

TECHNOLOGY AND INTERNATIONAL  
TRADE IN AGRICULTURAL PRODUCTS:  
A TEST OF SOME HYPOTHESIS

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PURDUE UNIVERSITY

1974





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AGRICULTURAL PRODUCTS: a test of some  
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Tese de Ph.D.

Purdue University  
Lafayette, Indiana  
1974

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## ACKNOWLEDGMENTS



I wish to express my gratitude to:

Dr. G. Edward Schuh, my major professor, for his objective guidance, stimulating counseling and personal friendship.

Dr. Joseph Havlicek, Jr., Dr. K. Rao Kadyiala and Dr. T. Kelley White, members of my advisory committee, for their assistance and constructive criticism of my work.

Dr. Earl W. Kehrberg for serving on the final examining committee and for this help during my years at Purdue. Dr. George F. Patrick for his comments and suggestions at different stages of this study.

Mrs. Andrea Miller and Mrs. Margaret Walker for their competent typing.

My wife Silvia for faithfully joining me in this journey.

I also want to acknowledge the financial support received from the USAID and The Ford Foundation which helped make possible my stay at Purdue.



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## ABSTRACT

Valentini, Rubens, Ph.D., Purdue University, May 1974. Technology and International Trade in Agricultural Products: A Test of Some Hypotheses.  
Major Professor: G. Edward Schuh.

To understand the factors underlying comparative advantage in agricultural trade is of great importance for the less developed countries. It is recognized that the export sector may place an effective constraint on economic development. In order for this not to be <sup>the</sup> case, exports must grow in order to pay for the increase in import demand that results from economic development. The study of agricultural exports is important because historically the export of such products has been an important source of exchange earnings for both advanced and low income countries. Of special importance in light of their "need" for exports as a source of growth is the fact that LDC's represent a declining share in the world trade in agricultural products.

This study focuses on an analysis of the agricultural component of total exports. The objective is to increase our understanding of the factors that affect the pattern of agricultural trade among countries. The maintained hypothesis of the study is that the capability to produce and absorb new production technology is an important element determining comparative advantage. The specific objectives of the study are: (1) to develop a conceptual framework for understanding the problem of extending and adapting presently received theory, (2) to obtain statistical estimates for an international cross-sectional export function for

agricultural products, and (3) to derive some general policy.

The economic model is based on a two-sector model of the economy in which labor and land are viewed as primary factors of production, and inherently different from a secondary factor, capital. The stock of land and labor of an economy are assumed to be wholly inert until they are improved by acts of investment. On the assumption that factor markets do not have infinite speed of adjustment, changes in relative factor prices are then hypothesized to induce the creation of new production technology. The model postulated suggests that with the disequilibrium assumption, technical progress will result in a perverse Rybcynski effect.

The empirical model is derived from a comparative statics algebraic model. An international or foreign trade offer curve is defined simply as domestic production minus domestic consumption. A positive difference implies an export supply function, while a negative one implies an import demand function. A reduced form equation for the foreign market for agricultural products was first estimated by ordinary least squares. Then a stepwise regression procedure was used to analyse the relative importance of the specified variables.

The specification of the model assumed a general equilibrium framework, with conventional inputs entered to represent the production side, along with proxies for human capital and investment in agricultural research and extension. Per capita income and population were entered to take account of domestic demand considerations. And to take account of trade intervention factors a policy variable was explicitly included.



The same model was analyzed with data for four different groups of countries to assess differences between net exporters and net importers of agricultural products and to determine whether there had been changes in structure over time for the net exporting countries.

The statistical results generated by the models generally support the economic theory behind the models. The results suggest a different relative explanatory power for production, consumption and policy variables in explaining agricultural trade of exporting and importing countries. Production variables are relatively important in the net exporting group and consumption and policy manipulations are relatively more important in the net importing group. Despite differences in relative explanatory power, the technology variables are in general important in both groups of countries.

The comparison over time points towards the increased importance of investments in agricultural research and development as a factor determining comparative advantage. Furthermore, the nature of the technological change seems to have been in the direction of easing the constraints put on the country's production and trade by inelastic supplies of land and labor tending, therefore, to validate the underlying induced technical change model.

## CHAPTER I

## INTRODUCTION

It is well recognized that the export sector may place an effective constraint on economic development. In order for this not to be the case, exports must grow in order to pay for the increase in import demand that results from economic development.<sup>1/</sup>

Although a great deal of attention has been given to the analysis of import demand, much less attention has been given to the analysis of export supply. More specifically, only a limited amount of research has been done either to identify and quantify the underlying econometric structure that describes export supply, or to identify the factors that affect the quantity of exports supplied.

The goal of the present study is to increase our knowledge with respect to the agricultural component of total exports. The study of agricultural exports is important because historically the export of such products has been an important source of exchange earnings for both the advanced and low-income countries. In the period 1965-1969 the average value of world trade in agricultural products was of the order of US\$49 billion,<sup>2/</sup> which represented about one-fifth of the value

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<sup>1/</sup> Unless, of course, the terms of trade should shift in favor of exports.

<sup>2/</sup> This and data in the following paragraph are taken from Mackie (38).



of total world trade. As a share of the total, this represented a decline from 50 percent in the 1920's and 1930's, and 32 percent in 1955.

Of special importance in light of the importance of exports as a means of financing a higher rate of economic growth is the fact that the LDC's represent a declining share in the world trade in agricultural products. For example, in 1955 the developed countries were responsible for 32 percent of world trade in agricultural products. By 1965-69 this figure had risen to 42 percent. The LDC's, on the other hand, were responsible for 45 percent of agricultural exports in 1955, but by the time of the 1965-69 period this share had declined to 34 percent of the total.

The "puzzle" in these data is that many analysts believe that the low-income countries should have a national comparative advantage in agricultural products, while the advanced countries should have a comparative advantage in industrial products.<sup>3/</sup> The maintained hypothesis of the present study is that the capability to produce and distribute a new production technology is an important basis for establishing and maintaining a comparative advantage in agricultural products. If this hypothesis is accepted, the failure of the low income countries to maintain their share of world markets in agricultural products may be due in part to their failure to invest in the capacity to produce an adequate flow of such new technology.

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<sup>3/</sup> For a contrasting view, see June Flanders (13).

Hayami and Ruttan,<sup>4/</sup> in their well-received<sup>5/</sup> recent book, hypothesize and support with considerable empirical evidence the proposition that the high productivity of agriculture in the developed countries is based on:

- a) "the development of a nonagriculture sector capable of transmitting increased productivity to agriculture in the form of cheaper sources of power and plant nutrients (for example, tractors and chemical fertilizers) and
- b) the capacity of society to generate a continuous sequence of technical innovations in agriculture which increases the demand for the inputs supplied by the industrial sector. A continuous stream of new technical knowledge and a flow of industrial inputs in which the new knowledge is embodied represents a necessary condition for modern agricultural development. This stream of new technical inputs must be complemented by investments in general education and in production education for farmers and by efforts to transform institutions to be consistent with the new growth potentials if the full productive potential of the new knowledge and the new inputs is to be realized."<sup>6/</sup>

The central focus of the present study is to make an empirical test of the role of technology, and more particularly variables representing differences in technological capabilities among countries, on the international trade in agricultural products. If such hypotheses are found to be consistent with the data, they may provide a basis for improved policy with respect to agricultural trade, and perhaps eventually provide a basis for obtaining higher growth rates in both the

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<sup>4/</sup> Hayami and Ruttan (16).

<sup>5/</sup> See reviews by Johnston (23), Schuh (57), Sahota (52) and Schultz (81).

<sup>6/</sup> Hayami and Ruttan (16) pp. 4-5.



lesser-developed and the advanced countries. As an important by-product, additional support may be provided for the importance of new production technology as a source of economic growth.

### Technology and Agricultural Trade

Intuitively, it seems quite plausible that differences in the level of production technology should be an important determinant of the comparative advantage that a country has in world trade. The introduction of new technology is generally believed to increase aggregate resource productivity, and higher productivity is generally believed to be a key element in gaining an improved trade position.

Despite the intuitive plausability of this notion, very little progress has been made in introducing technology into trade theory. And perhaps in large part because of this deficiency, there has been very little empirical work designed to test hypotheses about the role of technology in trade performance, or to test hypotheses about the role of variables representing the technological capability of countries in influencing the exports or imports of agricultural products.

Recent developments with models of induced technical change provide the basis for introducing technology into trade theory. In the field of agricultural development, Hayami and Ruttan have made perhaps the most significant contribution to our knowledge about induced technical change. They adopt Hicks' micro level factor-price inducement model to the aggregate agricultural sector, and argue that changing factor-price relations induce particular kinds of technical change. More specifically, a rise in the price of land as a result of inelastic



supply conditions leads to the development of fertilizer-responsive varieties of crops and the increased use of fertilizers, with the result that the constraint to output expansion imposed by an inelastic supply curve of land is eased. Similarly, an increase in the price of labor as a result of inelastic supply conditions for this factor leads to the adoption of mechanical innovations, with the result that this constraint to output growth is also eased.

This obviously makes production technology an endogenous variable within the system, rather than a variable that is determined exogenously. In addition it implies an efficiency path for technological development, with the implication that successful agricultural development will be obtained by developing that production technology which will ease the prevailing constraint to output expansion. These constraints are defined in terms of the primary inputs, land and labor. Capital, the secondary input in this framework, is assumed to be relatively elastic in supply.

In the present study this model of induced technical change is introduced into a more general growth model, with the result that technology becomes an endogenous variable within the trade theory. The model and the empirical research is an attempt to build on the insightful contributions of Hayami and Ruttan, and draws on their study for an important part of the data used in testing the model. The essence of the model is to argue that the presence of an indigenous capability to produce and distribute new production technology will alter a country's national comparative advantage, and make it a more effective competitor in world markets, other things being equal.



### Objectives of the Study

The general objective of this study is to improve our understanding of the factors determining agricultural exports. The specific objectives of the study are:

- 1) to develop a conceptual framework for understanding the problem by extending and adapting presently received theory;
- 2) to obtain statistical estimates of an international cross-sectional export function for agricultural products; and
- 3) to derive the economic implications from the theoretical and empirical results obtained.

### General Procedures

A model will be developed which provides a means of analyzing the role of natural factor endowments, domestic demand conditions, and variables representing technological capability in determining a country's comparative advantage in world markets. This model will be cast in the tradition of a two-sector economy, and combined with a separate model which will be employed to analyze the effects of exchange rate policies on agricultural exports.

The two models will then be integrated and a simplified algebraic model will be derived which provides an export function that can be utilized for the statistical analysis. The model will be tested with data from a cross-section of countries.<sup>7/</sup> The estimated coefficients of this function will be the elements upon which the economic implications will be drawn.

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<sup>7/</sup> An important part of the data are taken from Hayami and Ruttan's recent study (16). The remainder are taken from regular secondary sources.

### Background: Theoretical Antecedents

A number of contributions to the theory provide the basis for the conceptual model that is developed in the next chapter. The objective of this section is to trace these developments in order to show how the model is related to the larger body of trade literature. It starts with the contributions of the classical and neoclassical model, and shows how some of the assumptions of the latter model have been relaxed to provide a role for differences in technology, differences in human capital, and the conditions of product demand in explaining differences in comparative advantage and trade flows among countries.

The theory of comparative advantage is primarily concerned with the determination of commodity prices at the pre-trade equilibrium position. These prices in turn determine trade flows.

The forces underlying the determination of comparative costs, the major element behind comparative advantage, explain both the international differences in comparative costs and the inter-temporal differences in costs in any given economy. There has been two basic approaches to this problem. The first, in the Ricardian tradition, focuses upon the efficiency of productive resources. The second, in the Hecksher-Ohlin tradition, focuses on the factor-proportions of the economies and stresses the importance of differences in their factor endowments.<sup>8/</sup>

The following discussion is cast in the context of the Hecksher-Ohlin tradition and contributions to the literature which have attempted

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<sup>8/</sup> For details see Caves (9).



to modify the restrictive assumptions of that model.<sup>9/</sup> It should be noted in passing however, that the introduction of technological change or technological differences among countries in a very real sense revitalizes the Ricardian tradition.<sup>10/</sup>

Under the well known set of restrictive assumptions a strong version of the Heckscher-Ohlin theorem states that a country's comparative advantage lies in the production of commodities that make relatively intensive use of factors that are relatively plentiful in that country. These assumptions are:

1. Factors of production are completely uniform within countries and between them; all markets are perfectly competitive and there is perfect internal mobility.
2. The production functions are the same in the two countries; they evince constant returns to scale and they can be ranked uniquely by factor intensity, regardless of factor prices.
3. Demand conditions are also alike and yield unitary income elasticity for all consumer goods.
4. There is incomplete specialization in both countries.
5. There exists free trade and absence of transport costs.

Amano<sup>11/</sup> relaxed one of these restrictive assumptions by allowing for differences or shifts in the production functions, with the result that a country is expected to have a comparative advantage in the line

<sup>9/</sup> An alternative group of theories of international trade is based on the product cycle approach. The works of Vernon (70), Hirsch (17) and Wells (71), among others, are representative of this approach. A discussion of these theories is omitted, however, because their very nature makes them appropriate only to the explanation of trade in manufactured products. Morral's interesting exposition in (44), which attempts to reconcile the Heckscher-Ohlin and product cycle theories is worth noting, however.

<sup>10/</sup> For a discussion, see Jones (26).

<sup>11/</sup> Amano (2).



of production in which it has a relative technological advantage.<sup>12/</sup> He notes that this tendency may be strengthened or weakened by the nature of the technological advantage, however, because a technical change not only affects factor productivity, but also factor intensities, depending on the particular bias that it entails.

Amano also dropped the assumption of unitary income elasticity of demand for all consumer goods, and by means of general equilibrium considerations showed that the effect of biased technological advantage upon factor prices depends on the elasticity of substitution in consumption--compared with unity. This may be illustrated as follows. Suppose for the moment that the economy is composed of a labor-intensive and a capital-intensive sector, and that relative factor prices are fixed at levels that prevailed prior to the assumed technological change. Suppose further that a technological change occurs in the capital-intensive sector. The immediate consequence of the relative technological change is an increase in the quantity produced of the commodity which is assumed to be capital-intensive (commodity 2), and a relative decline in the price of that commodity relative to the other. If the elasticity of substitution in consumption is, say, greater than unity, this will imply a more proportionate increase in the quantity demanded relative to quantity supplied of commodity 2. Therefore, factors must move from industry 1 to industry 2 in order to clear the markets. This leads to a shift of factor prices in favor of labor, since industry 2 is capital intensive as compared to industry 1. If the elasticity of substitution in consumption is less than unity, on the other hand, the reverse will hold.

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<sup>12/</sup> Jones (26) also discusses differences in technology. His findings however, are less penetrating than Amano's.



Samuelson<sup>13/</sup> has shown that assumptions (1), (2), (4) and (5) suffice to prove the factor-price equalization theorem. This theorem says that given this more limited set of assumptions, trade will equalize the relative and absolute prices of factors between countries. Were factor-price equalization to occur, of course, all factor movements would be precluded.

Samuelson has also shown<sup>14/</sup> that if net savings occurred in one of the two countries, a change in the terms of trade would maintain equality in interest rates among countries, thereby precluding any flow of funds from the country with net savings to the other. In addition, Mundell's corollary<sup>15/</sup> would apply: when one country levied a tariff, no matter how small, all trade would cease.

It is worth noting that the factor-price equalization theorem just mentioned does not imply global equality of incomes per capita, since differences in labor force participation and in supplies of capital per worker could still make for differences in real incomes. But even when coupled with the existence of tariffs and transport costs, these two differences in economic structure do not provide a systematic explanation for the huge variations in income per capita among countries that are a fact in the modern world.

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13/ Samuelson (54).

14/ Samuelson (56).

15/ Samuelson (45).

In an important paper Mrs. Krueger<sup>16/</sup> states that models focusing upon technological differences among countries appear appropriate only if differences in resource endowments explain little of the economic differences, specifically income levels, among countries. Since this seems to be the case, and since we are interested in overcoming the static characteristics of the comparative costs theory(ies), it is believed appropriate to include broadly defined technological changes (or differences) and human capital explicitly as major shifters of such advantages. Support for this position is provided by the following quotes from Rosenberg:

I would say that when we accord a more prominent role to the effects of a dynamic technology, comparative advantage appears in a somewhat different light. It is no longer based upon cost differences that are rooted in immutable forces of climate or geology. Rather it is the continually changing result of human ingenuity and inventiveness, reflecting the different capacity of different countries to develop techniques which enable them to take advantage of opportunities which are only implicit in their resource endowment. The primacy of resource endowment recedes as an explanatory variable in a country's economic activities. (...). The difference in emphasis, then, is far from trivial. It is the differences between emphasizing an unalterable national resource endowment as the prime determinant of economic performance and emphasizing the level of technological sophistication and versatility. For the fact is that not only do different countries employ different technologies; countries also vary considerably in their ability to produce appropriate technical changes and to adopt and modify the technology of other countries to their own requirements.<sup>17/</sup>

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<sup>16/</sup> Krueger (32).

<sup>17/</sup> Rosenberg (50), p. 70.



Kenen<sup>18/</sup> uses a concept of capital on the lines suggested by Schultz<sup>19/</sup> and Becker<sup>20/</sup> and is able to develop a two factor-two country model, based on the same assumptions as listed above, which yields the usual results and yet overcomes two limitations of the original Hecksher-Ohlin model. One of these limitations is that imposed by the uniformity of interest rates that follows directly from the Hecksher-Ohlin model, and which precludes capital flows, and the other is the Mundell corollary, which argues that the presence of a tariff would preclude all trade. Hence, Kenen's model allows for foreign lending or investment in the context of capital formation, and is not restricted to a non-tariff world.

