
| | 1986 | 0.13 | 25.3% | 0.95 | 0.82 |
| Mexico | 1966 | 0.35 | 14.8% | 0.14 | 3.43 |
| | 1986 | 0.71 | 22.4% | 3.21 | 2.58 |
| Thailand | 1966 | 0.01 | 15.5% | 0.46 | 0.91 |
| | 1986 | 0.41 | 22.0% | 6.96 | 0.98 |
| Turkey | 1966 | 0.17 | 6.3% | 0.73 | 2.15 |
| | 1986 | 2.09 | 8.8% | 1.94 | 2.10 |
| Yugoslavia | 1966 | 0.31 | 1.7% | 3.76 | 1.55 |
| | 1986 | 14.23 | 2.1% | 9.79 | 2.62 |

[a] Tractor horsepower per farm worker.
[b] Irrigated land as a percent of arable land.
[c] Number of agricultural college graduates per 10 000 farm workers.
[d] Hectares of arable land per farm worker.
*Sources:* Hayami and Ruttan (1985), Food and Agriculture Organization of the United Nations, and UNESCO Statistical Yearbook (various issues).

Table 3
World resource shares: Developed countries (percent of world total)

| Country | Year | Tractor [a] | Irrigate [b] | Labor [c] | Arable [d] |
|---|---|---|---|---|---|
| Australia | 1966 | 2.08 | 0.88 | 0.05 | 3.07 |
| | 1986 | 1.91 | 0.78 | 0.04 | 3.41 |
| Canada | 1966 | 5.24 | 0.25 | 0.09 | 3.22 |
| | 1986 | 4.19 | 0.34 | 0.05 | 4.19 |
| France | 1966 | 7.16 | 0.46 | 0.42 | 1.43 |
| | 1986 | 7.31 | 0.52 | 0.15 | 1.31 |
| Germany | 1966 | 8.09 | 0.18 | 0.32 | 0.57 |
| | 1986 | 7.12 | 0.14 | 0.12 | 0.53 |
| Italy | 1966 | 3.15 | 1.61 | 0.58 | 0.96 |
| | 1986 | 5.04 | 1.34 | 0.19 | 0.66 |
| Japan | 1966 | 3.58 | 2.21 | 1.47 | 0.41 |
| | 1986 | 7.04 | 1.29 | 0.46 | 0.31 |
| Spain | 1966 | 1.15 | 1.48 | 0.45 | 1.20 |
| | 1986 | 2.66 | 1.44 | 0.17 | 1.13 |
| United Kingdom | 1966 | 3.06 | 0.07 | 0.06 | 0.51 |
| | 1986 | 2.50 | 0.07 | 0.06 | 0.51 |
| United States | 1966 | 48.76 | 9.94 | 0.49 | 13.62 |
| | 1986 | 26.93 | 8.02 | 0.30 | 13.68 |

Canada in total value by 1986 (college graduates per 10000 farm workers in the range of 5–40 for Europe versus 90–100 for North America). Developing nations had lower initial and ending values for agricultural education than the developed nations, with growth rates ranging from 0.6% (China) to 15.6% (Mexico). The growth rate of skill endowments for the United States (6.2%) was less than the average growth rate for developed countries (8.2%), but greater than the average growth rate for developing countries (5.0%). Canada rose from a rank of sixth to first in skill endowments. Other large gainers include European countries (West Germany and France) and

