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# Changing Agricultural Comparative Advantage

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## Abstract

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*Special circumstances in the agricultural sector have limited the use of comparative advantage in addressing the planner's dilemma of allocating investment between industry and agriculture and in examining the doctrine of food self-sufficiency. A three-factor model of agricultural trade, extending earlier models, is used to address some of these special circumstances and to formulate a theory of agricultural comparative advantage under changing economic conditions. Emphasis is placed on the short-run fixity of sector-specific capital stocks, the role of qualitative differences in land (natural resource) endowments, and on non-homothetic preferences. In addition to insights on agricultural comparative advantage, implications for project evaluation are considered.*

## Introduction

In low-income countries, development planners continually confront the question of whether to export agricultural products, import them, or strive for food self-sufficiency. Earlier theory held that surplus labor could be drawn from the agricultural sector to the industrial sector with little or no economic loss, and that investment in agriculture was inefficient (Lewis, 1954; Fei and Ranis, 1964). More recently, Hayami and Ruttan (1971), Evenson (1975), and others have argued for increased agricultural investment and particularly investment in agricultural research, where payoffs will equal or exceed those of industrial investments. This more current thinking provides support for the policies of many developing countries — who advocate greater food self-sufficiency. Such policies would seem to correspond in most instances to inward

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looking, import substitution development strategies. They emphasize increased production of imported agricultural commodities in favor of expansion of export goods production, including agricultural exports.

Flanders (1969) examined this "planner's dilemma" from the perspective of a trade economist. She argued that a country should base its production and trade decisions concerning agriculture versus industry on the concept of comparative advantage. She concluded that her "paper in part constitutes a polemic against the mystiques of the need for self-sufficiency in food production ...." (p. 184). Without actually constructing a theory of agricultural comparative advantage, she used its expected content to argue for what she felt would be the optimal production and trade patterns, and therefore the optimal investment decisions of a developing country. Anderson (1980) has continued this development by proposing the use of a three-factor trade model (based on the model of Jones (1977) to determine when a country's comparative advantage lay in agriculture.

On the other hand, several observers have argued that while comparative advantage theory should be applicable to trade in manufactured goods, agricultural production processes are sufficiently different that it is inapplicable as a guide to agricultural trade. For example, Ball (1966, pp. 77–78) argued that agriculture:

> is too broad; while some of every good may be produced in both countries, the composition of agricultural output (share of each good) is manifestly dissimilar. The effect of divergent national resource conditions is least easily ignored for agriculture; while the assumption that "available technological knowledge is approximately the same everywhere" (Minhas, 1963, p. 15) may be true for say, textiles, it is less so for agriculture. The relative efficiency of Japanese labor (vs. U.S. labor) has been shown to be least in agriculture, and an explanation has been offered that would also disqualify agriculture from the ranking test. The food industry may be second to agriculture in excessive breadth and dissimilarity of content.

Leontief (1956, p. 396) deleted agriculture from his analysis because:

> Agriculture, both as a producer of exports and competitive imports and as an employer of labor presents a special problem. Fluctuations in yield here and abroad — not to speak of government intervention — affect foreign trade in farm products to such an extent that the amounts of agricultural commodities exported and imported in one single year can be expected to reflect long-run comparative cost conditions much less than is the case for any other type of good.

These quotations suggest that we may need to extend or revise received theories of comparative advantage to adequately understand agricultural trade. Furthermore, despite the fact that the "law" of comparative advantage is one of the cornerstones of economic thought, its dictates are not widely accepted as a guide for practical affairs. Free trade is the exception rather than the rule in practice, especially for agriculture.

In principle, a properly formulated theory of agricultural comparative advantage should provide a framework for evaluation of food self-sufficiency policies and the agriculture versus industry debate. It should also serve as a vehicle for determination of the optimal production and trade patterns of a country on a commodity by commodity basis. It should be relevant for both industrialized and low-income countries, as the "planner's dilemma" cited above is faced by virtually all countries.

Our objective in this paper is to construct a simple model of agricultural comparative advantage, building on the work of Flanders (1969) and Anderson (1980) and extending the three-factor model of Jones (1977). That model focuses on some of the special circumstances relevant to agriculture, which are discussed in the next section of this paper. The model is designed to address issues raised by modern extensions of comparative advantage theory — which incorporate dynamic adjustments to explain observed trading behaviors — considered in the following section. A model of changing agricultural comparative advantage in the short and long run, emphasizing the role of investment, is then examined.