Another related strand of thought, initiated by Keesling<sup>21/</sup> in the mid-1960's, builds upon the dichotomy of skilled and unskilled labor. In an earlier paper<sup>22/</sup> Keesing had argued that by concentrating on manufactures it is possible to eliminate natural resources as a factor explaining trade patterns, and that, in as much as capital moves internationally at a much lower cost than labor, the skill pattern of an economy is prone to change much more slowly than its structure of physical capital.<sup>23/</sup> This provided the basis for introducing differences in the

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<sup>18/</sup> Kenen (30) and (31).

<sup>19/</sup> Schultz (59).

<sup>20/</sup> Becker (6).

<sup>21/</sup> Keesing (29), p. 6.

<sup>22/</sup> Keesing (28).

<sup>23/</sup> He notes that this will be especially true if skilled labor is needed to train more skilled labor of the same type.



stock of human capital into trade models, and led to what has been called the Hecksher-Ohlin human capital models.<sup>24/</sup> It should be noted in passing that the introduction of human capital or labor skills, and natural resources into the Hecksher-Ohlin model also helps dispell the Leontief paradox.<sup>25/ 26/</sup>

To conclude, the evolution of thought has been such as to modify the original restrictive assumptions of the Hecksher-Ohlin model by introducing differences in production functions among countries, by accounting for differences in endowments of human capital among countries, and by recognizing that demand conditions can influence the pattern of trade among countries. For the most part these models have treated the differences in technology among countries as exogenously determined, however. In the next chapter an attempt will be made to introduce the concept of induced technical change into a recent growth model that considers differences in human capital among countries, and which also provides results that are more general than those that follow from the original Hecksher-Ohlin formulation.

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<sup>24/</sup> See Morral (44).

<sup>25/</sup> Leontief (34) and (35).

<sup>26/</sup> For other explanations of the Leontief paradox see Valavanis-Veil (68) and (69), Jones (24), Robinson (49) and Johnson (22). It should be noted, however, that Leontief's explanation in (34) is the basis for Keesing's labor skills theory.



## CHAPTER II

## THE CONCEPTUAL MODEL

This chapter is divided into three parts. The first part draws on the theoretical antecedents discussed in the previous chapter to specify a generalized hypothesis about induced technological change and its role in comparative advantage. This hypothesis is derived in large part by introducing the Hayami-Ruttan induced technical change model into Kenen's two-sector model. The second part discusses in a simple way the role of trade policies in modifying the comparative advantage that a country might have, or in influencing its exports. And the third and final part presents a comparative statics model that permits an analysis of changes in comparative advantage that derive from changes or differences in technology. This model leads to an offer curve which serves as the basis for the later empirical work.

Induced Technological Change and ComparativeAdvantage: A Hypothesis

An underlying objective of the present study was to test or evaluate Hayami and Ruttan's induced technical change hypothesis of agricultural development<sup>27/</sup> as a basis for explaining international comparative advantage in the trade of agricultural products. The

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<sup>27/</sup> Hayami and Ruttan (16), Chs. 4 and 5.

means of doing this is to introduce Hayami and Ruttan's inducement hypothesis into Kenen's two-sector model.<sup>28/</sup> In this regard it is interesting to note that both works treat labor and land as primary factors of production that are inherently different from the secondary factor, capital.

Kenen treats "'capital' and 'nature' as the aboriginal agents of production."<sup>29/</sup> He assumes that every country has fixed stocks of land ( $N_1$ ) and labor ( $N_2$ ) (its natural endowment), and that the stocks are wholly inert: they must be improved by acts of investment before they can contribute to current production.

A single capital good or service is assumed to be used for all purposes. It is held in a central loan fund in each country. In actual fact, acts of investment could be expected to differentiate the natural endowment. Kenen assumes that these are changes in factor quantity rather than changes in factor quality, however, by pretending that investment in the natural endowment generates a single undifferentiated factor-service flow from land, and a second flow from labor, and that these two flows are the only inputs into production.

Investment of capital  $K$  in the "natural" resources of labor and land is hypothesized by Kenen to evoke a finite flow of factor services per unit of factor. These flows are hypothesized to be steady while they last, and investments are assumed to depreciate by "sudden death". Two constant-elasticity factor supply functions are specified for the

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<sup>28/</sup> Kenen (30) and (31).

<sup>29/</sup> Kenen (30), p. 441.



stocks of land and labor which yield, respectively, flows  $Z_1$  and  $Z_2$  of factor services.

For a given level  $K$  of capital stock a gross factor-service frontier can be derived. Such a frontier is shown in Figure 1 by the curve  $GG$ . If gross annual investment  $\hat{K}$  is optimally allocated<sup>30/</sup> in the stationary state,<sup>31/</sup> gross annual income, as measured by factor costs, will be at its maximum.

By defining a linear homogeneous production function for the capital good Kenen reduces the gross factor-service frontier to a net factor-service frontier. This is done by subtracting the amount of  $Z_1$  and  $Z_2$  needed to produce the level of gross investment capital,  $\hat{K}$ . This subtraction is illustrated in Figure 1 after the proper  $\hat{K}$ -isoquant has been selected. It results in the net factor-service frontier  $NN$ .

Given a wage-rate ratio,  $w = w_1/w_2$ , three factor-service ratios can be identified in Figure 1 that play a strategic role in Kenen's analysis:

$R_G = Z_2^*/Z_1^*$ , the gross factor ratio for the whole economy,

$R_N = Z_{2N}/Z_{1N}$ , the net factor ratio for the whole economy, and

$R_K = Z_{2K}/Z_{1K}$ , the factor ratio of the capital good industry.

Kenen discusses the importance of the ordering of these ratios<sup>32/</sup> on

<sup>30/</sup> This assumes that each individual worker and landlord invests optimal (income maximizing) quantities to develop their respective resources.

<sup>31/</sup> In the stationary state gross annual investment,  $\hat{K}$ , is equal to gross depreciation, which allows for the depreciation of human capital as well as tangible capital, and is also equal to the real value of new, annual lending.

<sup>32/</sup> It can be shown that these three factor ratios are related, and that they can be ordered uniquely whenever two of them are known.

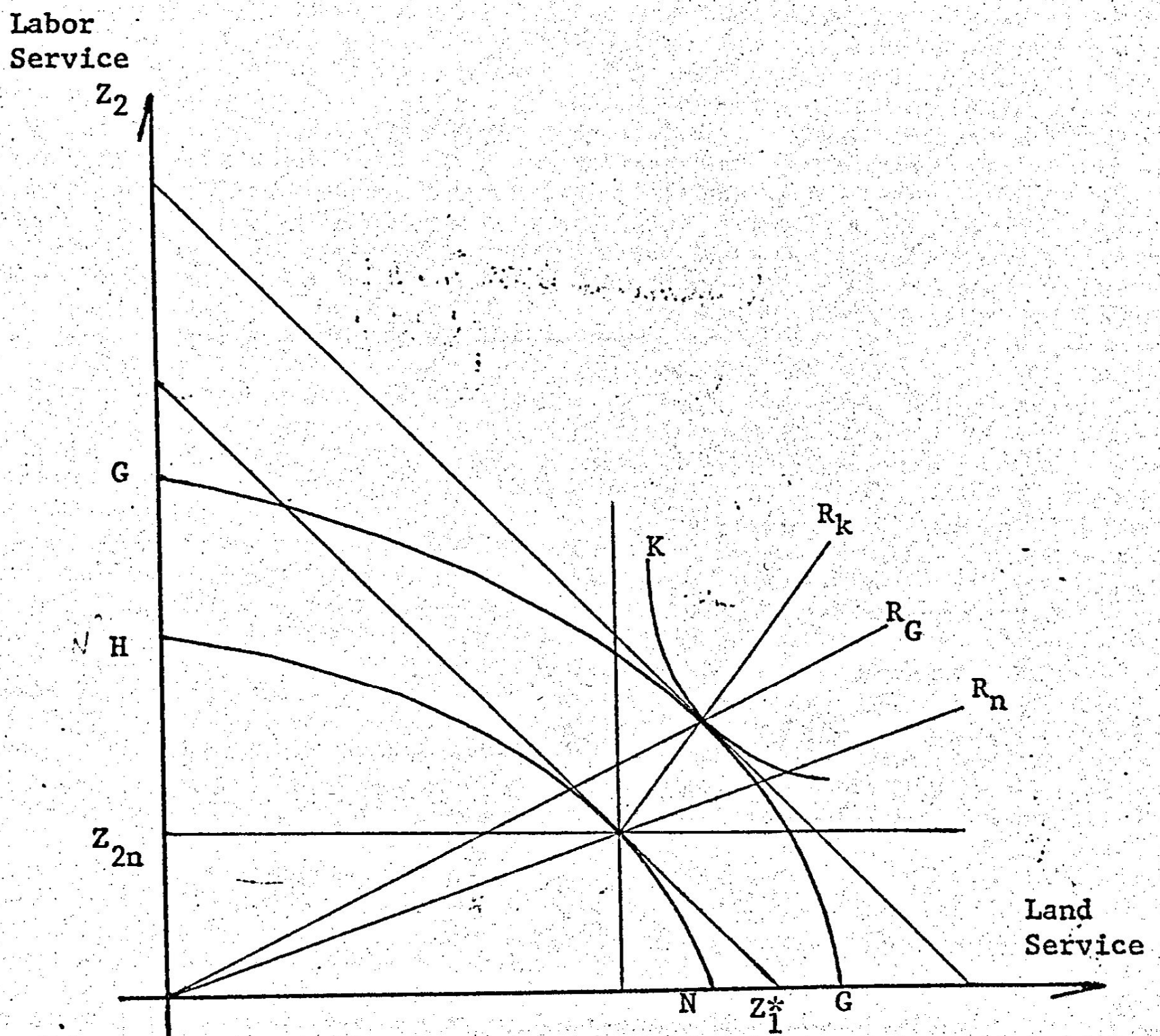


Figure 1. The Gross and Net Factor Service Frontiers.<sup>1/</sup>

<sup>1/</sup> Reproduced from Kenen (30), p. 445.



capital formation, the patterns of foreign trade, and the direction of foreign investment. The following discussion concentrates on the effects on foreign trade--the subject of the present study--and neglects the effects on capital formation and the direction of foreign investment.

The production of two goods, X and Y, is assumed, for which linear homogeneous production functions are specified. Moreover, the usual strong factor ordering with incomplete specialization is assumed, such that

$$R_1 = Z_{21}/Z_{11} > R_N > Z_{22}/Z_{12} = R_2$$

where, for any given  $w$ ,  $R_i$  is the factor intensity in the  $i$ th industry. The net factor-service frontier  $NN$  can thus be translated into a product space. The corresponding product transformation curve will have the usual properties.<sup>33/</sup>

In a comparative statics framework, changes in the stock variables,  $N_1$ ,  $N_2$ , and  $K$ , will induce systematic changes in the economy. An increase in  $N_1$  can be regarded as an increase in the physical stock of land in the economy, while an increase in  $N_2$  can be interpreted as an increase in the labor force. An increase in  $K$  represents net savings, and is equal to the increase in stationary state replacement investment that corresponds to a permanent change in the stock of capital.<sup>34/</sup>

Under the usual assumptions of instantaneous and perfect factor mobility, a change in either  $N_1$  or  $N_2$  will result in a reduction in the absolute output of the good which uses the increased factor relatively

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<sup>33/</sup> That is, it will be concave to the origin.

<sup>34/</sup> Kenen (31), p. 108.

less "intensively" in order to keep the relative price of the goods constant. In other words, Rybczynski's theorem<sup>35/</sup> would apply.

We will, on the other hand, hypothesize a disequilibrium model in which the factors of production are not instantly mobile among industries.<sup>36/</sup> A change in the natural endowment, therefore, can be expected to alter the wage-rate ratio via a change in the relative quantity of factor-services supplied. The net factor ratio,  $R_N$ , as well as  $R_G$  and  $R_K$ , will change accordingly. The factor ratios in the new equilibrium will therefore be different than they would be in case instant mobility were assumed.

It is at this point that Hayami and Ruttan's induced technology hypothesis comes into play. Their hypothesis is that "a common basis for success in achieving rapid growth in agricultural productivity is the capacity to generate an ecologically adapted and economically viable technology in each country or development region".<sup>37/</sup> This hypothesis is operationalized by them in the following terms:

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<sup>35/</sup> Rybczynski's theorem asserts that if the supply of one factor increases with the supply of the other factor constant the absolute output of the good which uses the increased factor relatively less "intensively" should diminish in order to keep the (exogenously determined) relative price of the good constant. See Ryczynski (51).

<sup>36/</sup> Unless a disequilibrium model is postulated, the factor-price model of induced technical change makes little sense. As Salter has pointed out in commenting on the Hicks micro-level model of induced technical change, in equilibrium the MVP per unit of expenditure on each resource will be the same, with the result that the firm would be indifferent to whether it economized on the use of one resource or the other. (See Salter (53). The analysis would appear to carry over to the macro level, which is the context in which Hayami and Ruttan specify their model.

<sup>37/</sup> Hayami and Ruttan (16), p. 4.



"A requisite for agricultural productivity growth is the capacity of the agricultural sector to adapt to a new set of factors and product prices. This adaptation involves not only the movement along a fixed production surface but also the creation of a new production surface which is optimal for the new set of prices....<sup>38/</sup> In the short-run, in which substitution among inputs is circumscribed by the rigidity of existing capital and equipment, production relationships can best be described by an activity with relatively fixed factor-factor and factor-product ratios. In the long-run, in which the constraints exercised by existing capital disappear and are replaced by the fund of available technical knowledge, including all alternative feasible factor-factor and factor-product combinations, production relationships can be adequately described by the neoclassical production function. In the secular period of production, in which the constraints given by the available fund of technical knowledge are further released to admit all potentially discoverable possibilities production relationships can be described by a metaproduction function which describes all conceivable technical alternatives that might be discovered.<sup>39/</sup>

The Hayami-Ruttan metaproduction function can thus be conceived as the envelope of the usual neoclassical production function.<sup>40/</sup>

To illustrate the concept in the context of the Kenen model, consider an exogenous increase in  $N_2$ , the land endowment. This increase, under the disequilibrium assumption of less than instantaneous mobility of factors, will result in a decrease in the price of land services relative to the price of labor. This shift in the factor price ratio will encourage the substitution of land for labor. With fixed technology, however, there is only limited potential for factor substitution. If technology is allowed to change, however, the elasticity of factor substitution is increased, with the larger elasticity of substitution embodied in the metaproduction function.

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<sup>38/</sup> Ibid., p. 82.

<sup>39/</sup> Ibid., pp. 82-83.

<sup>40/</sup> Brown ( ) and Appendix A.

Two effects of this change will alter the relations in the product space. First, the increase in  $N_1$ , the land endowment, will shift the transformation curve outwards by virtue of the increase in the land-service supply function. The outward shift of the transformation curve will occur all along the curve, but will be more pronounced in the direction of the good which is relatively more intensive in the use of land services. Second, the development of a new production technology in response to the changing factor price ratio, and which in this case will be labor-augmenting,<sup>41/</sup> will also shift the transformation function outwards.

This second effect, however, is limited to the good for which new technology is developed. In the case of the other good, however, the transformation curve will shift inwards because of a reverse Rybczynski effect.<sup>42/</sup> For simplicity's sake, without however limiting the generality of the argument, we assume that only the agricultural sector, as represented by  $X$ , is dynamic in the sense of experiencing technical progress in production.

These effects can be shown graphically by means of a Lerner-Pearce diagram (Figure 2). Suppose  $R_n^1$  is the initial net factor-service ratio for the economy. Accordingly,  $R_1^1$  and  $R_2^1$  will be the factor service ratios in the production of  $X$  and  $Y$ , respectively, given the factor price ratio,  $p_0$ . Assuming linear homogeneous production functions for both

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<sup>41/</sup> The new technology is assumed to be of a factor-augmenting kind, however biased it may be.

<sup>42/</sup> Pathological cases that result from such conditions as convex transformation curves are ruled out. For a treatment of such a case, see Teubal (64). It should be noted, however, that the inducement mechanism which Teubal uses is different than the one postulated here.