Table 4
World resource shares: Developing countries (percent of world total)

| Country | Year | Tractor [a] | Irrigate [b] | Labor [c] | Arable [d] |
|---|---|---|---|---|---|
| Argentina | 1966 | 1.05 | 0.74 | 0.19 | 1.68 |
| | 1986 | 0.79 | 0.75 | 0.12 | 1.91 |
| Brazil | 1966 | 0.82 | 0.42 | 1.57 | 3.41 |
| | 1986 | 2.98 | 1.06 | 1.28 | 4.73 |
| China | 1966 | 0.66 | 22.07 | 36.30 | 7.84 |
| | 1986 | 5.50 | 19.59 | 40.93 | 6.82 |
| Egypt | 1966 | 0.10 | 1.81 | 0.53 | 0.21 |
| | 1986 | 0.17 | 1.12 | 0.53 | 0.17 |
| India | 1966 | 0.35 | 17.32 | 18.00 | 12.29 |
| | 1986 | 2.50 | 18.60 | 19.07 | 12.08 |
| Mexico | 1966 | 0.50 | 2.11 | 0.76 | 1.71 |
| | 1986 | 0.61 | 2.29 | 0.84 | 1.69 |
| Thailand | 1966 | 0.03 | 1.15 | 1.48 | 0.88 |
| | 1986 | 0.72 | 1.73 | 1.72 | 1.30 |
| Turkey | 1966 | 0.42 | 0.97 | 1.31 | 1.86 |
| | 1986 | 2.35 | 0.96 | 1.10 | 1.79 |
| Yugoslavia | 1966 | 0.33 | 0.08 | 0.58 | 0.59 |
| | 1986 | 3.67 | 0.07 | 0.25 | 0.51 |

[a] Tractor horsepower, [b] irrigated land, [c] total agricultural labor, [d] arable land.

Latin American newly industrialized countries (Mexico and Brazil).

A fourth measure of investment in agriculture is the ratio of arable land to farm workers. Among developed nations, Australia, Canada, and the United States have consistently ranked one, two, and three in agricultural land to labor endowments, although growth rates have been relatively small. Aside from New Zealand, most industrialized countries have increased their relative land to labor endowments over the period 1966–86. On average, the developed country growth rate of arable land to labor was 3.7%. In contrast, most developing economies have experienced a weakening of their relative land intensity in agriculture – a consequence of relatively stable arable land area, but growing agricultural labor force. On average, the developing country growth rate of arable land to labor was −1.1%. This finding is surprising since conventional thought suggests that increased urbanization accompanying development diminishes the agricultural labor force.

In a multifactor context, resource abundance is appropriately determined by ranking a country's share of each world resource (Bowen, 1983). Tables 3 and 4 report selected developed and developing countries' shares of four world resources in 1966 and 1986. [4] In the 1960s, the United States was most abundant in agricultural capital (tractor horsepower), followed by skilled labor, arable land, irrigated land, and total agricultural labor. By 1986, however, U.S. capital abundance had eroded considerably. Although the United States remained most abundant in agricultural capital, the data suggest increased U.S. abundance in skilled labor and arable land per farm worker relative to capital. When assessed in terms of world resource shares, a dramatic decline in U.S. capital abundance is apparent.

Similarly, the decline in U.S. skilled labor abundance is apparent when assessing the changing U.S. share of total world resources. In contrast, other developed countries increased their share of skilled labor. Canadian skilled labor increased from 1.26 to 2.88 (percent of world total) between 1966 and 1986. France, Germany, Italy, Spain, and the United Kingdom all increased their share of skilled labor. Japan lost its share of skilled labor, which fell from 16.70 to 9.16 over the 20-year period.

Developed nations gaining shares of world tractor horsepower (proxy for agricultural capital accumulation) include France, Italy, Japan, and Spain. Gainers of share of irrigated land are Canada and France. Gainers of world shares of arable land per farm worker include Australia, Canada, and the United States. Developing nations experienced both gains and losses in skilled labor between 1966 and 1986. Gainers include Brazil, Egypt, Thailand, and Mexico. Losers of world share are Argentina, China (the biggest loser), India, Turkey, and Yugoslavia. Brazil, India, Mexico, and Thailand gained in share of irrigated agricultural land. Argentina, Brazil, and Thailand gained in world share of arable land per farm worker.

Overall, the data indicate substantial changes in international agricultural resource patterns between 1966 and 1986. For example, Brazil switched from abundance in arable land to greatest abundance in skilled labor; Thailand from abundance in total agricultural labor to skilled labor. In accordance with the H-O theory, these resource shifts can be expected to alter the patterns of world trade.