## Towards agricultural comparative advantage

Several of the special features of the agricultural sector, which may also be relevant to certain non-agricultural sectors, include:

(a) Agriculture is a land-based enterprise, so a three-factor model including natural resource endowments (land) is needed.

(b) The elasticity of substitution between capital and labor may be greater in agriculture than in industry, with the result that factor intensity reversals are common.

(c) One input in agricultural supply, weather conditions, is stochastic and not under the farmer's control (although irrigation and breeding for drought-resistant varieties can modify that dependence on weather).

(d) The biological production process involves a waiting period of several months to several years between input decisions and realization of the associated output.

(e) In certain types of agricultural production, such as livestock and certain perennial crops, the product "harvested" involves a capital stock. Harvest or slaughter then involves a disinvestment decision.

(f) The income elasticity of demand for farm products is less than one and falls as per capita income rises. Among farm products there is a range of elasticities, with that for livestock products being above the mean and that for tubers and cereals below the mean.

(g) Much of the agricultural capital stock and part of the labor force is "quasi-fixed" in the sense that its value in use exceeds its salvage value or opportunity cost outside the sector, but is less than the acquisition cost of another unit.

(h) Agricultural research in different countries appears to exhibit a scarce factor-saving bias (Hayami and Ruttan, 1971). That is, technological innovations respond to market incentives based on relative factor endowments.
(i) Many agricultural commodities are bulky — transportation costs represent a significant fraction of the value of an imported product.

Other forces affecting agricultural comparative advantage include the effects of energy prices, both through their effect on cost of production (fuel and fertilizer) and through the cost of ocean freight. The effects of past investments in marketing infrastructure including ports, roads, storage, and communications facilities, agricultural research facilities, and human capital formulation also need to be considered.

The above considerations in several instances correspond to dynamic or at least changing circumstances. The notion that fixed capital — including human capital, research and development, and infrastructure — is the product of past investment decisions based upon past economic conditions, and that comparative advantage in the long run might look very different if appropriate investments are made, is particularly important for the agricultural sector.

## Dynamic concepts of comparative advantage

Both Ricardian and Heckscher–Ohlin theories of comparative advantage are static concepts. Ricardian theory is based on the existence of differing production functions across countries, raising the question: Why do those functions differ? It is viewed as most appropriate for short-run questions. Heckscher (1919) and Ohlin (1933) proposed an alternative paradigm which argues that technology is sufficiently mobile across countries that production functions may be assumed identical. Relative endowments of two factors of production, labor and capital, determine a country's comparative advantage. The Heckscher–Ohlin model has considerable intuitive appeal and was consistent with casual empiricism, at least as an explanation of long-run comparative advantage.

Leontief (1954, 1956), utilizing his input–output analysis, carried out the first rigorous test of the Heckscher–Ohlin model. The United States was generally viewed as being a capital-abundant country relative to the rest of the world, but Leontief found that U.S. imports are more capital intensive than its exports. These results, which are now known as the Leontief Paradox, led to a flurry of ad hoc attempts to identify the source of the paradoxical results. One means of accounting for the Leontief paradox was recognition of the fact that free trade does not exist. A second category of explanations of the paradox considered demand factors (Valavanis-Vail, 1954; Linder, 1967). Both of these factors may be applicable to agricultural trade.

Most attempts to account for the Leontief Paradox have focused on the supply side, arguing that certain assumptions of the Heckscher–Ohlin model are violated in practice. Minhas (1963) argued that Heckscher and Ohlin's assumption of no factor intensity reversals was at the root of the paradox. Vanek (1959) and Naya (1967) argued that a third factor, natural resources, must also be included to adequately understand trade. Kenen (1965, 1970) and Keesing (1966) argued that Leontief used too narrow a concept of capital, ignoring human capital. Hufbauer (1970) argued that research and development capacity was another omitted factor of production from Leontief's analysis. Still others argue that it is unreasonable to assume identical production functions everywhere. They maintain that new or improved technologies are developed in certain countries which have large research and development capacities. Over time these technologies do get diffused around the world, but only with a lag (e.g. Hayami and Ruttan (1971) for agriculture). Finally, a "product cycle" theory was presented by Vernon (1966) and others. This theory suggests that the country which develops a new product has the comparative advantage until the market grows sufficiently to merit mass production using unskilled labor.