Z2

Z1

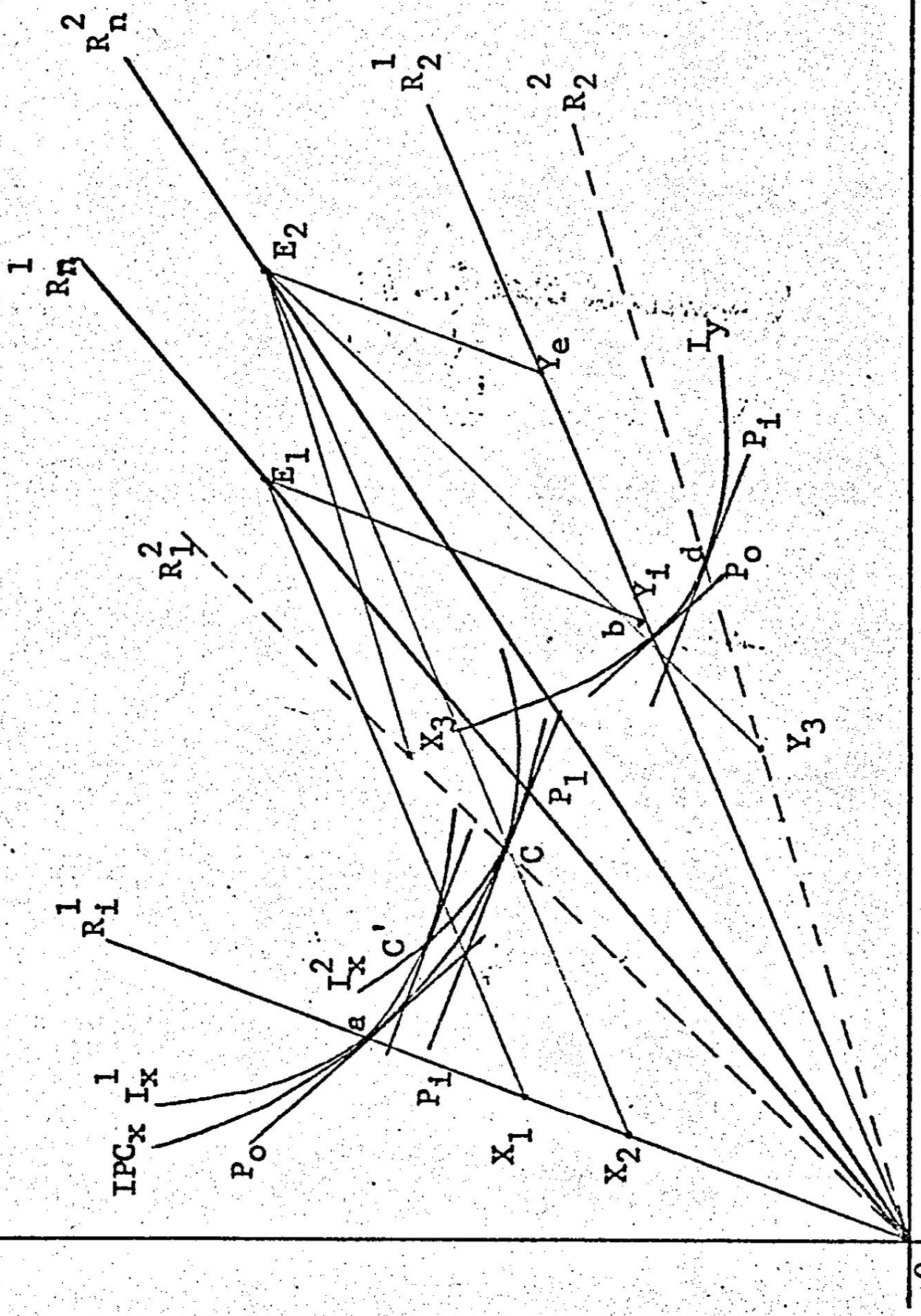


Figure 2. Induced Technical Change and Perverse Rybczynski Effect.

goods, the isoquant map can be represented by any arbitrary isoquant:

$I_2^1$  and  $I_y^1$ , for instance.

For the factor-service endowment  $E_1$ , production will take place at points  $X_1$  and  $Y_1$ . The effect of an increase in  $N_1$  will be to displace the factor-service endowment to  $E_2$ . If relative factor prices do not change, production would take place at points  $X_2$  and  $Y_2$ . In fact, however, production would take place at points  $x_2^1 < x_2$  and  $y_2^1 > y_2$ , (not shown in order to simplify the graph), because  $E_2$  would have moved further to the right if relative factor prices did not change in response to the increase in the stock of land. The position of  $E_2$  in the graph assumes this change in the factor price ratio (again in order to keep the graph as simple as possible).

With no change in technology the factor-service ratio for agriculture would be given by point  $C'$ . If, on the other hand, technology is allowed to change, the substitution of factors of production will take place along what Ahmad<sup>43/</sup> describes as the Innovation Possibility Curve,  $IPC_x$ , or along what Hayami and Ruttan call the metaproduction function. Factor proportions for factor-price ratio  $p_1$  is given by point  $C$  on  $I_x^2$ , the new medium-run neoclassical isoquant. Production will occur at points  $X_3$  and  $Y_3$ . It can therefore be seen that the hypothesized technical change outweighed the Rybczynski effect.

It is clear that this will not always be the case, even under the disequilibrium hypothesis. It all depends on the degree of difference in the factor intensity and the nature of the metaproduction function.

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43/ Ahmad (1).



The point that can be made, however, is that under the above assumptions technical progress will always work against the reduction in output of the good that is less intensive in the relatively cheaper production input.

The kind of technological change that is assumed above is one, for example, which permits an increase in the area operated by a worker. In agriculture this is usually achieved through an increase in the intensity of mechanical power per worker, which conceals the complementarity relationship between land and power. The increase in the land endowment ( $N_1$ ) that was postulated above could thus have brought about an increase in mechanical equipment per worker. This would be a case of labor-saving technical change.

A similar example could be presented for increases in the labor force. Land-saving techniques would result in this case, through improvements in chemical-biological processes. More specifically, farmers could be expected to adopt improved varieties that have a greater response to fertilizer and make greater use of chemical inputs such as commercial fertilizers and pesticides.<sup>44/</sup>

It is important to observe, however, that increases in the natural endowment are not the only means by which changes in relative factor prices are brought about. Changes in the factor-service supply functions could occur as a consequence of technical change in the supply industries,<sup>45/</sup>

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<sup>44/</sup> For details regarding the specific techniques associated with particular factor-saving or factor-augmenting innovations, see Hayami and Ruttan (16) Ch. 6.

<sup>45/</sup> Technical change in the fertilizer industry has been an important source of the relative decline in the price of that input in the last decade, and has in turn induced technical change in the agricultural sector.

as a consequence of technical change in the investment process, and so forth. In addition, changes in wage rates or factor prices may result from domestic or trade policies that change the factor prices faced by the firm.

A further example that is relevant for the present study, although somewhat extraneous to Hayami and Ruttan's basic model, arises in the case of the infant industry argument. The adoption of an import tariff policy designed to protect the nascent industry in many LDC's has as its natural consequence the working of the Stolper-Samuelson theorem,<sup>46/</sup> with the result that there is a domestic price increase of the relatively scarce factor of production. If the inducement mechanism herein adopted from Hayami and Ruttan is to be credited as general, the relevant technology to be pursued by the LDC's should in any case be one designed to save the relatively more expensive input.<sup>47/</sup>

The extension of this production model to a trade model can be easily accomplished. If we introduce demand conditions by means of the usual homothetic indifference curves, the postulated changes in the production technology will induce changes in the country's offer curve, thereby tending to give the country a comparative advantage in that sector where technology is more dynamic.

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<sup>46/</sup> The Stolper-Samuelson theorem asserts that under the five assumptions made on page , the price of the factor which is relatively scarce will increase in terms of the other factor or in terms of the price of any good as a result of the imposition of an import tariff. See Stolper-Samuelson (62).

<sup>47/</sup> This is true, of course, for any change in relative factor price, regardless of any protectionistic policy.



To operationalize the model resort can be made to the usual definition of the offer-curve as the difference between domestic production and consumption. Factor-augmenting, induced technical change will have the same kind of effects on export supply as discussed for production. Were the assumption of unitary elasticity of substitution in demand to be dropped, the same result presented by Amano<sup>48/</sup> would be obtained.

### Trade Intervention Factors

In order to increase the contribution of agriculture to goals of society other than of exchange earnings, countries at times place direct and/or indirect restrictions on agricultural exports.<sup>49/</sup> Two common such policies are export quotas and over-valuation of the exchange rate.<sup>50/</sup> In the present section a relatively simple partial equilibrium model that helps to understand the role of these "intervening" factors is presented.<sup>51/</sup>

The fundamental assumption made in this section is the small country assumption.<sup>52/</sup> The domestic market for any tradeable commodity such as

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<sup>48/</sup> Discussed in the last section of the previous chapter.

<sup>49/</sup> For a comprehensive treatment of trade intervention in agricultural products, and their inter-relation with domestic agricultural policies, see Johnson (21).

<sup>50/</sup> Exchange rate policies can also, of course, be used to promote agricultural exports. The emphasis here is on the over-valuation case because it has tended to be the more common policy in the post-war period. The analysis is symmetrical, however, except that under-valuation of the exchange rate will tend to increase exports rather than decrease them.

<sup>51/</sup> For a discussion of an over-valued exchange rate in terms of the model presented here see Thompson (65) and Schuh (58).

<sup>52/</sup> The home country is assumed to be so small relative to the rest of the world that its economic activities have negligible repercussions on the foreign economies via trade. International economic activities, however, are assumed to have noticeable effects on the domestic economy. In other words, this means the home country is a price taker.



agricultural products can be described by the demand schedule DD and the supply schedule SS, shown in Figure 3, which would define an equilibrium price,  $P_0$ , and an equilibrium quantity,  $Q_0$ , in the absence of trade. The vertical axis in the Figure measures agricultural prices in terms of the domestic currency, and the horizontal axis measures quantities.

For a fixed exchange rate,<sup>53/</sup>  $r$ , which translates any foreign price  $F$  to a domestic price,  $p$ , the foreign demand schedule, which is assumed to be perfectly elastic due to the small country assumption, can be represented by  $P_1F$ , corresponding to price  $P_1$ , in the domestic currency. Assume that  $r$  is the equilibrium<sup>54/</sup> exchange rate. The foreign price,  $F$ , will be translated into a domestic price  $\hat{P} > P$ , so long as the industry would be an export industry under equilibrium exchange rates and in the absence of other trade interventions. Under these conditions domestic production will be at  $OQ_2$ , domestic consumption at  $OQ_1$ , and quantity  $Q_1Q_2$  will be the quantity of exports of this product from the domestic economy.

Suppose, now, that the exchange rate is over-valued to level  $r_1$ . The consequence of this over-valuation varies according to whether it is viewed from a domestic or a foreign standpoint. Domestically, it corresponds to a downward shift of the foreign demand function to  $P_2F'$ , with a corresponding reduction in the domestic price (in terms of the domestic currency) to  $P_2$ . Internationally, it corresponds to an increase in the

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<sup>53/</sup> Defined as the number of units of the domestic currency required to purchase one unit of the foreign currency.

<sup>54/</sup> In line with Nurkse (46) and Meade (40), an equilibrium exchange rate is defined as one that maintains a country's external account in equilibrium for a period of five to ten years without the need for wholesale unemployment at home, no restrictions on trade, and an absence of temporary capital movements. Later in this study a less "ideal" equilibrium exchange rate will be defined.



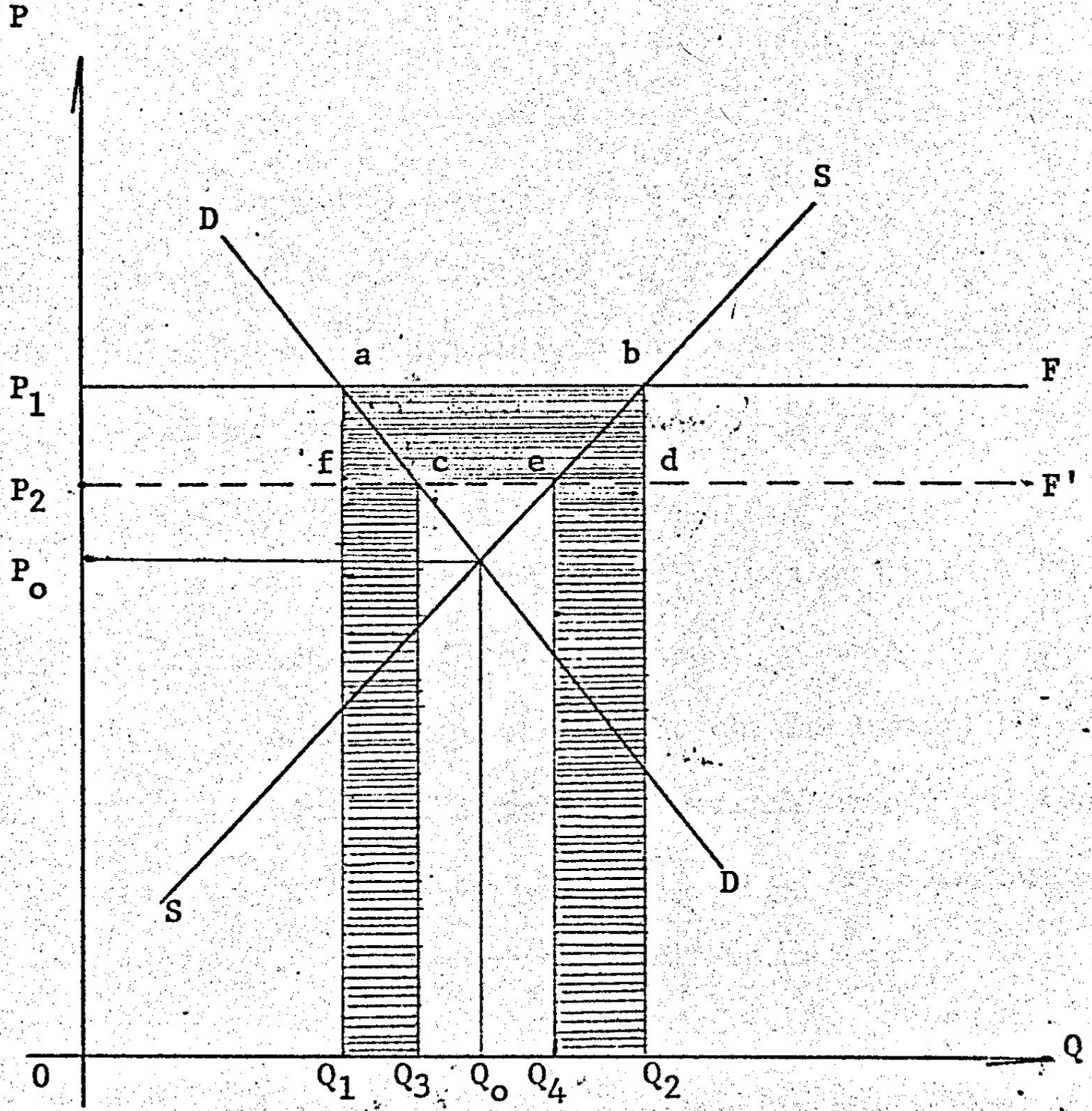


Figure 3. Market Conditions for Export Commodity.



price of the product, thereby resulting in a reduction in the quantity demanded.<sup>55/</sup> In terms of Figure 3 domestic production will be  $OQ_4$  under the changed conditions, domestic consumption will be  $OQ_3$ , and the quantity exported will be  $Q_3Q_4$ .

The magnitude of reduction in the quantity exported, as well as the reduction in exchange earnings (the shaded area in Figure 3) and the reduction in gross income to the sector (area  $P_1bQ_2Q_4eP_2$  in Figure 3), depends on the magnitude of the over-valuation and the elasticities of supply and demand. Should the devaluation persist for a long period of time, it is the long-run elasticities that are relevant.

Export quotas and taxes can be studied in the same framework.<sup>56/</sup> The usual reason for imposing export taxes or quotas is to prevent domestic prices from attaining international levels. A lump-sum tax applied to export has, in essence, the same effect as an over-valuation of the exchange-rate; that is, it shifts the foreign demand downwards.

If the reduction in domestic price were to be obtained (net) by an export quota, the same elasticities of supply and demand, or alternatively, of export supply, would have to be known. Figure 3 is of help in understanding the reasons for this. The reduction in domestic price from  $P_1$

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<sup>55/</sup> Observe that for a sufficiently large over-valuation the international price, as measured in terms of the domestic currency, will fall below the domestic, autarkic equilibrium price,  $P_0$ . Under these conditions the domestic country will become a net importer of agricultural products, other things remaining equal. For the purpose of the present analysis it is assumed that the over-valuation of the exchange rate is not sufficiently large to reverse the trade pattern. The argument, however, is perfectly general.

<sup>56/</sup> In fact, it is worth noting that an over-valued exchange rate is an implicit export tax.



to  $P_2$  via an over-valuation of the exchange rate resulted in a reduction in the quantity exported of  $Q_1Q_2$  plus  $Q_4Q_2$ . The same result<sup>57/</sup> would be achieved if, with fixed equilibrium exchange rate  $r$ , an export quota equal to  $Q_3Q_4$  had been established that reduced original exports,  $Q_1Q_2$ , by  $Q_1Q_3$  plus  $Q_4Q_2$ .

It is thus clear that despite its simplicity this approach enables one to reach interesting results. More complete results could, of course, be obtained by a general equilibrium analysis, at the cost, however, of complicating life considerably.

#### A Comparative Statics Model

There have been two strands of thought in the above discussion of conceptual considerations. The first was a model of induced technical change, which was introduced into commonly accepted trade theory by means of modifications to a model developed by Kenen. The second was a consideration of trade interventions, especially the role of the exchange rate, which act as intervening variables to modify comparative advantages that might be introduced by technological change.

What is needed now is a model that permits an analysis of changes in comparative advantage that derive from changes or differences in technology. A model adapted basically from Takayama<sup>58/</sup> is proposed in

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<sup>57/</sup> The "some results" refers only to the reduction in prices, however. Different forms of intervention may have quite different cost and benefits associated with them.

<sup>58/</sup> Takayama (63) Chs. 8 and 9.

this section. The model is a neoclassical model where full employment is the natural and basic assumption to make. Price is the key parameter of the system.

The two countries are assumed to each have a fixed stock of land,  $N_{1i}$  and labor,  $N_{2i}$ . Given a central loan fund in each country with capital at levels  $K_i$ , it will be assumed that two flows of factor services,  $Z_{1i}$  and  $Z_{2i}$  of land and labor services, respectively, will be generated in each country in the manner proposed by Kenen <sup>59/</sup> and described briefly above.

Let  $X_i$  and  $Y_i$  denote the output of the jointly produced goods  $X$  and  $Y$  in country  $i$ . It is assumed that the production of the two goods is obtained by combining land and labor according to two respective meta-production functions. A specially conceived production transformation curve incorporating the effects of induced technological change is assumed to represent the joint production process.

Following the neoclassical tradition, it is assumed that production takes place on the frontier. The relative price of the goods in each country determines the point on the respective transformation curve at which production takes place. The production in both countries can be represented by

$$X_i = X_i \left( \frac{P_{Xi}}{P_{Yi}} \right) \quad (17)$$

$$Y_i = Y_i \left( \frac{P_{Xi}}{P_{Yi}} \right) \quad (18)$$

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<sup>59/</sup> Kenen (30) and (31).