## 3. Factor abundance and changes in U.S. agricultural trade

To test whether changes in U.S. trade reflect the changes in factor abundance found above, the factor content of U.S. trade in 13 agricultural commodities is computed annually over 1976–88 (see Appendix). [5] The null hypothesis is to test if changes in U.S. trade reflect changes in agricultural factor endowments, in accordance with the Heckscher–Ohlin theory. Data on input coefficients were only available for 1977; the factor contents of each country's agricultural trade in other years are computed using year-specific trade vectors but constant input coefficients. Changes in input requirements could possibly modify conclusions based on the analysis below. However, we do not expect this to be a major problem since one may plausibly assume trade changes domi-


Fig. 1. Ratio of capital per worker embodied in U.S. agricultural exports relative to imports.

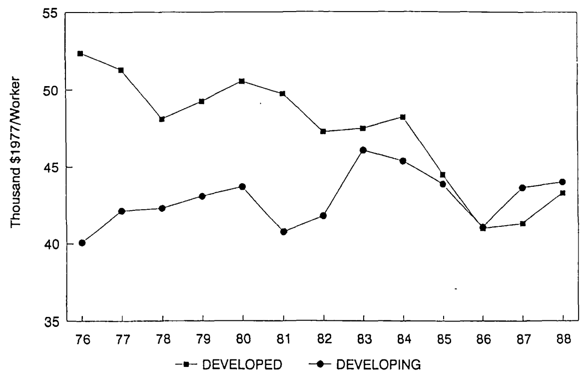


Fig. 2. Ratio of capital per worker embodied in U.S. agricultural exports to developed and developing countries.

nate changes in input usage (Bowen, 1983). Further, Heller (1976) found for Japan that input usage and trade changes moved in the same direction over time. Export–Import ratios are constructed using agricultural factors embodied in exports in the numerator, and agricultural factors embodied in imports in the denominator. Agricultural factors used in the ratios include capital per worker, skilled labor to total labor, and land to labor.

The results of computing the factor contents of U.S. trade in agricultural commodities over the period 1976–88 are shown in Figs. 1–6. Fig. 1 shows the ratio of U.S. capital per worker exports to capital per worker imports. No Leontief paradox is apparent: U.S. agricultural exports are found to be more capital-intensive than imports. However, capital intensity is decreasing over the period, suggesting that the United States met considerable competition in capital-intensive agricultural commodities, and that U.S. trade changed so that its relative exchange of capital with the world declined. Such a decline is consistent with the decline in U.S. capital abundance relative to the rest of the world observed previously.

Additional information on the movement in U.S. trade toward less capital-intensive agricultural sectors is provided by Fig. 2, which shows U.S. capital per worker exports of agricultural commodities to developed and developing countries. [6] In general, capital-intensive agricultural exports to developed countries met increasing competition over the period under study while developing countries continued to absorb modestly increasing amounts of U.S. capital-intensive agricultural exports. Although developing countries have been rapidly accumulating capital, we do not yet see them becoming greater competitors in capital-intensive agricultural sectors. Perhaps the very large difference in initial levels of capital between the United States and developing countries has created a lag in the shift of capital intensity of U.S. exports to these countries.

The export to import ratio of the exchange of skilled agricultural labor relative to total agricultural labor is illustrated in Fig. 3. The ratio underwent considerable fluctuation but, overall, exhibits a slight decline over the period. This result

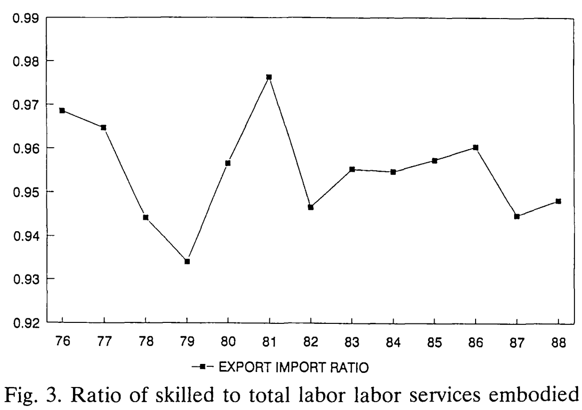


Fig. 3. Ratio of skilled to total labor labor services embodied in U.S. agricultural exports relative to imports.