Many of the post-Leontief Paradox contributions to the theory of comparative advantage have brought dynamic forces associated with the process of economic development into the analysis. The process of economic growth corresponds to shifting the production possibility frontier (PPF) of an economy outwards. Explanations of a country's comparative advantage should therefore be able to explain the direction of this dynamic process.

At about the same time as the various trade economists cited above were attempting to explain the Leontief Paradox, another group of economists was attempting to identify the sources of economic growth for the United States and other industrialized economies. It has become clear that growth in the stocks of conventional factors of production — labor, capital, and land — could not account for more than a fraction of the growth in GNP. Jorgenson and Griliches (1967), Griliches (1964), Denison (1974), and others provided empirical evidence that in the United States much of the previously unexplained economic growth could be accounted for by growth in the stock of human capital, by investments in research and development, and by improvements in the quality of inputs used (often embodying improved technology). It is not by coincidence that these "sources of growth" turn out to be among the same variables identified as important determinants of the locus of comparative advantage following the Leontief Paradox.

An important question is whether the PPF shifts outward "neutrally", i.e. proportionately in all directions, or whether there is "bias" in the sense that it expands faster in certain dimensions than in others. In the latter case, the shape of the PPF changes in the course of economic growth and one should expect the country's comparative advantage to change in the process.

The "planner's dilemma" cited earlier may therefore be viewed as requiring

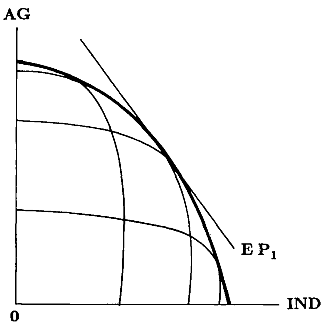


Fig. 1. Short-run versus long-run production possibilities.

the identification of a country's long-run comparative advantage. If one takes the view that the problem of economic development is to allocate — either through public or private decisions — a country's pool of scarce investment resources in any given year to maximize the growth in national income, the investment decisions made should be based upon a dynamic concept of comparative advantage (Bruno, 1970). Viewing comparative advantage within the investment or planning problem mandates consideration of several issues.

For present purposes, we shall assume that capital is malleable in the planning period in the sense that investment funds can be put to any use. Once a given investment is sunk, however, it is fixed in the use to which it was put. This is a "putty-clay" growth model. Among the possible investment "projects" available in the planning period are physical capital, human capital, research and infrastructure investments *in the various sectors*. Once these investments are then "sunk", short-run comparative advantage is determined.

This can be illustrated in Fig. 1, in which we draw a long-run PPF, the locus of all possible production possibilities assuming that the capital stock (or at least investment) can be freely shifted among uses. This is a planning curve, which is the envelope of all short-run PPFs, each of which represents a specific capital complement, and which corresponds to variations in variable factor inputs only (labor in the Heckscher–Ohlin model). Each short-run curve has a lower elasticity of transformation than the planning curve. This is consistent with our assumption that once an investment is sunk, it has few, if any, alternative uses. Expected national income is maximized here by selecting the specific capital complement (the specific mix of physical and human capital, infrastructure, and research by sector) associated with the short-run PPF tangent to the long-run PPF and the expected long-run international terms of trade.

The pattern of past investments made in a country determines the shape of its PPF at any point in time. A country's capital investment strategy, both past and present, is likely to determine the shape of its future PPF, and in turn its comparative advantage, to a greater extent than its endowments of land and labor. The shape of the PPF in a mature economy may bear no resemblance to that determined by its original primary factor endowments.

If a country distorts domestic prices away from the international terms of trade, it provides false signals to investment decision-makers in a perfectly competitive environment. That will result in choosing the wrong capital complement — producing a lower than feasible national income, and slowing the rate of economic growth. Since it means that the PPF will be shaped differently, this changes both the volume *and conceivably the mix* of the country's exports and imports. At any point in time, the existing capital complement dictates both short-run and potential long-run comparative advantage.

## A three-factor model of agricultural comparative advantage

In order to provide a more rigorous framework for examination of the issues raised above, a three-factor, two-sector model of agricultural comparative advantage is developed here. It goes beyond Jones' (1977) model, in that capital is included in the agricultural production function, so that a true three-factor long-run model is examined. As the Ricardo–Viner structure employed here (Mayer, 1974) assumes sector-specific capital stocks, there are four factors in the short run; this reduces to three in the long run. The model is designed within the framework of investment planning, so that both short- and long-run comparative advantage are identified. It is used as a comparative statics model, however, in that long-run, full equilibrium adjustment is considered, and not the path of that adjustment. Emphasis is placed on addition of a third factor, land, on non-homothetic preferences, and on the short-run fixity of capital investment.