The aggregate output in country  $i$  in terms of good  $Y$  can be denoted as

$$V_i = P_i X_i + Y_i \quad (19)$$

where

$$P_i = \frac{P_{xi}}{P_{yi}}$$

Let  $C_{xi}$  and  $C_{yi}$  denote the consumption demand<sup>60/</sup> of goods  $X$  and  $Y$ , respectively, in country  $i$ . Adopting the usual aggregation assumption that each country acts as though it were a single consumer, a utility function,  $U_i$ , can be maximized for each country subject to its respective budget constraint. That is,

$$\max U_i (C_{xi}, C_{yi}) \quad (20)$$

$$\text{s.t. } P_i C_{xi} + C_{yi} = V_i$$

where  $V_i$  is aggregate output in country  $i$ , in terms of good  $y$ .

Under the usual assumption that  $U$  is concave it is possible to obtain the demand functions in terms of the parameters  $p_i$  and  $V_i$ :

$$C_{xi} = C_{xi}(p_i, V_i) \quad (21)$$

$$C_{yi} = C_{yi}(p_i, V_i) \quad (22)$$

where (21) and (22) are homogeneous of degree zero. The excess supply functions are defined as

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<sup>60/</sup> Money is not explicitly introduced in the model, despite our interest in the role of the exchange rate as a relative price. To do so would complicate the model unnecessarily. It can be assumed however, that money is the only means of storing value in the economy and that money yields no interest. In this case money enters as a third commodity.

$$E_{xi} = X_i(p_i) - C_{xi}(p_i, v_i) \quad (23)$$

$$E_{yi} = Y_i(p_i) - C_{yi}(p_i, v_i) \quad (24)$$

It is assumed that at any given equilibrium, country 1 exports good X and imports good Y. That is,  $E_{x1} > 0$  and  $E_{y1} < 0$ , respectively, and country 2 accordingly exports good Y and imports good X.

The balance of payments equation for country 1 in terms of country 2's currency is

$$B_1 = P_{x2}E_{x2} - P_{y2}E_{y1} \quad (25)$$

which, of course, is zero in equilibrium.<sup>61/</sup>

The world equilibrium of each good requires that

$$E_{x1} + E_{x2} = 0 \quad (26)$$

$$E_{y1} + E_{y2} = 0 \quad (27)$$

When (26) and/or (27) are satisfied, equilibrium in the balance of payments is implied. That is,

$$B_1 = 0$$

The exchange rate E is defined as the number of units of country 1's currency required to purchase one unit of country 2's currency:

$$\frac{P_{x1}}{P_{x2}} = \frac{P_{y1}}{P_{y2}} = E \quad (28)$$

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<sup>61/</sup> It is assumed that there is no capital mobility between countries so that the balance of payments consists of the balance of trade alone.



For simplicity,  $E$  is assumed to be equal to unity, which implies

$P_{x1}/P_{y1} = P_{x2}/P_{y2} = p$ . It should be noted that since money is not explicitly introduced into the model the exchange rate plays no significant role.<sup>62/</sup>

Variations of this model, with and without money explicitly introduced, and based on the usual neoclassical production function, are used by Takayama, the original proponent of the model, to analyze basic pure trade questions such as the Marshall-Lerner condition, the exchange stability question, and the exchange devaluation problem. Incorporated with the metaproduction function concept this model may prove useful in explaining the effect of changes in technology on trade patterns, in the way presented in the second section of this chapter. In essence, any movement along a metaproduction function shifts the transformation curve outwards, thereby changing the excess supply function.

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<sup>62/</sup> If the economy is assumed to operate under a fixed exchange rate, with fiat currency, the balance of payments of country 1 ( $B_1$  as defined in (26)) is not necessarily in equilibrium. An excess demand function for country 1's currency must then be defined.

Finally, it has to be assumed that a disequilibrium in the balance of payments does not interfere with each country's money supply. That is, if both countries adopt a complete sterilization policy, then  $M_1^S$  (the money supply in country  $i$ ) can be considered fixed for both countries.

### CHAPTER III

#### THE EMPIRICAL MODEL, STATISTICAL PROCEDURES, AND DESCRIPTION OF THE DATA

The model described in the last section of the previous Chapter allows for the simultaneous determination of the excess demand functions and the relative prices. The focus of the present study is not to test that model, however, since to do so it would be necessary to consider the production and consumption side of both goods, which goes beyond the scope of the study. Rather, the research reported here had as its primary goal to evaluate the effects of differences in technology upon comparative advantage in agricultural trade. To this end, the theoretical model of Chapter II can be transformed by means of some simplifying assumptions into an empirical model that is suitable for testing hypotheses derived from the conceptual model. This is done in section one of this chapter. Section two presents a discussion of the statistical procedures to be used in the empirical work, and section 3 describes the data.

#### The Empirical Model

The first step is to restrict the analysis to the agricultural sector. This in itself raises some problems, however, since agriculture has tended to be ignored in previous studies of international trade.



Agriculture is usually deleted from trade studies for a number of reasons.

Ball, for instance, argues <sup>63/</sup> 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 natural 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. Measures of factor inputs may be least reliable in the case of 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 rankings test. The food industry may be second to agriculture in excessive breadth and dissimilarity of content."

Leontief is also incisive in deleting agriculture from trade studies:

"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."<sup>64/</sup>

The criticism that the composition of agricultural output is greatly dissimilar among countries is difficult to overcome, for it obviously is. Nonetheless, very pragmatic reasons such as the availability of data and the fact that satisfactory empirical results

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<sup>63/</sup> Ball (5), pp. 77-78.

<sup>64/</sup> Leontief (35), p. 396.

have been obtained under this assumption in studies of other problems<sup>65/</sup> make this problem easier to live with. In addition, the importance of agricultural trade problems on the contemporary world scene points up the potential contributions of improved knowledge in this area.<sup>66/</sup>

The other restrictions to a consideration of agriculture in trade studies that were pointed out above may, however, be objected to on a number of grounds. In the first place, the prevalence of differences in natural resource endowments should be taken into explicit account rather than ignored by deleting agriculture from empirical studies. This is especially the case in view of the fact that the whole body of neoclassical trade theory is based on a consideration of the natural endowment of factors of production.

Second, differences in the level of technologies are the very element the present research proposes to study. Previous studies of the relative efficiency of labor, as discussed by Minas<sup>67/</sup> and Arrow, et al.,<sup>68/</sup> for example, are based on computations using tangible capital. As has been pointed out by Kenen,<sup>69/</sup> they make no allowance for investment in men. In addition, it should be noted that they disregard the

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<sup>65/</sup> Hayami and Ruttan, for example, have used aggregate data across countries to test hypotheses about induced technical change and agricultural development. See (16).

<sup>66/</sup> Both Hayami and Ruttan and D. Gale Johnson have stressed the massive disequilibrium in world agriculture and the implications in terms of an ever-widening gap in per capita incomes among countries and the loss in production efficiency that results. See (16) and (21).

<sup>67/</sup> Minas (43).

<sup>68/</sup> Arrow et al. (3).

<sup>69/</sup>



As for Leontief's restrictions, a sufficiently large sample in which differences in yields are not only stochastic but endogenous, and in which enough variation in factor markets exist, may possibly ease the difficulty of obtaining production coefficients for agriculture. Moreover, for certain kinds of questions multiple-year averaging is feasible and may help reduce the problem of unsystematic variations in yield that are due to variations in climatic conditions.

The restriction of the study to a consideration of only one sector should not imply that the analysis is limited to a partial equilibrium framework. The relatively simple comparative statics model presented at the end of the previous chapter makes clear the simultaneous determination of exports and imports under the constraint of a zero trade balance. In a model with a flexible exchange rate this will always be the case. If, however, the model is built featuring a fixed exchange rate, the rate has to be exogenously manipulated, as a policy variable, in order to equate exports and imports.

Nurkse's and Meade's definition of an equilibrium exchange rate, which was referred to above, is a less than ideal measure for empirical work. It disregards the many manipulations of the foreign sector that are undertaken in order to achieve some domestic policy goal, usually protection of a domestic industry or industries. Such interventions may involve different combinations of tariffs, subsidies, and actual exchange rate manipulations. As the system of protection is altered, together with shifts in monetary and fiscal policies, the equilibrium exchange rate will also change.<sup>70/</sup> In fact, for each set or combination of policies

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<sup>70/</sup> See Balassa and Schydrowsky (4).



there is a corresponding equilibrium exchange rate, and in the absence of appropriate shadow exchange rates, some proxy will have to be defined.

A third consideration refers to the data to be used. Although either time-series or cross-section data could be used, the latter have some advantages for the present study. For example, size and income levels among countries are practically uncorrelated and the effects of the two can easily be separated statistically. In addition, cross-sectional data among countries will typically provide ample variance in the data.

An important part of the data used for the present study will be taken from Hayami and Ruttan's earlier study. This has certain advantages since the existence, in a statistical sense, of the metaproduction function is basic to the model postulated. The Hayami and Ruttan study provided support for such an underlying production function. By using their data for the relevant variables, it will be possible to re-test this hypothesis for the various sub-sets of countries that are used to test the model.

A fourth assumption relates to the type of domestic supply function implied by the use of the metaproduction function. Since the metaproduction function is the envelope of a family of neoclassical production functions, it implies a larger elasticity of substitution between factors than the functions it envelopes. Moreover, movements along the surface of a metaproduction function conceal changes in production technology. As a result, the supply relation derived from such a function differs from the usual supply function in the sense that technology now becomes a variable. The own price slope of the supply relationship derived from the metaproduction function is thus expected to be smaller (and therefore



more elastic) than that of any "common" supply function that could be derived from the enveloped neoclassical production functions.

The statistical model for testing purposes is derived from the comparative statics model of the previous chapter, with the role of technology introduced through the Kenen model by means of the Hayami-Ruttan model of induced technical change. It will be recalled that the import demand for good  $X$ , agriculture products in the present case, by country 2, was specified as

$$E_{x2} = X_2(p) - C_{x2}(p, v_2) < 0, \quad (\text{imports})$$

while the export supply of good  $X$  by country 1 was specified as

$$E_{x1} = X_1(p) - (X_q(p, v_1)) > 0 \quad (\text{exports})$$

with the world equilibrium condition being

$$E_{x1} + E_{x2} = 0. \quad (\text{equilibrium condition})$$

The  $X_i$  refer to the outputs of the respective agricultural sectors, and are postulated to be a function of  $p$ , the relative price of good  $X$ . The  $C_{xi}$  refer to the domestic consumptions of agricultural products, and are postulated to be a function of  $p$ , the relative price of good  $X$ , and total national income,  $v_i$ , which reflects both population and per capita income. When the system is in equilibrium,  $p$  would be common among the countries. When domestic output is less than domestic consumption, the country is an importer, and vice versa for an exporter.

This system could be studied either in terms of its structural equations, as implied above (demand and supply equations), or in terms

of the reduced forms implied by the system. It was decided to focus on the reduced forms, since to do so simplifies the statistical problems while at the same time providing a convenient means of testing hypotheses about specified demand and supply variables on both exports and imports.

One advantage of proceeding in this way is that the analysis can focus on the "quantity" variables of exports and imports, while ignoring the more difficult problem of prices, which may be distorted and difficult to interpret because of trade interventions and exchange rates that are set at non-equilibrium levels. Hence, as a first approximation, trade could be formulated as a function of output and consumption of the respective countries. But it is desired to conduct the analysis at a still more detailed level of specification in order that more detailed hypotheses can be tested. Hence, on the production side, output is replaced by the inputs used in agriculture (by means of the production function). On the consumption side, the variable is replaced by two explanatory variables -- population and per capita income.

The reduced form equation for estimational purposes is therefore

$$E_x = E_x(Z, S, W)$$

where Z refers to the variables in the metaproduction function in order to test technology variables, S refers to the demand variables, and W is a variable designed to reflect differences in the degree of trade intervention (more specifically the degree to which the exchange rate is over- or under-valued). An advantage of including all the variables from the production function is that this permits some analysis of the role of conventional inputs such as land and labor, as well as the role of modern inputs such as fertilizer and mechanical inputs and the "purer"



technology variables such as research and development inputs and education.

The reduced form equation should also show the income variables of the demanding country. It is impossible to specify such a variable when the supply equation is derived from cross-sectional data, however. The difficulty stems from the inter-country matrix of commerce. The countries represented in the cross-sectional data are trade partners of each other as well as of the rest of the world. Since the income and population variables of the countries considered in the sample have a fairly large variance, and are likely correlated with effective international demand conditions, it is likely that these two variables will capture at least some part of the international demand effects. As a consequence, the interpretation of their respective coefficients will be complicated. But since they are the reduced form coefficients of an over-identified system the difficulty of interpretation is inherent. It is not believed that this will prejudice the analysis, however, since the coefficients relevant to the present study are the ones related to the factors of production.

Four models were specified for testing.<sup>71/</sup> One model was tested with a pool of cross-section and time-series data for exporting countries. A second model was tested with a similar pool of data for importing countries. And two models were tested for the exporting countries, each using cross-section data for a different time period. It should be noted

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<sup>71/</sup> Actually, what was done is the pooling of cross-section data for two different periods of time, 1957-61 and 1962-66 respectively.

that the data were scaled in such a way that the same signs would be expected on the independent variables independently of whether they were fitted with data from exporting or importing countries. Hence, a large value of imports for an importing country corresponds to a small value of exports for an exporting country.

### Statistical Procedures

Since all the variables included as independent variables in the reduced form are presumably exogenous to the dependent variable, ordinary least squares is an appropriate estimate procedure. The only variable which may violate this assumption in a serious way is the policy or trade intervention variable. Two of the three proxies tried for this variable were the balance of trade and the total balance (see below). Obviously, either of these may be jointly dependent with net agricultural exports, the dependent variable. It will be shown below, however, that this did not appear to be a serious problem.

All models are specified to be linear in the logarithms to the natural base. This implies the statistical assumption that the logarithm of the error terms are normally distributed with mean zero and variance  $\sigma^2$ .

At a second phase of the analysis a Stepwise Regression<sup>72/</sup> procedure was used. It should be noted that this procedure was not used to

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<sup>72/</sup> Draper and Smith (11), pp. .



select variables for the models, but rather to select from among the variables specified a priori those that had the higher explanatory power.<sup>73/</sup> The relative importance of the independent variables in predicting the dependent variable is of considerable value in understanding the theoretical model presented in this dissertation.

In the Stepwise Regression one variable is entered in the equation at each step. The order of entrance is determined by using the partial correlation coefficient as a measure of the importance of variables not yet in the equation. The method provides for the re-examination at every stage of the analysis of variables incorporated into the model in previous stages. A variable which may have been the best single variable to enter at an earlier stage may, at a later stage, be superfluous because of the relationships between it and other variables now in the regression. The method provides, therefore, for an expeditious way of checking for multicollinearity. Since multicollinearity does not bias the significance test, a sequential F test criterion may be used to check each variable for inclusion or deletion at a pre-selected percentage point of the appropriate F distribution. The sequential F test measures the contribution to the regression sum of squares of each variable, given that a set of zero to n variables are already in the equation.

All four models tested have the same specification:

$$Y_i = \alpha + B_{1i}X_{1i} + B_{2i}X_{2i} + B_{3i}X_{3i} + B_{4i}X_{4i} + B_{5i}X_{5i} + B_{6i}X_{6i} \\ + B_{7i}X_{7i} + \gamma_{1i}Z_{1i} + \gamma_{2i}Z_{2i} + S_iW_i + U_i$$

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<sup>73/</sup> The Stepwise Regression procedures were used only as a second phase of the statistical analysis.

where, for  $i = 1 \dots 4$  representing the four models.

$Y_1$  = net agricultural exports

$X_{1i}$  = labor

$X_{2i}$  = land

$X_{3i}$  = livestock

$X_{4i}$  = fertilizer

$X_{5i}$  = machinery

$X_{6i}$  = general education (to represent the general stock of human capital in the economy)

$X_{7i}$  = technical education (to represent the capability to produce and distribute new production technology)

$Z_{1i}$  = per capita income

$Z_{2i}$  = population

$W_i$  = policy variable

$U_i$  = the random error term.

#### Description of the Data

The countries included in the various samples are listed in Table 1.

The variables were defined as follows:

Net Agricultural Exports: agricultural exports (in million U.S. dollars)

minus agricultural imports (in million U.S. dollars). Countries with a

positive balance were classified as net exporters. Countries with a

negative balance were classified as net importers. Five billion U.S.

dollars were added to all values as a linear transformation;<sup>74/</sup> the

objective to make all values positive. Data were taken from the United

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<sup>74/</sup> It should be observed that this was done, of course, before the logarithm transformation is carried out. This will not cause any difficulty in the analysis, however, because the relative size of the coefficients of the reduced form are of no special interest in this study.



Nations' Trade Yearbook and includes within the Standard International Trade Classification (revised) 0 (ten two digit entires), 1 (entry 11 only), 2 (entries 21, 22, 231.1, 26 and 29), and 4 (entries 41, 42, and 43). The data are measured as five year averages.

Labor:<sup>75/</sup> number of male workers in agriculture (1,000's). Data are for 1960 and 1965.

Land:<sup>75/</sup> agricultural land area (1,000's hectares). Data are for 1960 and 1965.

Livestock:<sup>75/</sup> 1,000 livestock units. Data are for 1960 and 1965.

Fertilizer:<sup>75/</sup> fertilizer consumption ( $N + P_2O_5 + K_2O$ ). 1,000 metric tons. Data are for 1960 and 1965.

Machinery:<sup>75/</sup> tractor horsepower, 1,000 hp. Data are for 1960 and 1965.

General Education:<sup>75/</sup> school enrollment ratio. Average data (1950, 55, and 60) for 1960 and (1955, 60 and 65) for 1965.

Technical Education:<sup>75/</sup> number of Agricultural College graduates per 10,000 farm workers. Average data (1958-62 for 1960 and (1963-67) for 1965.

Per Capita Income: U.S. dollars per capita. The national Income data (line 99c) were taken from International Financial Statistics. Averaged over the five year periods and divided by 1960 and 1965 IFS population data (line 99z). All data are rounded to the nearest \$10.00.

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<sup>75/</sup> These data are taken from Hayami and Ruttan (16). A more detailed description can be found in Appendix A of their book.