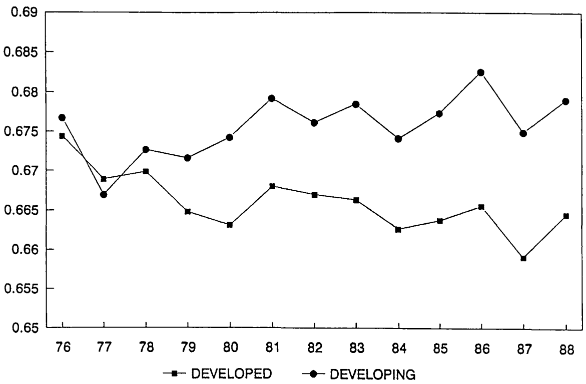


Fig. 4. Ratio of skilled to total labor labor services embodied in U.S. agricultural exports to developed and developing countries.

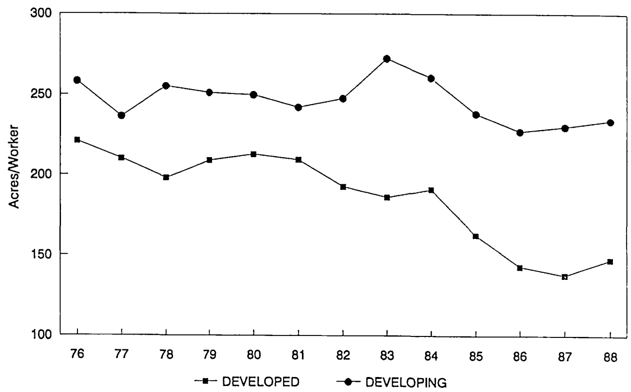


Fig. 6. Ratio of land to labor embodied in U.S. agricultural exports to developed and developing countries.

is consistent with the relatively slow growth rate observed in U.S. skilled labor.

Further information on the movement in U.S. trade toward less skill-intensive sectors is provided by Fig. 4, which shows U.S. agricultural exports of skilled relative to total labor to developed and developing countries. Exports to developing countries shifted toward skill-intensive agricultural sectors whereas the skill content of exports to developed countries continuously declined. These patterns suggest that as developed countries proceeded in accumulating skilled labor, they were increasingly able to compete with the United States in skill-intensive agricultural sectors. In contrast, developing countries have not become greater competitors in skill-intensive agricultural sectors. This is consistent with the observation that over the period 1966–86, the U.S. growth rate in skilled labor has been above the average growth rate in developing countries.

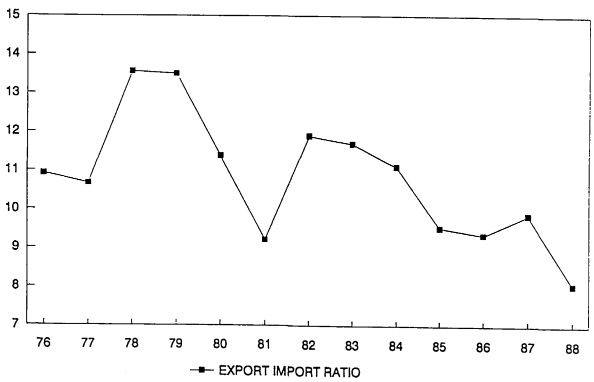


Fig. 5. Ratio of land to labor embodied in U.S. agricultural exports relative to imports.