We begin by assuming the existence of a social welfare function defined for aggregate industrial good consumption and aggregate agricultural good consumption. A country's problem then is to maximize social welfare subject to constraints, or

$$\text{Maximize } U(Y_c, X_c) \tag{1}$$

where $Y_c$ = consumption of the agricultural aggregate good, $X_c$ = consumption of the non-agricultural (industrial) aggregate good, and $U$ is the social welfare function. Social welfare is maximized subject to a number of constraints defining the country's production and trading possibilities.

Production functions for each of the two goods are:

$$Y = G^y(L_y, K_y, T) \tag{2}$$

$$X = G^x(L_x, K_x) \tag{3}$$

where $Y$ = production of the agricultural good, $X$ = production of the industrial good, $L_i$ = allocation of labor to production of good $i$, $K_i$ = capital stock of sector $i$, $T$ = land, and $G^i$ are production functions relating factors to outputs. It should be noted that land is specific to the agricultural sector, while labor and capital are utilized in each sector.

Resource availabilities and the existing capital stocks then define the production possibility frontier for this country. Total labor availability is assumed fixed at any instant in time:

$$L_x + L_y = \bar{L} \tag{4}$$

where $\bar{L}$ is the total labor available. It is also assumed that a fixed level of malleable investment funds ($\bar{I}$) is available, so that

$$I_x + I_y = \bar{I} \tag{5}$$

Investment increases the sector-specific capital stocks (ignoring depreciation) so that

$$K_y = I_y + K_y^o \tag{6}$$

$$K_x = I_x + K_x^o \tag{7}$$

The stock of land is also assumed fixed at $\bar{T}$. Alternative labor and investment allocations trace out the planning curve cited earlier, while alternative labor allocations for a given investment allocation trace out the short-run production possibility frontiers corresponding to each capital complement shown in Fig. 1.

Trading opportunities in the international market then complete this model. A balance of payments constraint requires that

$$P(Y - Y_c) + (X - X_c) = 0 \tag{8}$$

where $P$ = international price ratio of agricultural goods prices relative to non-agricultural goods prices.

For simplicity, we shall assume trade balance requiring that the value of exports at international prices equals the value of imports. Results would not be materially changed by assuming non-zero net foreign capital flows. Non-agricultural goods are the numeraire, and $P$ is assumed fixed. Hence, the small country assumption is invoked, as the country's actions cannot alter world market prices.

This model differs very little from more standard forms of the Heckscher–Ohlin model. Introduction of the land endowment, however, ensures that agricultural production functions, and hence production possibility frontiers, differ across countries according to their land (resource) endowment. While the function of a third factor of production, like land, may not be adequately captured by a variable whose only dimension is area, its introduction explains at least some of the cross-country variation in production possibilities. A land measure adjusted for quality might better capture this concept. Also, it may be useful to think of labor as corresponding to variable factors of production, while capital corresponds to augmentable but sunk (sector-specific) factors of production. Land then represents factors which are not augmentable.

This model may be rewritten in a form more convenient for comparative advantage analysis, utilizing some simplifying assumptions. First, assuming linearly homogeneous production functions (constant returns to scale):

$$X = L_x G^x(1, K_x/L_x) = L_x f^x(k_x) \tag{9}$$

$$Y = L_y G^y(1, K_y/L_y, T/L_y) = L_y f^y(k_y, t_y) \tag{10}$$

where $k_i$ is the capital–labor ratio in sector $i$, and $t$ is the land–labor ratio (in sector y).

Also, defining $\alpha = L_y/\bar{L}$, the share of labor in agriculture, $\beta = I_y/\bar{I}$, agriculture's investment share, $\gamma = PY/Z$, the agricultural consumption share, and $Z = PX + X$, national income at international (border) prices, then the problem becomes:

$$\text{Maximize } U(\gamma Z/P,\ (1-\gamma)Z) \tag{11}$$

subject to:

$$Z = P\alpha\,\bar{L}f^y\left(k_y^o + \frac{\beta\,\bar{i}}{\alpha}, \frac{t}{\alpha}\right) + (1-\alpha)\bar{L}f^x\left(k_x^o + \frac{(1-\beta)}{(1-\alpha)}\bar{i}\right) \tag{12}$$

where $\alpha$, $\beta$, and $\gamma$ range between 0 and 1 (assuming non-specialization), $k_i^o$ is the initial capital labor ratio in sector $i$, and $\bar{i} = \bar{I}/\bar{L}$ or the total investment per worker.