Table 1. Countries Composing the Sample; Different Groupings and Periods.

Exporting Countries		Importing Countries
1957-61	1962-66	1957-61 and 1962-66
1 Argentina	Argentina	Austria
2 Australia	Australia	Belgium-Luxemburg
3 Brazil	Brazil	Chile
4 Canada	Canada	Finland
5 Ceylon	Colombia	France
6 Colombia	Denmark	Germany
7 Denmark	Greece	Israel
8 Greece	Ireland	Italy
9 India	Mexico	Japan
10 Ireland	Netherlands	Sweden
11 Mexico	New Zealand	Switzerland
12 Netherlands	Norway	United Kingdom
13 New Zealand	Pakistan	Venezuela
14 Norway	Peru	Austria
15 Pakistan	Philippines	Belgium-Luxemburg
16 Peru	South Africa	Chile
17 Philippines	Syria	Finland
18 South Africa	Taiwan	France
19 Spain	Turkey	Germany
20 Syria	United Arab Republic	India
21 Taiwan	United States	Israel
22 Turkey		Italy
23 United States		Japan
24		Portugual
25		Sapin
26		Sweden
27		United Kingdom
28		Venezuela



Population: in million inhabitants. Data are taken from IFS  
(line 99z) for 1960 and 1965.

Trade Variable: Three alternative variables were used:

- 1) Trade Balance: Commodity exports (in million U.S. dollars) minus Commodity Imports (in million U.S. dollars) plus 3 million U.S. dollars to make all values positive. Data from U.N. Trade Yearbook were averaged: (1957-61) for 1960 and (1962-66) for 1965.
- 2) Reserves Over Imports: IFS data were averaged over the relevant periods and normalized by mean World Reserves/World Imports for the corresponding period.
- 3) Total Balance: Includes balance of goods and services averaged for the relevant periods. IMF Balance of Payments Yearbook was used as the source.

All the data used in estimating the statistical models are reported in Appendix A.

## CHAPTER IV

## ANALYSIS AND DISCUSSION OF THE RESULTS

This chapter reports the statistical results and attempts to provide an economic interpretation of them in light of what is set forth in the theoretical framework presented earlier. The chapter is divided into three basic parts. In the first part estimates of the postulated metaproduction functions are presented for the countries included in the sample. This was presumed to be useful since the samples are basically sub-sets of the larger Hayami-Ruttan sample, and since knowledge of the parameters for the sub-sets may prove useful in interpreting the statistical tests of our own model. In the second part the results for the exporting and importing countries are presented, with the discussion focusing on the difference in results obtained for the two groups. The third part presents results for the exporting countries in which a comparison was made between models estimated with data from the 1957-61 period and models estimated with data from the 1962-66 period. The chapter terminates with some concluding comments.

The Metaproduction Functions

The economic model developed in Chapter II presumes the existence of an innovation possibility curve (IPC). In empirical terms this hypothesized IPC may be assumed to be approximated by a metaproduction



function, which is the envelope of a family of neo-classical production functions. Such a function incorporating general education and technical education as shift variables was assumed to exist by Hayami and Ruttan,<sup>76/</sup> who obtained statistical estimates of it for an international cross-section of 42 countries. To check the propriety of testing the hypothesis advanced in the present study with the data for the group of countries described in Chapter III, the same specification of the meta-production function used by Hayami and Ruttan<sup>77/</sup> was fitted with data from each group.

The existence of the metaproduction function is part of the maintained hypothesis underlying the empirical model. If this assumption is not made, however, the alternative of a conventional production function that does not include variables such as education and research and development variables is likely to be nothing more than a "bogus" equation, because it does not seem plausible that all countries face the same agricultural production function excluding these variables. But one of the reasons for estimating the metaproduction function directly is to test the plausibility of the maintained hypothesis.<sup>78/</sup>

The statistical fitting of the metaproduction function to the different groups allowed two additional hypotheses to be tested. The

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<sup>76/</sup> Hayami and Ruttan (16), Ch. 4.

<sup>77/</sup> Ibid., page 93, Table 5-1, specification Q-8.

<sup>78/</sup> For the mathematical derivation of a functional form for a family of production functions which have a C.E.S. type envelope function see Hu (18).



first was the only one regression equation could be used for both groups of net importers and exporters of agricultural products. The second was that the aggregation of the observations over time was appropriate. In other words, it was desired to test whether it was appropriate to assume that the process of technological change in agriculture is sufficiently general to permit the aggregation of all countries, regardless of whether they were net exporters or net importers of agricultural products. Furthermore, it was desired to test whether this process of technical change was stable over time.

For both hypotheses the data did not permit the rejection of the null hypothesis that one regression relationship could represent both net exporters and net importers in favor of an alternative hypothesis that specific relationships were needed. Chow's<sup>79/</sup> test for the first hypothesis yielded an observed F value of 1.32 to be compared to an expected  $F_{(.05; 8, 54)} = 2.11$ . For the aggregation of the net exporting countries<sup>80/</sup> over time (periods 1957-61 and 1962-66) the observed F value was .454 against an expected  $F_{(.05; 8, 26)} = 2.32$ . The possibility of aggregation of net importing countries over time was assumed, for the degrees of freedom in each period were not sufficient to permit a statistical test.

The estimated coefficients and related statistics for the meta-production functions are presented in Table 2, together with Hayami and Ruttan's estimates for the period 1957-62. The overall results are

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<sup>79/</sup> Chow (10) and alternatively Fisher (14).

<sup>80/</sup> All references to exporters and importers are made with respect to agricultural trade alone.



	Labor	Land	Livestock	Fertilizer	Machinery	Education	Technical Education	Corrected R <sup>2</sup>
Exporters	.402	.048	.351	.080	.093	.199	.193	.9234
1957-61 +	(5.276)	(.834)	(3.828)	(1.350)	(1.611)	(.832)	(3.666)	(72.84)
1962-66	<.001	<.25	<.001	<.10	<.10	<.25	<.001	<.01
Importers	.341	-.007	.202	.309	.090	.197	-.016	.9723
1957-61	(4.517)	(.055)	(1.952)	(2.829)	(1.066)	(.497)	(.236)	(12.98)
1962-66	<.001	1.0	<.05	<.001	<.15	<.35	<.50	<.01
Exporters	.415	.068	.317	.079	.089	.347	.158	.9295
1957-61	(3.748)	(.838)	(2.362)	(1.007)	(1.024)	(1.075)	(2.279)	(39.65)
1962-66	<.005	<.25	<.02	<.25	<.25	<.15	<.02	<.01
Exporters	.472	-.010	.417	.007	.141	-.074	.332	.9049
1962-66	(3.676)	(.108)	(2.874)	(.065)	(1.529)	(.169)	(3.074)	(26.04)
1962-66	<.005	1.0	<.01	1.0	<.10	<.50	<.005	<.01
Export-Import	.382	.046	.289	.131	.130	.110	.138	.9394
1957-61	(7.388)	(.995)	(4.522)	(2.700)	(3.233)	(.568)	(3.453)	(155.7)
1962-66	<.001	<.25	<.001	<.005	<.005	<.25	<.001	<.01
Hayami & Rutan (Q.8)	.413	.076	.236	.123	.116	.324	.142	.950
1957-62	(5.507)	(1.206)	(2.554)	(1.952)	(.060)	(.248)	(.055)	
1962-66	<.001	<.15	<.01	<.05	<.05	<.10	<.01	

*This figure reported in the first*

Note: Equations are linear in the logarithms (base e) and were estimated by ordinary least squares. The first entry in each cell is the coefficient of the variable; the second entry (in parentheses) is the value of the t-ratio value; and the third entry is the significance level of the t-test. The R<sup>2</sup> column reports F-test values rather than t-values.

judged to be reasonably satisfactory. The sum of squares due to regression tend to be high relative to the respective total sum of squares, as indicated by the high  $R^2$ 's after correction for degrees of freedom. All of the coefficients of determination are significantly different from zero at the .01 level. The individual coefficients are reasonably stable over the different periods and over the two sub-groups. The coefficient for land, which is statistically significant at less than the .15 level with the Hayami-Ruttan sample, is markedly weaker in each of the five equations estimated for our sub-groups and the pool, and shows no statistical significance at all either for the pooled importing countries or for the importing countries in the period 1957-66. For the sample of importing countries the coefficients of the shift variables, general education and technical education, show a large component of chance. For the exporting countries coefficients of fertilizer and general education appear with null and low significance, respectively. Despite these problems, however, it appears that the data are appropriate for further analysis. Hence, the original specification discussed in Chapter III was estimated for each of the four samples.

#### Estimates of the Export Equations

In estimating the export equations an initial experiment was conducted to decide which of the three policy variables would be more appropriate to use: trade balance, reserves as a proportion of imports, or total external balance. The results of this experiment are presented in Appendix B. Reserves over imports and total balance failed to yield satisfactory results, either in an economic or statistical sense. For



that reason the policy variable used in the results presented in this chapter is the trade balance.

It should be noted that there is a possible simultaneity problem between the trade balance and the dependent variable, net agricultural exports. In terms of the tests of hypotheses to be made herein, this should not create serious problems, since the focus of the study is not to evaluate the effect of over- or under-valuation of the exchange rate<sup>81/</sup> or agricultural trade. Rather, the reason for including this variable was merely to take trade policy or interventions into account, thereby attempting to control for their effect on international comparative advantage. Moreover, it should be noted that the statistical results to be presented below do not suggest that the simultaneity problem was important empirically.

Once more Chow's test was instrumental in testing two aggregation hypotheses: first, that the data for the exporting countries could be aggregated over the two periods; and, second, that despite the use of identically specified functions, exporting and importing countries do not constitute a homogenous group insofar as each group has a set of coefficients for the regression equation that are statistically different. The respective observed F-values for the two tests were .454 (compared to a tabled  $F_{(.01; 8, 26)} = 3.29$ ) and 13.28 (compared to  $F_{(.01; 11, 50)} = 2.62$ ). Accordingly, the null hypothesis that only one regression could rightfully represent both periods could not be

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<sup>81/</sup> For different but interesting attempts to do so theoretically, see Ridler and Yandle (47) and Schuh (58). For empirical estimates see, for instance Thompson (65).

rejected for the case of aggregation over time of the exporting countries data. For the case of aggregation of exporting and importing countries, the test led to the acceptance of the alternative hypothesis that the aggregation could not be made.

The statistical results (Table 3) do not provide strong support for the full model. Variables hypothesized to appear in the equation do not have uniformly strong statistical support, and some have signs that are contrary to a priori expectations. The statistical results do provide, at least general support for the overall hypothesis advanced, that technological factors are at least partially associated with international comparative advantage.

The statistical results will be discussed in more detail on a step by step basis. The results for the exporting countries with data pooled for the 1957-61 and 1962-66 periods will be considered first. The results for the importing countries for the same periods will then be discussed and compared to the ones for the exporting countries. And finally, the results for the stepwise regression procedure for the same two groups will be analyzed.

#### Net Exporters

Equation (1) in Table 3 is for the exporting countries with data from the 1957-61 and 1962-66 time period pooled. The included variables explained slightly over 60 percent of the variance in the dependent variable after correction for the degrees of freedom. The F-test was significant at the .01 level, which indicates that one can be 99 percent confident that not all coefficients are equal to zero. Analysis of the



individual coefficients by means of Student-Fisher t-tests indicates that six variables have coefficients that are significantly different from zero at meaningful significance levels: labor at the .01 level of significance; land at the .02 level; livestock at .001; machinery at .10; general education at .05; and technical education at the .15 level. All of the variables from the metaproduction function except fertilizer have coefficients that are larger than their standard errors. All are significantly different from zero at usually accepted levels except for fertilizer and technical education. Neither of the demand variables, per capita income or population, have coefficients that are significantly different from zero at usually accepted levels, nor does the policy variable.

The coefficients for labor and machinery have signs that are contrary to a priori expectations. The results for labor are consistent with the hypothesis that the exporting countries have excess labor in their agricultural sector. We are reluctant to accept this interpretation, however, for there is sufficient evidence in the literature to render this explanation at least dubious.<sup>82/</sup> An alternative explanation is that there is some error in the specification of the variable, but this also does not appear to be a plausible explanation, given that the variable performed well in the estimates of the underlying production function.

The level of significance of the coefficient in both equations (1) and (2) and the sign in each of the three equations for exporting countries make it difficult to attribute the negative sign to chance

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<sup>82/</sup> See Kao et al. (27).

alone. One reasonable possibility, however, is that the labor variable is picking up some demand effects. It should be noted that per capita income and population were included in the model in order to take account of domestic demand considerations. However, since neither of these two variables have coefficients that are significantly different from zero at usually accepted levels, the possibility that the labor variable is picking up demand considerations is at least plausible. The simple correlation<sup>83/</sup> between labor and the population and per capita income variables is high (.89 and -.68, respectively). It should be noted that the size of the agricultural labor force will be at least partially determined by the stage of development of the economy and in turn by the level of per capita income.

Another plausible explanation is that there are problems of multicollinearity between land and labor. The simple correlations are .44. Multicollinearity can so disturb the results as to cause an incorrect sign.

The statistical evidence for a negative coefficient on machinery is not as strong as that for labor. However, data will be presented below which suggests that the problem in this case is due to inter-correlation. Further discussion of this coefficient will be postponed until the data for exporters is disaggregated into two periods. When that is done the effect of multicollinearity is made more evident.

It should be noted that the coefficients for land and livestock are significantly different from zero at the .02 and .001 levels,

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<sup>83/</sup> The correlation coefficient tables are shown in Appendix C.



respectively, and have the expected positive signs. These results support the neoclassical or Heckscher-Ohlin theory of trade, since it turns out that countries included in the sample of net exporting countries are more well-endowed with land and livestock. The means of these two variables are 79,637 hectares and 26,368 animal units for exporting countries, as against 18,182 hectares and 14,865 animal units for the importing countries. Since agricultural production tends to be based primarily on land and on the size of the livestock herd, the Heckscher-Ohlin theory would predict that agricultural exports would tend to come from countries that are more well-endowed with land and livestock,<sup>84/</sup> and that such variables would have a statistically significant coefficient in models designed to explain agricultural exports.<sup>85/</sup>

The statistical results for the general education and technical education variables suggest that more than the factor endowment of conventional resources is important, however. Both coefficients have the expected sign and the coefficient of general education is significantly different from zero at better than the 5 percent level. The coefficient for technical education is not as strong statistically, but it is significantly different from zero at better than the 15 percent level. Hence, the statistical results for these two variables provide support for the maintained hypothesis that differences in the level of technology, as represented by the levels of general education and technical education, are determinants of the level of agricultural exports.

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<sup>84/</sup> On a quantity basis.

<sup>85/</sup> It should be noted that livestock products are an important component of the exports of the net exporting countries.

The finding that these variables help explain the level of agricultural exports is consistent with other research which has found that the same or comparable variables are important determinants of agricultural output.<sup>86/</sup> In addition, it is consistent with the general findings of other researchers who have studied trade in industrial goods.<sup>87/</sup>

The lack of direct statistical support for the domestic demand variables, per capita income and population, suggests that in the case of exporting countries the production side outweighs domestic demand considerations. However, this inference must be qualified, since as noted earlier, the agricultural labor force variable may be picking up the effects of domestic demand.

The coefficient of the policy variable (the trade balance) was not significantly different from zero at usually accepted levels. This suggests that at least in the case of countries that were net agricultural exporters, trade policy was not an important determinant of agricultural exports. The lack of significance of the coefficient of this variable also suggests that the expressed concern about the problem of simultaneity between the trade balance and the level of agricultural exports may not be a serious issue.

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<sup>86/</sup> See Hayami and Ruttan (16), Griliches (15) and Emerson and Kisler (12).

<sup>87/</sup> For example, Keesing (28) and (29), Ball (5) and Morral (44).



### Net Importers

Before discussing the results for the importing countries it should be recalled that the dependent variable was defined in such a way that the analysis of the individual coefficients can be done in the same way as for net exporting countries. Net exports was defined as the value of agricultural exports (in millions of U.S. dollars) minus the value of agricultural imports (in millions of U.S. dollars) plus 5000 million U.S. dollars (to make all values positive). Hence, net exports are a continuous variable, with the total sample divided according to whether the countries were net exporters or net importers. As a result, the coefficients in the equation describing the behavior of the importing countries would have the same expected signs as in the equation describing the behavior of the net exporting countries.

The results for the net importing countries with the data for the two time periods pooled are presented as equation (4) in Table 3. It should be noted that the  $R^2$  corrected for degrees of freedom is substantially larger than was the case in the equation for net exporters, and is also significantly different from zero by the F-test at better than the one-percent level.