Fig. 5 shows the ratio of U.S. land per worker exports to land per worker imports. This reveals that U.S. agricultural exports are more land-intensive than imports. However, land intensity is decreasing over the period, suggesting that the United States met considerable competition in land-intensive commodities, and that U.S. trade changed so that its relative exchange of land with the world declined. An indication of what motivates this movement in trade away from land-intensive agricultural commodities (e.g. foodgrains) is suggested by Fig. 6, which shows U.S. exports of land relative to labor in developing and developed countries. Consistent with high land to labor growth rates in developed countries, we find increasing competition particularly from these countries in land-intensive agricultural commodities. In contrast, U.S. export competitiveness with developing countries in land-intensive commodities remains largely unchanged, consistent with the finding that both U.S. and developing country land to labor endowments have been declining over time.

## 4. Conclusions

Consistent with the H-O theory, the results suggest changing world patterns of resource abundance are an important explanation of the increased competition faced by the United States in agricultural commodities and of the evolving structure of world trade. Slower growth of skilled labor, capital, and arable land in the United States compared to the rest of the world had a pronounced effect on the composition of its trade in agricultural commodities. Analysis of the direction of U.S. trade suggests that more rapid accumulation of capital, skilled labor, and arable land in developed countries permitted these countries to reduce their absorption of these resources from the United States or, alternatively, to increasingly compete with the United States in capital, skill, and land-intensive agricultural sectors. Developing countries continue to absorb modestly increasing amounts of U.S. skilled labor and capital services; U.S. competitiveness with developing countries in land-intensive agricultural sectors is relatively unchanged over the period under study.

## Appendix: Factor content of U.S. agricultural trade

*Capital.* Capital input coefficients for disaggregated agricultural commodities are not available. As a proxy for capital endowments we multiply the 1977 value for fixed private capital in the primary product farm sector (Musgrave, 1986) by the average farm depreciation share in trucks, tractors, structures and motor vehicle repair parts for 13 agricultural sectors. The farm depreciation distributions shown in Table A-1 are from the I/O table of the National Aggregate Analysis Section of the Economic Research Service, USDA (1990).

Table A-1
Farm depreciation distributions

| Sector | Depreciation share [a] | | | |
|---|---|---|---|---|
| | Trucks | Motor vehicle repair parts | Structures | Tractors |
| Meats | 0.196 | 0.197 | 0.202 | 0.186 |
| Poultry | 0.017 | 0.018 | 0.015 | 0.014 |
| Dairy | 0.021 | 0.033 | 0.074 | 0.081 |
| Foodgrains | 0.072 | 0.071 | 0.073 | 0.073 |
| Feedgrains | 0.352 | 0.349 | 0.348 | 0.323 |
| Cotton | 0.023 | 0.021 | 0.034 | 0.023 |
| Tobacco | 0.048 | 0.052 | 0.028 | 0.049 |
| Oilcrops | 0.114 | 0.112 | 0.109 | 0.114 |
| Vegetables | 0.048 | 0.044 | 0.040 | 0.047 |
| Fruits | 0.036 | 0.033 | 0.034 | 0.034 |
| Nuts | 0.005 | 0.005 | 0.005 | 0.005 |
| Sugar crops | 0.013 | 0.012 | 0.005 | 0.012 |
| Greenhouse | 0.018 | 0.016 | 0.009 | 0.013 |

[a] Columns do not add to one because forestry, miscellaneous crops, and other livestock are not included.

*Land.* Data on harvested acres by crop are from the Agricultural Statistics Yearbook of the USDA (1989).