The first order conditions for optimal decisions are

$$\frac{\partial L}{\partial \gamma} = \frac{\partial U}{\partial Y_c}\frac{Z}{P} - \frac{\partial U}{\partial X_c} Z = 0 \tag{13}$$

$$\begin{aligned}\frac{\partial L}{\partial \alpha} = &- \lambda P\bar{L}f^y - \lambda P\alpha\bar{L}\frac{\partial f^y}{\partial t_y}(-t/\alpha^2) - \lambda P\alpha\bar{L}\frac{\partial f^y}{\partial k_y}\left(-\frac{\beta\,\bar{i}}{\alpha^2}\right) \\ &+ \lambda\bar{L}f^x - (1-\alpha)\,\bar{L}\frac{\partial f^x}{\partial k_x}\left(\frac{(1-\beta)\,\bar{i}}{(1-\alpha)^2}\right) = 0\end{aligned} \tag{14}$$

$$\frac{\partial L}{\partial \beta} = -\lambda P\alpha\bar{L}\,\frac{\partial f^y}{\partial k_y}\left(\frac{\bar{i}}{\alpha}\right) - \lambda(1-\alpha)\bar{L}\,\frac{\partial f^x}{\partial k_x}\left(\frac{-\bar{i}}{1-\alpha}\right) \tag{15}$$

$$\frac{\partial L}{\partial \lambda} = Z - P\alpha\bar{L}\ f^y + (1-\alpha)\ \bar{L}f^x = 0 \tag{16}$$

$$\frac{\partial L}{\partial Z} = \frac{\partial U}{\partial Y_c}\frac{\gamma}{P} + \frac{\partial U}{\partial X_c}(1-\alpha) + \lambda = 0 \tag{17}$$

Equation (17) simply requires the marginal rate of substitution in consumption to equal the international price ratio. Hence, consumption decisions are independent of production decisions, except for the effect of production on income. This problem could therefore easily have been separated into the consumer's and producer's problems and those solved independently — yielding the same first order conditions. That is, one could first pose the problem:

$$\text{Maximize } Z = P\alpha\bar{L}\, f^{y}\left(k_{y}^{o} + \frac{\beta\bar{i}}{\alpha}, \frac{t}{\alpha}\right) + 1-\alpha\ \bar{L}\, f^{x}\left(k_{x}^{o} + \frac{(1-\beta)}{(1-\alpha)}\,\bar{i}\right) \tag{18}$$

and first-order conditions would correspond to eqns. (14) and (15) (less a factor $-\lambda$, which is the marginal utility of income; eqns. (16) and (17) define national income $Z$ and the marginal utility of income, $\lambda$). Then, for the given level of national income, the consumption problem would be solved:

$$\text{Maximize } U(\gamma Z/P,\ (1-\gamma)Z) \tag{19}$$

where $Z$ was found in the preceeding problem, yielding eqn. (13).

Typically, homothetic preferences are assumed such that the product mix is independent of the level of income. Then, the objective function would become $Z\ U(\gamma/P,\ 1-\gamma)$, so that the mix of consumption goods (the optimal value of $\gamma$) would be independent of $Z$. For agricultural goods, whose income elasticities of demand are typically low and decline as per capita income rises, this assumption is unreasonable.

Assuming homothetic preferences is unnecessary to determine optimal production patterns. That assumption is misleading in determining consumption patterns for agricultural versus industrial commodities. For a given PPF, trade patterns can differ substantially, depending upon preferences (Linder, 1967). Nevertheless, the emphasis on supply in the comparative advantage literature may not be entirely ill-founded, if one takes an existing demand, and hence trade pattern, as given and is concerned with the effects of changes in investments. From a practical standpoint, therefore, comparative advantage criteria should be formulated on the basis of national income maximization at international prices, as is currently done for most project evaluation methodologies.

Equations (14) and (15) reduce to the standard result that the marginal rate of transformation in production must also equal the international price ratio. Also, the marginal value products of factors must be equated across sectors where they are used (this is found more easily by finding first order conditions for the untransformed problem which yield these results directly).