The statistical results for the individual variables present an interesting contrast to those obtained for the equation describing the exports of the net exporting countries. On the production side the coefficient of labor has the expected sign and is highly significant. The coefficient of land is contrary to expectations, on the other hand, although it is not significantly different from zero at usually accepted

Table 3. Ordinary Least Squares Regression Estimates of the Reduced Form Coefficients, net

Equation	Labor	Land	Live- stock	Ferti- lizer	Machinery	Gen. Educa.	Tech. Educa.	Per Cap. Income	Popu- lation	Trade Balance	R <sup>2</sup>
Exporters	-.041	.021	.043	-.001	-.018	.076	.009	-.009	.016	-.009	.60
(1) 1957-61	(1.594)	(2.196)	(2.927)	(.096)	(1.471)	(1.815)	(1.036)	(.330)	(.662)	(.224)	(7.32)
+ 1962-66	<.10	<.02	<.001	1.0	<.10	<.05	<.15	<.40	<.30	<.50	<.01
Exporters	-.058	.017	.050	.0002	-.011	.059	.0001	-.048	.011	-.013	.508
(2) 1957-61	(1.686)	(1.498)	(2.566)	(.020)	(.621)	(1.512)	(.006)	(1.095)	(.329)	(.254)	(2.92)
	<.10	<.10	<.02	1.0	<.30	<.10	1.0	<.15	<.40	<.50	<.05
Exporters	-.004	.024	.037	-.001	-.011	.073	.033	.009	.009	-.036	.77
(3) 1962-66	(.106)	(1.869)	(2.911)	(.520)	(.703)	(1.264)	(1.845)	(.249)	(.262)	(.536)	(7.03)
	1.0	<.05	<.05	<.40	<.25	<.15	<.05	<.50	<.50	<.40	<.01
Importers	2.398	-.225	.107	.644	-.469	-.831	.533	.886	-2.772	.859	.843
(4) 1957-61	(4.857)	(.702)	(.330)	(2.016)	(1.475)	(.739)	(2.324)	(1.868)	(4.936)	(3.243)	14.50
1962-66	<.001	<.30	<.50	<.05	<.10	<.20	<.02	<.05	<.001	<.01	<.01

Note: The equations are linear in the logarithms (base e). The first entry in each cell is the estimated coefficient, the second entry (in parenthesis) is the t ratio value; and the third entry is the statistical significance level for the t-test (one-tailed). The R<sup>2</sup> column reports values for the F-test rather than for the t-test.



levels. Also contrary to the results with the equation for net exporters, the coefficient for the livestock variable is not significantly different from zero at usually accepted levels, while the coefficient for fertilizer is significantly different from zero and has the expected signs. The coefficient of machinery continues to have a sign that is contrary to expectations and a relatively weak level of significance.

The technology variables are also contrary to those obtained for exporting countries. General education has a sign that is contrary to expectations, although it is not significantly different from zero at usually accepted levels. The coefficient of technical education, on the other hand, is strongly significant and has the expected sign.

The two demand variables have coefficients that are significantly different from zero at usually accepted levels, and this also is in contrast to the results in the equation for net exporters. It should be noted, however, that the coefficient of per capita income has a sign that is contrary to a priori expectations.

The coefficient of the policy variable is highly significant and has the expected sign. The rationale for this variable was that a large trade balance, other things being equal, would reflect a tendency for the exchange rate to be under-valued, and vice versa. Hence, a direct effect would be expected between the trade balance and the net exports.

The statistical results with this variable are in agreement with theoretical expectations with regard to the devaluation problem. If the

Robinson-Metzler-Bickerdike condition<sup>88/</sup> is satisfied, a devaluation is expected to increase exports and reduce imports. There is no reason to believe that the necessary and sufficient conditions are not met in the general case. Therefore, we can have some confidence that the trade balance is an appropriate proxy to use for exchange rate (and associated trade intervention) policy. It should be remembered, however, that there may be a problem of simultaneity bias with the coefficient of this variable, since the trade balance may be large because net agricultural exports are large. In the present context, however, the variable is used primarily as a "control" variable to take account of trade policy when analyzing the effects of other variables. The size of the coefficient is therefore of no particular importance.

There appear to be at least two problems of inter-correlation in the equation for net importers. The first is between land and labor. The coefficient of correlation between these two variables is .85. Hence, the labor variable may be picking up the effects of land, and possibly the effects of livestock, since the latter tends to be land-intensive.

Similarly, there may be a problem between education and per capita income. The coefficient of correlation between these two variables is .71. Hence, the fact that the per capita income variable has the wrong sign may be a result of its picking up the effects of general education.

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$\frac{88/nf(1+d)}{d+nf} + \frac{f(d-1)}{nd+f}$  when  $\eta$  are demand and  $\epsilon$  are supply elasticities and  $f$  and  $d$  stand for foreign and domestic countries, respectively.

For details see Metzler (41), Robinson (49), Bickerdike (7), Jones (24) and Takayama (63), Ch. 9.



This would explain the lack of significance of the coefficient on general education and also the failure to obtain the expected sign for it.

Possibly because of the problem of inter-correlation between land and labor, the statistical results do not provide strong support for the Hecksher-Ohlin theory. The coefficients of neither land nor livestock are statistically significant, which would be consistent with the theory. However, if the coefficient of labor is picking up the effects of these other variables, that evidence may be considerably weakened. In the same vein, however, the significance of the labor variable may reflect the relative factor endowments and the composition of trade of the countries that are net importers. It was decided not to pursue this hypothesis in the present study since it goes beyond the central thrust of the research. However, it merits further study.

There is support again for the technology variables in the equation for importers. The coefficient for technical education is strong and has the expected sign. The coefficient for general education has the wrong sign, however, and is statistically weak. But it should be remembered that there may be problems of multicollinearity between education and the per capita income variable.

It should be noted that there is another interesting aspect to the statistical results. Fertilizer and machinery are "modern" inputs in that they tend to be associated with an agriculture that uses more advanced levels of technology. It is interesting to note that fertilizer has the expected sign and is significantly different from zero in the equation for importers, and this in the presence of a strong technical education variable. In the equation for exporters, on the other hand,

neither variable had a statistically strong coefficient, although there was some support for the technical education variable. This suggests that there may be some relationship between the investment in research and development and the importance of fertilizer as a determinant of net exports.

Finally, it should be noted that demand and trade policy are relatively important variables in explaining net agricultural exports of importing countries. Both the coefficients of population and trade balance have the expected sign and are highly significant. The fact that these variables would tend to be strong in the case of countries that are net importers, and that the production variables would tend to be strong in the case of countries that are net exporters, has a certain degree of intuitive appeal and plausibility.

#### Stepwise Regression Results

In order to gain some insight with respect to the relative importance of the explanatory variables, the data were also analyzed by means of stepwise regression. As was noted earlier this procedure was not used to "hunt" for explanatory variables that might enter the equation. Rather, it was carried out as a second step of the analysis, with the goal being largely to gain insights into the relative explanatory power of the individual variables. It turned out that the use of the procedure provided insights as to when there were problems of multicollinearity.

The results from using the stepwise procedure for the pooled data for net exporters are presented in Table 4. The single most important



Table 4. Stepwise Regression Estimates of the Reduced Form Coefficients, Exporting Countries, Posted Data for Periods 1957-61 and 1962-66.

	Labor	Land	Live- Stock	Ferti- Lizer	Machinery	General Education	Tech. Ed.	P.C. Income	Popu- lation	Trade Bal.	R <sup>2</sup>
Step 1		.025									.3753
Land		(25.230)									(25.23)
		.000									1.000
Step 2		.028				.088					.5694
Gen.		(43.35)				(18.476)					(27.10)
Educa.		.000				.000					1.000
Step 3	-.010	.031				.061					.5855
Labor	(1.558)	(41.47)				(4.141)					(18.83)
	.219	.000				.049					1.000
Step 4	-.023	.015	.013			.043					.6385
Live- stock	(5.787)	(3.166)	(5.713)			(2.174)					(17.22)
	.021	.083	.022			.148					1.000
Step 5	-.028	.019	.042		-.013	.072					.6669
Mach- inery	(8.842)	(5.288)	(8.887)		(3.248)	(4.882)					(15.22)
	.005	.027	.005		.079	.033					1.000
Step 6	-.027	.021	.044		-.019	.068	.011				.6850
Tech.	(7.158)	(6.175)	(10.151)		(5.290)	(4.322)	(2.119)				(13.41)
Educa.	.011	.018	.003		.027	.045	.154				1.000
Step 7	-.038	.021	.044		-.020	.066	.009				.6876
Popula-	(3.076)	(6.121)	(9.640)		(5.44)	(3.981)	(1.285)				(11.32)
	.088	.018	.004		.025	.054	.264				1.000
Step 8	-.041		.044		-.018	.073	.009	-.009	.014		.6888
Income	(2.861)	(5.578)	(9.440)		(2.311)	(3.613)	(1.138)	(1.138)	(.398)		(9.68)
	.100	.024	.004		.137	.066	.293	.714	.532		1.000
Step 9	-.042	.021	.043		-.018	.075	.009	-.009	.016	-.009	.6893
Trade	(2.840)	(5.338)	(8.823)		(2.238)	(3.534)	(1.135)	(.142)	(.443)	(.056)	(8.38)
Balance	.101	.027	.005		.144	.069	.294	.709	5.10	.814	1.000
Step 10	T-level or tolerance level insufficient for further computation.										

Note: The in parenthesis values are sequential F test estimated values.

explanatory variable was land, with an F-value (for the sequential F-test) significant at a less than 1-percent level. It should be noted that approximately 38 percent of the total variation in the dependent variables is accounted for by the land variable alone. This provides relatively strong support for the Hecksher-Ohlin theory.

Once land is already in the equation, the next most important variable is general education. As a proxy for human capital general education adds another 18 percent to the  $R^2$  uncorrected for degrees of freedom, and enters at a significance level smaller than 1-percent. This suggests that general education explains in the neighborhood of 28 percent of the variation left unexplained by land, and provides relatively strong support for the basic maintained hypothesis of the present study.

Labor is the next variable to enter the equation, but it adds very little to the explanatory power of the model. It has a negative coefficient, suggesting--as was noted earlier--that it is picking up some of the demand effects, although its level of statistical significance is relatively low.

Livestock is the next variable to enter the equation, and contributes some 5 percent to the coefficient of multiple determination. The sequential F-test indicates a strongly significant variable.

The effect of livestock on the size of the coefficients of land, labor and general education should be noted, as well as its effect on the level of significance of the other variables. The sequential F-test indicates a decline in the level of significance for land and general education, while the level of significance for labor increases



markedly. This suggests a problem of inter-correlation between these variables, although to this point it cannot be regarded as too serious. The four variables now included are responsible for 64 percent of the variation in agricultural exports.

Machinery was the fifth variable to enter the equation, at the 8-percent level of significance, and contributed roughly .03 to the multiple  $R^2$ . It has a negative coefficient similar to that which was obtained with the full model. Technical education was the next variable to enter the equation, with an F-value indicating a not unreasonable .15 level of significance. The  $R^2$  was increased by another 2 percent.

The remaining variables, per capita income, population, the policy variable, and fertilizer were added to the equation only at a high level of chance and contributed, altogether, only .004 to the  $R^2$ . These variables entered the equation at the cost of reducing the regression's overall F-value by one-third due, at least in part, to the reduction in degrees of freedom of the residuals.

To conclude, the results with the stepwise regression procedures applied to the equation for exporters provide relatively strong support for both the basic hypothesis of this study and the Heckscher-Ohlin theory. Land is the first variable to enter the equation and contributes almost half of the ultimate explanatory power of the model. At the same time, however, general education was the second variable to enter, and contributed a relatively large amount to the explanatory power of the model. Moreover, the coefficient of the general education variable was relatively stable through the various steps of the analysis,



its level of statistical significance changed substantially at only one step.

The other technology variable, technical education, did not perform as well, however, although when it first entered the equation its level of statistical significance was a not unreasonable 15 percent and it had the expected sign. As additional variables entered the equation the level of significance declined substantially because of problems of inter-correlation, although the size of the coefficient remained relatively stable.

An interesting finding in light of the earlier discussion about the fertilizer variable is that there does appear to be an interaction between the fertilizer variable and technical education. The fertilizer variable did not enter the stepwise analysis because of an insufficient tolerance-level for entrance. However, the results of equation (1) in Table 3 indicates that when fertilizer is included in the model, the significance of the technical education variable increases again to the 15-percent level, with little or no change in the size of the coefficient.

A final observation is to note that the bulk of the explanatory model is obtained when four variables have entered the equation. Two of these (land and livestock) are consistent with the Heckscher-Ohlin theory, one (education) is consistent with the basic hypothesis of the present study, and one (labor) appears to be picking up the effects of domestic demand. In the case of the countries that are net agricultural exporters, the policy variable is one of the last to enter the equation, and has very little explanatory power.



The same procedures were used for an analysis of the pooled data for the countries that were net importers. The results are presented in Table 5. The single most important variable explaining the variations in the net (negative) exports of the importing countries is the policy variable. Approximately 51 percent of the total variation in the dependent variable is explained by variations in this variable.

It will be remembered that the principal reason for including this variable in the analysis was to account for differences in exchange rate policies, although it is clear that the trade balance variable that is used as a proxy for this variable embodies much more than that. More specifically, the size of the trade balance may reflect the structure of tariffs, locational advantages and disadvantages, and other factors which might affect the competitive position of a country. As was noted in Chapter III, however, there exists an exchange rate which equates exports and imports even in the presence of such restrictions. The positive coefficient for the trade balance variable implies that the lower the trade deficit (or the higher the trade surplus), the smaller the amount of agricultural imports, other things being equal.

As has been noted earlier, however, it could be argued to the contrary, i.e., that the causality flows in a reverse direction. This would imply in the case of the equation for importers that agricultural imports are the determinant of total trade deficits. This may well be the case for a few under-developed countries which are not self sufficient in food production and which must periodically import foodstuffs to rescue their population from starvation. An examination

Table 5. Stepwise Regression Estimates of the Reduced Form Coefficients for the Periods 1957-61 and 1962-66.

	Labor	Land	Live- stock	Ferti- lizer	Machinery	General Educa.	Tech. Educa.	P.C. Income	Popu- lation	Trade Bal.	Unadj. R <sup>2</sup>
Step I										1.660	.5068
Trade Bal.										(27.71)	(26.71)
Step II										.000	0
Per Cap. Income										1.666	.5657
Step III										(29.385)	(16.28)
Popula- tion										.000	0
Step 4	.992									1.418	.6431
Labor	(9.590)									(21.70)	(14.42)
Step 5	1.633	-.535								.032	0
Land	(24.633)	(11.11)								1.149	.748
Step 6	1.630	-.418		.269						.001	0
Ferti- lizer	(27.591)	(6.582)		(3.709)						.000	0
Step 7	.000	.018		.068						1.021	.8578
Tech. Educ.	(25.071)	(2.457)		(3.395)						.000	0
Step 8	.000	.133		.080						.197	.8714
Mach.	(27.401)	(.782)		(.252)						(16.428)	(19.36)
Step 9	2.325	-.172		.546						.001	0
Live- stock	(28.536)	(.546)		(5.154)						.000	0
Step 10	.000	.388		.035						.875	.8895
Trade Bal.	(27.401)	(.782)		(.080)						(15.589)	(15.19)
Step 10	2.329	0.142		.700						.001	0
Live- stock	(28.536)	(.546)		(7.062)						.005	-.8946
Step 10	.000	.469		.016						.001	0
Trade Bal.	(27.401)	(.782)		(.035)						(17.128)	(16.98)
Step 10	2.398	-.225		.107						.859	.8953
Live- stock	(23.585)	.494		(.109)						.005	0
Step 10	.000	.492		.745						.001	0
Trade Bal.	(23.585)	.492		(.745)						(10.516)	(16.98)

Note: The in parenthesis values are the sequential F test estimated values.



of the countries that comprise our sample,<sup>89/</sup> however, suggests that this is not likely the case. With only a very few exceptions they are all developed countries with high per capita income levels and relatively low rates of population growth. Given the relatively low income elasticity of demand for agricultural products that would be expected in those countries, it is unlikely that agricultural imports consistently cause large or persistent trade deficits. Even if climatic restrictions are admitted that cause most countries in the sample to import the bulk of their tropical agricultural products, it is not likely that countries would pursue a persistent deficit on this account, especially in view of the fact that some of these countries have quite high levels of productivity in a number of products.

In light of this reasoning it appears plausible to assume that the trade balance is reflecting at least partially exchange rate and other considerations that affect trade, and that these policies are determined for the most part in a manner exogenous to the agricultural sector.

Hence the problem of joint determination is not likely serious.

The next two variables to enter the equation were the demand variables. Per capita income entered first, with a negative sign and at the .08 significance level. This is as implied by the postulated theory, and is contrary to the results obtained with the full model. The coefficient of population is also negative, and is significant at the .03 level of confidence.

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<sup>89/</sup> Table 1, Chapter III.

Two explanations are generally offered for a negative coefficient for a population variable in trade models, with both based on an opportunity cost theory of trade. Learner and Stern<sup>90/</sup> argued that "countries with greater population will have heavy demands for home goods since foreign goods are dispensed with in order to feed, clothe, and shelter the inhabitants". This was the basic logic behind the introduction of the variables in the present study. Linnemann,<sup>91/</sup> however, has argued that the variable reflects economies of scale in production and significant barriers to trade.

The results obtained here are consistent with both interpretations. Since a reconciliation of the two positions would require further research and is beyond the scope of the present study, no attempt was made to provide evidence in support of either interpretation. For present purposes it suffices to note that the two demand variables have strong statistical support for their inclusion in the model, and that together with the policy variable they are able to explain 64 percent of the variation in net (negative) agricultural exports of the importing countries.

The next variable to enter the equation was the size of the agricultural labor force. It should be noted that the sign of the coefficient of per capita income is reversed when this variable enters, and that a substantial change occurs in the size of the coefficient of population. The multicollinearity among these variables is therefore

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<sup>90/</sup> Learner and Stern (33), p. 152.

<sup>91/</sup> Linnemann (39), p. 15.



obvious. Moreover it appears that in addition to the possibility of a collinearity problem between general education and per capita income that was noted earlier, there is a problem between agricultural labor and per capita income. It should also be noted that agricultural labor was the first variable to enter on the production side. This relative strength supports the argument presented earlier that this variable was probably picking up the effect of other production variables.

Land is the fifth variable to enter the equation, and it does so with a negative coefficient similar to that it had in the full model. When it first enters it is highly significant. It should also be noted that the coefficient of the per capita income variable changes substantially when the land variable enters, suggesting another problem of inter-correlation.

The next variable to enter the equation was fertilizer, one of the modern inputs. Its level of significance was relatively high, although it added relatively little to the unadjusted sum of squares. This was followed by technical education. Machinery was the next variable to enter, and with a negative coefficient as in the full model. It should be noted that both the size of the coefficient for technical education and its level of significance increase when the machinery variable enters.

The next to last variable to enter was general education, and the last the livestock variable. General education has a negative coefficient like it had in the full model, although it is not statistically significant at usually accepted levels even when it first enters.