Table A-2

| 1. Skilled workers per million \$ 1977 output | | 2. Capital (\$1977) per dollar 1977 output | | 3. Thousand acres per million \$ 1977 output | |
|---|---|---|---|---|---|
| Tobacco | 47.4 | Tobacco | 1.97 | Food grains | 12351 |
| Poultry | 33.6 | Feed grains | 1.58 | Feed grains | 6771 |
| Fruits | 19.7 | Food grains | 1.47 | Oilseeds | 5079 |
| Nuts | 19.6 | Oilseeds | 1.03 | Cotton | 3266 |
| Dairy | 18.7 | Fruits | 0.93 | Sugar crops | 1833 |
| Vegetables | 17.0 | Nuts | 0.93 | Nuts | 853 |
| Greenhouse | 15.6 | Sugar | 0.93 | Fruits | 720 |
| Sugar crops | 15.3 | Vegetables | 0.84 | Vegetables | 543 |
| Oilseeds | 15.3 | Cotton | 0.78 | Tobacco | 417 |
| Meats | 15.3 | Meats | 0.73 | Greenhouse | 166 |
| Food grains | 14.1 | Greenhouse | 0.57 | Poultry | 0 |
| Feed grains | 14.1 | Dairy | 0.54 | Meats | 0 |
| Cotton | 5.4 | Poultry | 0.24 | Dairy | 0 |

*Labor*. The Department of Commerce (Yuskavage, 1985) provides information on full-time and part-time employees in 17 primary agricultural sectors. However, these estimates do not include self-employed persons and unpaid family workers, which are especially important in farming. The Office of Economic Growth and Employment Projections in the Bureau of Labor Statistics (U.S. Department of Labor, 1989) estimates that for the U.S. farm sector as a whole, self-employed and unpaid family workers accounted for 63% of total employment in 1977. These estimates do not indicate educational or skill characteristics of the labor force. However, Oliveira and Cox (1989) provide demographic information on each of the three components of the agricultural work force (hired farm workers, farm operators, and unpaid farm workers). Following the educational characteristics of these work force groups described in the report, we identify farm operators and unpaid farm workers as skilled labor, and hired farm workers as unskilled. The skill shares and shares of total work force from the report are used to distribute the Bureau of Labor Statistics estimate of total 1977 agricultural employment among primary agricultural sectors.

*Summary*

Table A-2 reports the capital, land, and labor intensity of 13 agricultural commodities derived from the above sources.

## Notes

[1] Following Hayami and Ruttan (1985), tractor horsepower is estimated by the following formula:

$T_{it} = h_{it}N_{rit} + 5N_{git}$

where $T$ is total tractor horsepower; $h$ is average horsepower per riding tractor; $N_r$ is the number of riding tractors; $N_g$ is the number of garden tractors; and subscripts $i$ and $t$ represent, respectively, country and year (information on total and garden tractor endowments is from the Food and Agriculture Organization of the United Nations, Production Yearbook). Average horsepower per garden tractor is assumed to be five for all countries. Also following Hayami and Ruttan (1985), average riding tractor horsepower in various countries in the years 1966, 1976, and 1986 are as follows: United States and Canada (40, 50, 60); New Zealand and Australia (30, 45, 60); Belgium-Luxembourg, Denmark, France, Germany, Netherlands, UK (30, 40, 50); Other countries (30, 35, 40).

[2] A complete list for 59 countries is available upon request.

[3] Among the countries in our resource supply data set, developed countries are identified as Australia, Austria, Belgium-Luxembourg (Blux), Finland, France, Germany, Iceland, Japan, Netherlands, New Zealand, Sweden, Switzerland, United Kingdom, and the United States. All other countries are identified as developing countries.

[4] Although our data set includes most of the world's major market economies, the estimated world resource shares are nevertheless approximations since country observations for only 59 countries are reported.

[5] Agricultural trade data is from USDA Foreign Agricultural Trade of the United States (FATUS). The agricultural commodities studied include: dairy, poultry, meats, cotton, foodgrains (rice, rye, wheat), feedgrains (barley, corn, oats, sorghum), tobacco, fruits, nuts, vegetables, sugar crops, oilseeds, and greenhouse products.

[6] FATUS identifies developed countries as Canada, Western Europe, Israel, Japan, Australia, New Zealand, and the Republic of South Africa. Developing countries include all other countries except centrally planned economies (Cuba, Eastern Europe, USSR, mainland China, Mongolia, Vietnam, and North Korea).

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