This model shows that the production mix at which those conditions are met depends for any given country upon its initial capital endowments, $k_{x}^{o}$ and $k_{y}^{o}$, relative to labor as well as its land endowment relative to labor, $t$. These define the differing production functions across countries. Furthermore, in the short run capital stocks are considered fixed ($i=0$), and eqn. (16) is satisfied identically. In that case, eqn. (14) now determines the optimal labor allocation at fixed capital stocks, $k_y^o$ and $k_x^o$, and corresponds to the optimality condition for the short-run PPF of Fig. 1.

Some insight into the composition of production can be gained by looking at a rearrangement of eqn. (14):

$$Pf^y - f^x = P\frac{\partial f^y}{\partial t}\frac{t}{\alpha} + \left(P\frac{\partial f^y}{\partial k_y}\frac{\beta}{\alpha} - \frac{\partial f^x}{\partial k_x}\frac{(1-\beta)}{(1-\alpha)}\right)\bar{i} \qquad (20)$$

This shows that the value of output per worker in agriculture less the value of output per worker in industry increases as land per worker increases. It will either increase or decrease, depending on the magnitudes of $\partial f^y/\partial k_y$ and $\partial f^x/\partial k_x$, the marginal product of a unit of capital per worker in agriculture and industry, as investment increases. Both results are hardly unexpected — land-abundant countries should be expected to produce and export more agricultural goods, and capital-abundant countries will produce either industrial or agricultural production, depending upon the expected returns to that factor. It should be noted that the marginal product of capital is itself a function of the land endowment, and so it may cause these returns to differ across countries. Also, with non-homothetic preferences, even though some insight into the production mix is gained, there is no guarantee that the trade mix will follow that pattern.

## Comparative advantage and project evaluation: bridging the gap

A theory of comparative advantage becomes practical when it provides guidance to economic planners in addressing resource allocation problems. If our theory of agricultural comparative advantage then is to prove useful, it must provide insights into procedures for project evaluation. The literature on project evaluation techniques is well grounded in trade theory, recognizing that shadow prices for traded commodities are appropriately set at border price levels (Bacha and Taylor, 1971). The crucial issues which arise are due to the existence of non-traded goods and factors, and to distortions. Comparative advantage, rather than absolute advantage, is the relevant criterion for trade determination because exchange rate adjustments allow policymakers to alter the ratio of traded goods prices to non-traded prices in practice.

Srinivasan and Bhagwati (1978) have examined this question of shadow pricing non-traded goods when distortions exist, in order to evaluate effective rates of protection and domestic resource costs as project evaluation methodologies. Their approach is based on a Heckscher–Ohlin theory of comparative advantage, where goods are tradable, factors (labor and capital) are not, and shadow prices for factors must be derived from international commodity prices. They propose that shadow prices for capital and labor must satisfy the zero profit conditions for each sector. These arise when a country's objective is to maximize national income at international prices and when production functions are linearly homogeneous (constant returns to scale). They then argue that in the absence of distortions, these shadow prices correspond exactly to those suggested by Bacha and Taylor (1971), so that domestic resource costs calculated using these shadow prices will properly order projects.

Labor and capital input coefficients are determined by optimality conditions at world market prices in an undistorted Heckscher–Ohlin model. Where distortions are maintained, the input coefficients are determined by the suboptimal domestic commodity prices, but shadow prices are then calculated at international prics. In that case, Srinivasan and Bhagwati argue that domestic resource costs using appropriate shadow prices will properly order projects, whereas effective rates of protection do not, since the wrong shadow prices are implicitly assumed.

Our two-sector, three-factor model of comparative advantage differs slightly from the Heckscher–Ohlin comparative advantage model, and so our evaluation of project selection criteria is similar to that of Srinivasan and Bhagwati (1978). As they note, however, their use of fixed input–output coefficients, determined by international prices, depends on a two-sector assumption. With three factors and two goods, factor endowments matter to technique selection and to determination of shadow prices. In this case, with the third factor, land, included for our model, shadow prices must obey the following:

$$P_1 = w\frac{L_x}{X} + r\frac{K_x}{X} \tag{21}$$

$$P_{2y} = w\frac{L_y}{Y} + r\frac{K_y}{Y} + \tau\frac{T}{Y} \tag{22}$$

where $\tau$ is the shadow price of land. Furthermore, first-order conditions for the earlier problem tell us that

$$\tau = \frac{P\partial f^y}{\partial t} \tag{23}$$

or the shadow price of land is simply the marginal physical product of land times the international price of the agricultural good. The initial capital stocks by sector in our model act as the distortion of the Srinivasan–Bhagwati approach, restricting capital allocations between sectors and hence constraining the optimal input–output coefficients. Again, a domestic resource cost calculated using appropriate shadow prices for non-traded commodities would yield the proper ordering of projects, so long as a shadow price of land is included in the calculation.