To conclude, the stepwise analysis provides support for the conclusions drawn in the analysis of the full model. It appears to be

clear, for example, that the policy variable and domestic demand considerations dominate in explaining cross-country variations in the net (negative) exports of importing countries. The conventional production variables are the next most important, with rather strong evidence that the labor variable tends to pick up some of the effects of the other production variables. A modern input, fertilizer, enters prior to either of the more basic technology variables, with technical education variable the next to enter.

It should be noted that collinearity appears to be more common in the case of the equation for importing countries, with a considerable amount of instability in the coefficients being the result. However, this does not alter the earlier conclusions drawn, since the coefficient of the technical education variable is relatively strong once it enters, with a reasonably stable coefficient. A change in the size of a coefficient when a variable that is correlated is introduced into the equation is to be expected. What is important is that the coefficient of technical education as well as other variables is significantly different from zero even in the presence of the collinearity.

Finally, it should be noted that production variables and the technology variables are relatively important in the equation for net exporters, and relatively less important in the equation for net importers. This provides support for both the Heckscher-Ohlin theory and the basic maintained hypothesis of the present study. Moreover, the policy variable and the variables representing domestic demand are



the dominant variables explaining variations in net (negative) exports in the equation for net importers.

#### A Temporal Comparison for the

#### Exporting Equations

It was also desired to make separate tests of the model for separate time periods in order to detect whether any change in structure had occurred. This was feasible only in the case of net exporters, since the number of net importing countries was too small to provide a suitable number of degrees of freedom.

The statistical results with the extended model are presented in Table 3 in order to facilitate a comparison with the pooled data.<sup>92/</sup> The results for the two disaggregated periods are broadly similar to those obtained with the pooled data. There are a couple of interesting differences, however. In the first place the adjusted  $R^2$  is smaller in the early period than in the later period. Moreover, the technical education variable is significant at usually accepted levels in the latter period, although the significance of the coefficient for general education declines somewhat. These results suggest that investments in agricultural research and development have become more important over time.

The same stepwise analysis was performed for the two periods independently. The results are presented in Tables 6 and 7. They are

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<sup>92/</sup> The results discussed in this section are based on a sample of 20 countries for which data were available for both periods. See note to Tables 6 and 7.

PERIOD 1957-61

	Labor	Land	Live- stock	Ferti- lizer	Machinery	General Educa.	Tech. Educa.	Per Cap. Income	Popu- lation	Trade Unconnected Bal.	R <sup>2</sup>
Step 1		.028									.3859
Land		(11.309)									(11.31)
		.003									1.000
Step 2	-.015	.026									.4740
Labor	(2.848)	(15.311)									(7.66)
	.110	.001									1.000
Step 3	-.024	.009	.033								.5711
Live- stock	(6.366)	(.599)	(3.625)								(7.10)
	.023	.450	.075								1.000
Step 4	-.041	.012	.052		-.017						.6553
Mach.	(10.701)	(1.395)	(7.615)		(3.660)						(7.13)
	.256	.256	.015		(.075)						1.000
Step 5	-.036	.016	.053		-.024	.048					.6856
Gen. Educa.	(7.123)	(2.134)	(8.025)		(5.074)	(1.350)					(6.10)
	.018	.166	.013		.041	.265					1.000
Step 6	-.043	.016	.051		-.010	.082		-.040			.7113
Per Cap. Income	(8.283)	(2.117)	(7.424)		(.422)	(2.504)		(1.158)			(5.34)
	.013	.169	.017		.527	.138		.301			1.000
Step 7	-.037	.016	.049		-.009	.085		-.035		-.041	.7261
Trade Bal.	(4.845)	(2.277)	(6.373)		(.300)	(2.603)		(.829)		(.650)	(4.54)
	.048	.157	.027		.594	.133		.380		.436	1.000
Step 8	-.020	.017	.051		-.011	.063	.015	.031		-.074	.7486
Tech. Educa.	(2.530)	(2.408)	(6.850)		(.452)	(1.228)	(.981)	(.658)		(1.473)	(4.09)
	.140	.149	.024		.515	.291	.343	.435		.250	1.000
Step 9	-.033	.019	.050	.007	-.013	.057	.013	-.034		-.081	.7559
Ferti- lizer	(2.665)	(2.544)	(6.095)	(.298)	(.530)	(.922)	(.696)	(.724)		(1.578)	(3.44)
	.134	.142	.033	.597	.483	.360	.424	.415		.238	1.000

F-level or tolerance level insufficient for further computation.

Note: The in parentheses values are sequential F test estimated values.

L/ The countries included in the sample are: Argentina, Australia, Brazil, Canada, Colombia, Denmark, Greece, Iceland, Mexico, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, South Africa, Syria, Taiwan, Turkey, and United States.



	Labor	Land	Live-stock	Fertilizer	Machinery	General Educa.	Tech. Educa.	Per Cap. Income	Population	Trade Unconnected Bal.	R <sup>2</sup>
Step 1 Mach.					.033 (20.407)						.5313 (20.41) 1.000
Step 2 Land		.022 (8.711)			.022 (9.606)						.6901 (18.93) 1.000
Step 3 Tech. Educa.		.035 (19.039)			.004 (.202) .659		.027 (7.176) .016				.7861 (19.60) 1.000
Step 4 Live-stock		.018 (3.058)	.033 (4.599)		.002 (.047) .831		.036 (12.951) .003				.8363 (19.15) 1.000
Step 5 Gen. Educa.		.024 (4.760)	.032 (4.693)		.009 (.844) .374		.029 (6.903) .020				.8570 (16.78) 1.000
Step 6 Trade Bal.		.026 (5.234)	.034 (5.090)		.008 (.691) .421		.032 (7.420) .017				.8641 (13.78) 1.000
Step 7 Fertilizer		.024 (3.758)	.038 (5.044)	.007 (.332)	.007 (.489) .498		.034 (7.370) .019				.8678 (11.25) 1.000
Step 8 Per Cap. Income		.024 (3.570)	.038 (4.751)	.007 (.342)	.011 (.487) .500		.032 (5.602) .037	.008 (.097) .761			.8689 (9.11) 1.000
Step 9 Population		.024 (3.338)	.037 (3.599)	.009 (.398)	.011 (.492) .499		.034 (5.159) .046	.011 (.745) .711	.009 (.086) .776		.8700 (7.44) 1.000
Step 10	.007 (.022) .885	.025 (3.021) .116	.037 (3.264) .104	.008 (.223) .648	.012 (.460) .515	.077 (1.298) .284	.031 (1.668) .229	.008 (.045) .837	.011 (.076) .788	.034 (.253) .627	.8704 (6.04) 1.000

Note: The in parentheses values are sequential F test estimated values.

1/ The countries included in the sample are: Argentina, Australia, Brazil, Canada, Colombia, Denmark, Greece, Iceland, Mexico, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, South Africa, Syria, Taiwan, Turkey, and United States.

also broadly similar to those obtained with the pooled data. Production variables tend to enter the equation first, followed by the technology variables. The domestic demand and policy variables tend to enter last, although their order changes between the two periods.

There are again some interesting differences, however. In the early period land was the first variable to enter the equation. In the latter period machinery, a modern input, was the first to enter, and explained a much larger fraction (in terms of the unadjusted  $R^2$ ) of the variance in the dependent variable. Education came in at step 5 in the first period, and aside from its inter-correlation with per capita income, had a reasonably stable coefficient. Both fertilizer and technical education entered the equation in the last steps.

In the latter period, however, technical education entered at the third step, and maintained a relatively high level of significance through each step, with the introduction of the remaining variables. What is especially pleasing is the stability of the coefficient as additional variables are added to the equation.

The coefficient of the machinery variable is quite unstable in the presence of the alternative specifications. It suffers a change in sign in step 4 when livestock enters the equation.

Finally, it should be noted that at step 5 the equation contains five variables that explain 85 percent of the variance in the dependent variable. Two of these are conventional production variables, and two are the technology variables. General education does not have a coefficient that is significant at usually acceptable levels. Even in that case, the coefficient is reasonably strong.



The basis of the change in results between the two periods merits some additional analysis. To this end the means of some variables and relevant average productivity measures are presented in Table 8, together with an estimate of their percentage change between the two periods. It should be noted that labor, land and livestock, the conventional inputs increased somewhat between the two periods. Fertilizer and machinery, however, the two modern inputs, increased very substantially between the two periods, with technical education, which serves as a proxy for investment in agricultural research, increasing even more. The level of general education increased somewhat in the exporting countries, but not on near the scale as the other modern inputs and the technology variable.

Hence, the reason for the increased importance of technical education in the more recent period is rather obvious. Agriculture in the net exporting countries was becoming increasingly based on modern inputs and research and development. Although education was obviously of some importance, it was less important in the more recent period, perhaps in part because it had failed to increase at the same rate as the other modern inputs.

#### Some Concluding Comments

The statistical support for the underlying maintained hypothesis of this study are reasonably strong. The two variables that are used to represent technology tend to have coefficients that are significantly different from zero and of the expected signs both in equations for net exporters and for net importers. The two variables have different relative importance in the exporting and importing equations, but at least one of them is always statistically important.

Table 8. Means of Selected Variables and Average Productivity Measures, Periods, 1957-61 and 1962-66.

	1957-61	1962-66	Percent Change
Labor	2,716	3,038	11.8
Land	80,866	86,615	3.4
Livestock	22,427	24,417	8.9
Fertilizer	540	710	31.5
Machinery	10,147	13,121	29.3
General Education	66.35	70.85	6.8
Technical Education	5.57	7.93	42.4
Agricultural Production	40,496	45,226	11.7
Production per Man	14.91	14.89	0.0
Production per Land	.50	.54	8.0
Machinery per Man	3.74	4.32	17.6
Fertilizer/Land	.0067	.0085	26.9
Land per Man	29.77	27.52	-7.6



In addition, when it was possible to disaggregate the data by time period, as was the case with exporters, the variable representing investments in agricultural research and development is found to be stronger in the more recent period. This is consistent with the notion, also supported by corollary data, that agriculture around the world is becoming increasingly dependent on new production technology. It would be expected therefore, that investments in agricultural research would play a larger role in explaining variations in agricultural trade in the more recent period.

## CHAPTER V

SUMMARY, CONCLUSIONS, AND SUGGESTIONS  
FOR ADDITIONAL RESEARCHSummary

Despite recent contributions trade theory is still cast in either one or the other of two basic streams of thought: the Ricardian tradition or the Heckscher-Ohlin tradition. The present study represents an attempt to integrate both approaches by introducing the technological differences that are basic to the comparative cost theory into the neo-classical approach which assumes that all countries face the same production functions.

The Heckscher-Ohlin model implies factor-price equalization. More appropriately, a subset of the assumptions necessary for the Heckscher-Ohlin model suffices to prove factor price equalization. For whatever reasons, however, equalized factor prices are not a characteristic of the real world. Nor does the isotecchnology assumption appear to have much empirical relevance.

In developing the conceptual model for the present study an attempt was made to obtain greater descriptive reality by incorporating the differential factor price ratios into a model of growth and trade. It was hypothesized that a change in factor price relatives would induce the creation and adoption of a new technology that is optimal for the



net set of relative prices. Substitution among factors of production is assumed to take place along a metaproduction function, which is defined as the envelope of a series of neoclassical production functions.

The concept of a metaproduction function was then introduced into the basic structure of Kenen's two sector model. Kenen's model is based on the works of Vanek, Schultz and Becker. Vanek postulates a complementarity between capital and land. Schultz and Becker postulate a complementarity between capital and labor. Kenen combines these suggestions in a formal model in which he treats each input, the factor-service flows from land and labor, as though they were produced by acts of investments.

Kenen's approach is consistent with Hayami and Ruttan's model of agricultural development, and permits a more comprehensive explanation of international differences in real incomes than had previously been available. It is well-recognized that free trade will equalize the price of factor-services, but will not always equalize net factor incomes. Income differences can be explained by resorting to the differences in supply of tangible capital per worker and differences in labor force participation, which are the usual explanation. But the explanation can also be found in differences in the stocks of human capital and in the quality of the natural endowments which have both been improved by investment.

In addition, the general model is assumed to be a disequilibrium model where factors do not have infinite, instant mobility among industries. If this assumption is not made a change in the economic availability of any factor would result in a reallocation of factors

For the empirical work an international or foreign trade offer curve was defined simply as domestic production minus domestic consumption. A positive difference implies an export supply function, while a negative one implies an import demand function. A reduced form equation for the foreign market for agricultural products, which is described by the above supply and demand functions, was estimated by ordinary least squares.

A general equilibrium framework was assumed with conventional inputs entered to represent the production side, along with proxies for human capital and investment in research and extension. More specifically, the variables on the production side included labor, land, livestock, fertilizer, machinery, general education and technological education. Per capita income and population were entered to take account of domestic demand considerations. And to take account of possible interferences to trade from exchange rate and other trade policy. The trade balance for the country was included as a final independent variable.

The dependent variable was the country's net agricultural exports (imports). The net concept was used because in dealing with aggregated agricultural production it has to be assumed that domestic production competes with foreign production.

The data corresponds to a cross-sectional sample of 44 exporting countries (23 for the period 1957-61 and 21 for 1952-66) and 28 importing countries (14 in each period). The averages for the 5-year periods were used in order to eliminate the effect of short term fluctuations.



between industries, with no effect on factor price relatives. Under this assumption, and under the hypothesized inducement mechanism, it is shown that the effect of a technological change in production due to a change in factor-price relatives is in the opposite direction of the Rybckzynski effect. However, whether or not the induced technological effect outweighs the Rybckzynski effect depends on the nature of the relevant production functions.

It is also hypothesized, almost tautologically, that for the exporting countries the production side outweighs the consumption side, and vice versa for the case of the importing countries. The same inducement mechanism and consequent technological effect remain, however. In addition, it was hypothesized that the exchange rate and trade intervention policies could influence comparative advantage. An additional aspect of the model was an analysis of the feed back effect of induced technological changes via the goods market when the elasticity of substitution in consumption is not unitary.

The central idea of the study is thus that induced technological changes alter comparative advantage in the sense that the constraints put on production and trade by the country's natural resource endowment are eased. Rather than have the Heckscher-Ohlin framework dismissed, a new dimension is added to it: that of an indigenous technological capability that can alter international comparative advantage. It could even be argued that the metaproduction function here hypothesized is the very concept of the internationally common production function that is assumed to exist in the conventional Heckscher-Ohlin model.



Four models are analyzed: one for exporting countries where data for the two periods, 1957-61 and 1962-66, were pooled together; one for net importing countries, with the data pooled in the same way; and finally, separate tests for the two time periods for net agricultural exports, with the objective of determining whether there had been any change in the importance of the variables over time. In addition to estimating these models with ordinary least squares, a stepwise regression procedure was used with the same specified variables in order to assess the relative importance of the independent variables in explaining the variations in the dependent variables.

#### Conclusions

The statistical results provide reasonably strong support for both the Heckscher-Ohlin theory and the underlying maintained hypothesis of this study that human capital and investments in technology affect international comparative advantage in agricultural trade. Additionally the results suggest a different relative explanatory power for production, consumption, and policy variables in explaining variations on net (positive) exports of exporting countries and net (negative) exports of importing countries.

The production and technology variables are relatively important in the equations for net exporters of agricultural products, and relatively less important in the equation for net importers. The policy variable and the domestic demand variables show relatively little explanatory power in the equation for exporters, while these same variables dominate in explaining cross country variations of the net (negative) exports of the importing countries.



Despite differences in relative explanatory power, the variables used to represent technology are in general important in both groups of countries, net exporters and net importers. Investments in technology tend to increase exports in the former group and tend to reduce imports in the latter.

The analysis of the models for the exporting countries for separate time periods suggests that there has been some change in structure over time. It points towards the increased importance of investments in agricultural research and development as a factor determining comparative advantage. This is consistent with the notion that as time passes agriculture becomes increasingly dependent on new production technology, in contrast to being based on the "natural" resources inherent in the agricultural sector. Trade in agricultural products that may have at one time been the result of a natural resource based comparative advantage appears to be growing ever less so.

The general hypotheses of this study are, therefore, reasonably well supported by the data: Human capital and investments in agricultural research and development appear to be relatively important elements in explaining trade in agricultural products. Furthermore, the nature of the technological change seems to have been in the direction of easing the constraints put on the countries' production and trade by inelastic supplies of land and labor tending, therefore, to validate the underlying induced change mechanism.

### Suggestions for Additional Research

The research reported herein suggests additional research activities that might be productively pursued. For example, additional insights might be gained by applying the same methodology to the analysis of data covering periods of time different from the ones studied here. The analysis of data for a period prior to 1957-61 and for one more recent than 1962-66, for instance, could be useful in checking the patterns observed for the two periods studied. The empirical evidence which shows the increased importance over time of technology in explaining trade in agricultural products could be verified by the analysis of such additional time periods.

The empirical testing of the existence of the metaproduction function is not in itself an exercise in international trade. However, the importance of the concept for the research reported here and for development models in general make the empirical test of the concept very important.

The induced change mechanism that was postulated was only marginally tested in this dissertation. Other studies have yet to offer either a definite specification of this process or very much supporting evidence. The important role that the underlying induced technical change mechanism plays in this study calls for further tests of its empirical relevance.

The aggregation of agricultural exports into a single variable, as was done in this dissertation, may be responsible for the introduction of "noise" in the statistical analysis. Furthermore, the abstraction of product mix considerations may, in some cases, conceal the effect of differences or changes in technology on comparative advantage. This may be especially the case with the aggregation of livestock and



agricultural products, which clearly have a different production base. In addition some products are climate specific and comparative advantage will in large part be based on nature. Attempts could be made to overcome these limitations to the present study.

Case studies of individual countries or groups of "similar" countries, especially in a time series approach, would possibly extend the understanding of the effects of changes in technology upon international comparative advantage. If individual countries were studied, it might be possible to investigate the specific direction technological progress has taken over time. This could then be related to the underlying changes in factor markets and to exports of agricultural products, either in the aggregate or for specific products.