The important lesson to be learned is that shadow prices of non-traded inputs to production can and should be calculated so that national income at international prices is maximized. If distortions exist, they will be included as constraints in the maximization process, but the basic process of shadow price calculation is similar. This corresponds with the concept of comparative advantage, in that for a given set of international prices and production possibilities, a country can find and achieve a comparative advantage in the production of some export goods, so long as it is willing to alter the ratio of traded to non-traded goods prices appropriately, or at least to evaluate investment alternatives at properly calculated shadow prices for non-traded goods. Evaluation of agricultural projects necessitates inclusion of land and consideration of sunk investments in the calculation of those shadow prices.

## Evaluation and summary

The novel features of this model are consideration of a third factor of production for the agricultural sector (land), non-homothetic preferences, and the relevance of sunk capital investments to determination of agricultural comparative advantage. The latter issue suggests that an empirical investigation examine changes in trade patterns in response to changing economic conditions. Furthermore, factors of production cannot be considered freely mobile between sectors. Rents to land and sector specific capital need to be explicitly evaluated to calculate agricultural comparative advantage. Also, as income levels change, one should expect the pattern of demand, and hence trade, to change as well.

The model as presented here is used in a comparative statics framework. Few additional insights would be gained by recasting this model in a fully dynamic framework, and yet such a revision would require considerably more complex mathematical relationships. Reformulation in a dynamic framework requires only rewriting the model period by period, and linking periods through investment allocations. The main advantage of the dynamic framework would be to assess the pattern of variation in time of optimal resource allocations (read comparative advantage) if parameters of the model, such as capital–labor ratios, land–labor ratios, or the international terms of trade change over time. In addition, a sector producing investment goods might be introduced to examine the consequences of tradeoffs between importing capital goods versus producing them at home. These issues are certainly of some practical importance, and treatment of item (e) in the list of agriculture's special characteristics (i.e. the need for a disinvestment decision) would require such a dynamic model.

The most crucial deficiency of the model as now formulated is the lack of consideration of risk. Items (c) and (d) in the list of agriculture's special characteristics (i.e. weather and the length of the waiting period between input decisions and realization of output) both introduce the concept of risk as important to agriculture. Leontief's criticism of comparative advantage as a relevant concept for agriculture refers specifically to the risk associated with agricultural production. The framework presented is conducive to inclusion of risk since it recognizes different adjustment opportunities for the short and long run. What is needed is reformulation of the optimality conditions for production patterns, by rewriting the objective function as maximization of expected utility. Consideration of the effects of risk aversion could then be incorporated along the lines followed by Jabara and Thompson (1980). They found that diversification or self-sufficiency may be an appropriate response to the variability of international prices.

To empirically operationalize this framework, a production specification richer than a three-input specification is necessary to capture the diversity of agricultural production possibilities across countries. It is unlikely that a land variable, even adjusted for quality, can capture the potential variations in agricultural production functions. The diversity of capital inputs to both industry and agriculture (human, physical, infrastructural, etc.) may also need to be treated separately. The need to define properly capital inputs, including all such elements, is a lesson which has emerged both from the recent developments in the comparative advantage literature and from studies of the sources of economic growth. Problems which must be considered include both definitions of factor inputs, level of specification of production functions, and the degree of aggregation of such a model.

Insights into this operationalization are provided by looking at how this model of agricultural advantage relates to project evaluation methodology. Of particular importance is the shadow pricing of sector specific factors, especially land.

The major lesson to emerge from this paper, however, is that comparative advantage must not be considered as a purely static concept. Consideration of initial conditions, both in terms of endowments and in terms of sector specificity, as well as explicit integration of capital theory with comparative advantage theory are called for. This integration and the need for a richer model specification are particularly important if the concept of comparative advantage is to be useful in evaluating a country's potential for agricultural trade. If recognition of these issues is made, the next step, moving comparative advantage along as a relevant concept for project evaluation, can be taken along the lines indicated above.

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