Finally, a related point is the specification of export supply functions. Very little has been done in this area, and what has been done either for agricultural or other products, has consistently failed to yield good statistical results. It can be hypothesized that the statistical results are usually poor because the usual specification fails to take into account the changes in production technology, either over time or across countries. The results of the present study suggest that the introduction of proxies for human capital and technology may provide a useful means of improving the specification of export supply functions.

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APPENDIX A

Table A-1. Basic Data for the Exporting Countries, period 1957-61.

	No. of male workers in agriculture 1,000's	Agricultural land area 1,000 hectares	Livestock 1,000 livestock units	Fertilizer consumption (N+P <sub>2</sub> O <sub>5</sub> +K <sub>2</sub> O) 1,000 metric tons	Tractor horsepower 1,000 hp.	School enrollment ratio
Argentina	1,334	136,386	48,270	24	5,634	73
Australia	392	485,837	31,220	819	9,491	91
Brazil	8,911	148,178	107,713	228	2,364	50
Canada	420	64,170	11,689	527	24,549	81
Colombia	1,957	21,759	14,522	116	940	51
Denmark	273	3,033	4,610	455	4,861	88
Greece	1,096	8,678	3,271	214	1,467	72
Ireland	316	4,709	5,480	224	1,895	95
Mexico	5,998	112,608	41,716	266	1,738	59
Netherlands	351	2,255	4,590	531	2,234	91
New Zealand	109	13,634	11,781	373	2,967	91
Norway	95	1,008	1,280	158	2,250	88
Pakistan	23,206	28,071	41,607	103	50	27
Peru	797	14,701	7,006	94	300	57
Philippines	4,183	11,318	7,307	109	163	75
South Africa	1,493	107,824	15,949	270	4,008	70
Syria	508	13,057	1,404	18	241	42
Taiwan	1,320	901	1,131	196	61	70
Turkey	4,907	54,378	20,555	100	1,590	46
Un. Arab Rep.	4,509	2,767	4,709	280	221	43
United States	3,088	439,800	107,238	9,380	195,625	100



Table A-1. (continued)

	No. of grads from agri. colleges per 10,000 farm workers	National income per capita U.S.\$	Popula- tion millions	Net agri. exports + 5,000 million U.S.\$	Balance of trade + 3,000 million U.S.\$	Agri. output + 5,000 1,000 wheat units	Reserves/ imports - World reserves/ imports	Balance of goods and services + 2,000 mil. U.S.\$
Argentina	2.18	650	22.54	6,224.0	3,268.2	62,253	.42	2,095.6
Australia	24.72	1,410	11.39	6,913.9	3,046.0	54,279	1.16	1,447.6
Brazil	.90	90	80.77	5,900.6	3,113.5	97,842	.58	1,883.4
Canada	15.61	2,080	19.60	5,794.6	3,356.7	53,414	.84	1,229.9
Colombia	1.01	230	18.02	5,324.3	2,948.9	22,590	.40	1,884.2
Denmark	7.13	1,520	4.76	5,698.9	2,553.4	20,219	.46	1,844.6
Greece	2.05	510	8.58	5,080.8	2,376.1	18,283	.51	1,616.2
Ireland	4.80	710	2.88	5,178.5	2,655.8	12,659	1.05	1,832.8
Mexico	.20	380	42.69	5,447.7	2,716.3	37,743	.88	1,693.4
Netherlands	13.73	1,140	12.29	5,447.7	1,929.8	23,681	.77	2,001.0
New Zealand	24.09	1,570	2.63	5,798.9	3,036.9	23,128	.35	1,962.8
Norway	13.09	1,320	3.72	5,003.2	2,251.9	8,176	.46	1,852.8
Pakistan	.13	80	102.90	5,112.8	2,570.3	55,621	.63	1,515.0
Peru	4.59	270	11.65	5,151.9	2,996.3	13,815	.54	1,906.0
Philippines	1.15	130	32.34	5,309.7	2,980.2	22,252	.40	2,028.0
South Africa	2.50	470	17.87	5,458.3	2,753.1	23,804	.79	1,979.1
Syria	2.22	160	5.23	5,098.5	2,934.1	10,675	.32	1,986.6
Taiwan	7.25	160	12.44	5,088.5	2,551.0	15,737	1.28	1,949.3
Turkey	1.51	230	31.15	5,292.0	2,791.5	42,097	.58	1,861.0
Un. Arab Rep.	5.51	150	29.39	5,081.9	2,606.3	25,699	.51	1,717.8
United States	27.78	2,610	194.59	6,507.9	7,953.9	386,252	1.12	9,570.0

I/ Description for the data reported here is found in Chapter III of this study.

	No. of male workers in agriculture 1,000's	Agricultural land area		Livestock		Fertilizer consumption		Tractor horsepower 1,000 hp.	School enrollment ratio
		1,000 hectares	1,000 hectares	1,000 units	1,000 metric tons	(N+P <sub>2</sub> O <sub>5</sub> +K <sub>2</sub> O)	1,000 metric tons		
Argentina	1,295	137,829	46,043	14	3,485	69			
Australia	395	468,135	30,223	605	7,782	89			
Brazil	8,698	137,034	87,705	191	1,972	39			
Canada	434	62,848	10,963	324	16,800	77			
Ceylon	1,263	1,723	2,093	57	13	67			
Colombia	1,612	19,653	15,194	38	741	40			
Denmark	303	3,127	4,746	386	3,227	86			
Greece	1,101	8,911	3,595	144	818	70			
India	86,847	176,036	207,240	340	686	26			
Ireland	343	4,705	4,695	174	1,243	98			
Mexico	5,287	102,909	37,599	188	1,229	44			
Netherlands	387	2,317	4,202	467	1,857	90			
New Zealand	112	13,341	10,284	263	2,452	97			
Norway	103	1,033	1,398	145	1,368	85			
Pakistan	18,464	25,000	40,023	48	137	23			
Peru	758	13,956	6,656	76	204	49			
Philippines	3,959	7,954	6,305	66	128	76			
South Africa	1,415	101,170	15,523	213	2,250	58			
Spain	3,023	33,880	9,277	659	1,273	61			
Syria	477	12,566	1,110	9	123	39			
Taiwan	1,116	880	1,180	173	37	59			
Turkey	4,469	54,018	20,255	45	1,375	39			
United States	3,542	439,941	100,834	7,225	155,540	100			



	No. of grads from agri. colleges per 10,000 workers	National income per capita U.S.\$	Popula- tion millions	Net Agri. exports + 5,000 million U.S.\$	Balance of trade + 3,000 million U.S.\$	Agri. output + 5,000 1,000 wheat units	Reserves/ imports - World reserves/ imports	Balance of goods and services + 2,000 mil. U.S.\$
Argentina	1.82	450	20.70	5,843.7	2,735.1	56,626	.49	1,737.5
Australia	9.02	1,110	10.28	6,403.1	3,097.9	47,054	.98	1,585.5
Brazil	.60	80	69.73	5,922.9	2,890.2	87,162	.56	1,654.4
Canada	11.40	1,450	17.91	5,344.7	2,831.8	41,633	.64	936.2
Ceylon	.03	120	9.90	5,189.1	2,966.4	9,906	.68	1,965.0
Colombia	.39	190	15.40	5,309.1	2,994.1	21,594	.68	1,993.9
Denmark	5.20	910	4.58	5,513.0	3,079.4	19,378	.30	2,002.3
Greece	.97	340	8.33	5,052.8	2,602.4	15,911	.68	1,824.0
India	.41	60	429.00	5,070.7	2,234.1	190,986	.30	1,179.9
Ireland	4.64	500	2.83	5,088.9	2,732.4	12,812	1.00	1,935.3
Mexico	.15	280	36.05	5,358.4	2,136.6	32,354	.73	1,855.0
Netherlands	11.15	760	11.48	5,228.5	2,395.3	21,709	.70	2,244.9
New Zealand	19.23	1,220	2.37	5,668.3	3,073.6	20,882	.43	1,935.4
Norway	10.06	930	3.58	5,002.8	2,441.7	8,195	.36	1,875.4
Pakistan	.26	60	92.70	5,192.7	2,952.7	50,125	1.03	1,801.1
Peru	1.66	170	10.02	5,092.5	2,995.3	12,751	.30	1,943.4
Philippines	1.60	190	27.41	5,234.6	2,923.3	19,945	.26	1,841.8
South Africa	1.57	360	15.94	5,341.8	2,620.9	23,804	.41	2,032.4
Spain	.93	310	30.30	5,024.9	2,710.9	47,096	.75	1,953.3
Syria	2.43	140	4.56	5,044.3	2,922.1	9,504	.41	1,952.7
Taiway	6.18	110	10.61	5,113.6	2,906.2	14,009	.96	1,880.0
Turkey	1.15	160	27.51	5,224.2	2,896.5	36,856	1.02	1,904.6
United States	21.82	2,190	180.68	5,321.1	8,270.4	357,619	1.16	6,490.2

	No. of male workers in agriculture 1,000's	Agricultural land area 1,000 hectares	Livestock 1,000 units	Fertilizer consumption (N+P <sub>2</sub> O <sub>5</sub> +K <sub>2</sub> O) 1,000 metric tons	Tractor horsepower 1,000 hp.	School enrollment ratio:
Austria	297	4,050	2,794	221	2,247	72
Belgium-Luxemburg	215	1,857	3,030	377	1,405	92
Chile	512	13,742	3,906	77	473	68
Finland	187	2,849	2,074	216	2,288	82
France	2,395	34,539	20,949	2,183	18,996	80
Germany	1,477	14,254	14,939	2,307	16,173	87
Israel	77	1,210	267	32	214	85
Italy	3,898	20,930	11,762	816	7,536	56
Japan	4,897	7,020	4,558	1,577	5,234	90
Sweden	225	4,282	2,797	286	4,682	79
Switzerland	233	2,161	1,864	99	652	72
United Kingdom	877	19,894	14,971	984	12,989	79
Venezuela	650	19,178	6,544	13	320	56
Austria	267	3,984	2,720	304	3,922	70
Belgium-Luxemburg	174	1,791	3,216	452	2,217	99
Chile	533	14,954	4,030	102	734	74
Finland	173	2,883	2,023	283	3,819	83
France	2,205	34,000	21,360	2,816	25,934	91
Germany	1,273	14,059	15,789	2,627	23,782	86
India	91,339	177,243	224,483	599	1,587	33
Israel	80	1,223	336	36	317	88
Italy	3,364	20,440	11,704	931	13,055	60
Japan	4,405	7,683	4,801	1,780	29,431	89
Portugal	1,047	4,918	2,367	158	489	61
Spain	3,442	34,769	7,803	755	4,546	67
Sweden	201	3,735	2,367	343	6,985	79
United Kingdom	799	19,623	15,635	1,464	13,037	85
Venezuela	685	22,193	7,130	30	467	70



	No. of grads from agri. colleges per 10,000 farm workers	National income per capita U.S.\$	Popula- tion millions	Net.Aagri. exports + 5,000 million U.S.\$	Balance of trade + 3,000 million U.S.\$	Agri. output + 5,000 1,000 wheat units	Reserves/ Imports - World reserves/ imports	Balance of goods and services + 2,000 mil. U.S.\$
Austria	5.79	640	7.05	4,767.6	2,779.9	14,419	1.04	2,012.2
Belgium-Luxemb.	11.77	970	9.15	4,527.1	2,809.5	16,361	.76	2,136.5
Chile	2.21	390	7.69	4,944.1	2,995.7	11,607	.34	1,855.2
Finland	7.81	990	4.43	4,856.2	2,961.5	10,756	.52	1,995.8
France	2.46	940	45.70	3,893.5	3,021.4	91,093	.55	2,086.7
Germany	7.62	930	53.22	1,954.6	4,379.4	62,023	1.28	3,754.0
Israel	8.05	820	2.11	4,955.6	2,708.1	7,229	.58	1,658.3
Italy	1.50	510	49.64	4,277.6	2,147.3	67,709	1.30	2,204.0
Japan	14.24	330	93.21	3,171.6	2,247.3	57,436	.62	1,898.7
Sweden	6.89	1,480	7.48	4,681.6	2,742.7	14,971	.40	1,970.7
Switzerland	5.27	1,290	5.36	4,687.8	2,631.5	11,827	2.00	2,047.2
United Kingdom	7.40	1,060	52.35	66.4	931.4	43,605	.47	2,390.3
Venezuela	.83	790	7.36	4,879.5	4,071.9	10,437	1.03	2,061.6
Austria	8.46	900	7.26	4,730.0	2,560.2	15,472	1.54	1,924.8
Belgium-Luxemb.	12.03	1,310	9.46	4,464.4	2,765.1	17,501	.36	2,006.8
Chile	5.48	420	8.71	4,892.8	3,030.1	12,118	.41	1,859.8
Finland	10.44	1,250	4.61	4,352.2	2,832.9	11,598	.46	1,856.8
France	3.75	1,410	48.80	4,200.9	2,376.4	105,195	1.33	2,272.8
Germany	8.65	1,420	56.84	1,052.7	4,342.9	68,147	1.20	3,059.8
India	.99	80	486.65	4,903.9	2,067.8	205,046	.49	867.2
Israel	11.25	920	2.56	4,952.1	2,623.6	8,108	1.67	1,500.8
Italy	1.65	840	51.58	3,620.1	1,805.7	72,751	1.35	2,568.8
Japan	20.54	650	97.95	2,746.5	2,453.4	62,921	.65	2,248.8
Portugaul	.42	320	9.20	4,921.3	2,207.7	13,981	2.54	1,897.4
Spain	.77	518	31.60	4,878.4	1,460.3	47,092	1.28	1,447.2
Sweden	8.20	2,160	7.73	4,593.0	2,734.8	15,061	.54	1,925.6
United Kingdom	8.51	1,370	54.44	80.5	411.8	50,731	.47	2,325.6
Venezuela	.91	738	8.72	4,874.8	4,466.7	12,291	1.34	2,281.4

APPENDIX B



Reserves/World Imports of the Relevant Period) on the Policy Variable.

Period	Labor	Land	Live-stock	Fertilizer	Machinery	General Educa.	Tech. Educa.	Per Cap. Income	Population	Reserves / Imports	R <sup>2</sup>
Exporters 1957-61 1962-66	-.042 (.026)	.019 (.009)	.045 (.015)	-.003 (.010)	-.017 (.012)	.073 (.041)	.009 (.009)	-.009 (.027)	.015 (.024)	.014 (.019)	.6944 (7.499)
Exporters 1957-61	-.058 (.034)	.016 (.012)	.052 (.019)	-.001 (.012)	-.011 (.017)	.087 (.058)	.001 (.010)	-.048 (.043)	.009 (.032)	.011 (.022)	.7134 (2.987)
Exporters 1962-66	-.004 (.040)	.023 (.013)	.037 (.020)	-.007 (.018)	-.013 (.016)	.076 (.061)	.030 (.017)	.011 (.035)	.005 (.033)	-.007 (.034)	.8721 (6.821)
Importers 1957-61 & 1962-66	3.307 (.521)	-.609 (.400)	.668 (.350)	.364 (.392)	-.299 (.401)	.684 (1.299)	.715 (.313)	.895 (.624)	-3.867 (.572)	.051 (.272)	.8309 (8.353)

Note: The values in parentheses are standard errors of the estimates. The R<sup>2</sup> column reports the value of the F test rather than standard error.

Table B-2. Regression Coefficients for the Four Models Using Local Explanatory Variables.

Period	Labor	Land	Live-Stock	Fertilizer	Machinery	General Educa.	Tech. Educa.	Per Cap. Income	Population	Reserves / Imports	R <sup>2</sup>
Exporters 1957-61	-.041 (.026)	.020 (.009)	.042 (.015)	-.001 (.010)	-.017 (.012)	.076 (.042)	.009 (.009)	-.009 (.027)	.016 (.025)	-.004 (.026)	.6892 (7.388)
Exporters 1957-61	-.058 (.034)	.017 (.011)	.049 (.020)	.001 (.011)	-.009 (.017)	.094 (.058)	-.001 (.010)	-.049 (.043)	.012 (.032)	0.023 (.033)	.7192 (3.07)
Exporters 1962-66	-.005 (.039)	.021 (.012)	.038 (.019)	-.008 (.016)	-.010 (.016)	.078 (.059)	.031 (.017)	.008 (.035)	.010 (.034)	-.021 (.036)	.8759 (7.058)
Importers 1957-61	3.324 (.528)	-.637 (.398)	.669 (.365)	.364 (.428)	-.303 (.441)	.709 (1.503)	.688 (.324)	.925 (.611)	-3.860 (.595)	-.012 (.719)	.8305 (8.333)
Importers 1962-66											

Note: The values in parenthesis are standard errors of the estimates. The R<sup>2</sup> column reports the value of the F test rather than standard error.



VITA

## VITA

Rubens Valentini was born in Sao Paulo, Brazil, on April 1, 1945.

In March 1964 he enrolled at the Escola Superior de Agricultura "Luiz de Queiroz," Universidade de Sao Paulo, and graduated in January 1969 with a B. S. in Agriculture (Engenheiro Agronomo) with a major in Agricultural Economics.

In March 1969 he joined the staff of the Universidade do Sao Paulo as an Instructor in Agricultural Economics. In December 1970 he received the degree of Doutor em Agronomia from the Universidade de Sao Paulo.

In February 1971 he entered Purdue University, Department of Agricultural Economics, and completed the requirements for the degree of Doctor of Philosophy in May 1974.



Table C-1. Correlation coefficient matrix.

Exporting countries, periods 1957-61 and 1962-66.

Land	.43592	.86520	.30208	.64290	.51917	.69344	.75425	.35107	.13474	.39090
Livestock	.62155	.24452	.47485	.49186	.57027	.83416	.36546	.44620	.38191	
Fertilizer	.03910	.56403	.26170	.49610	.70806	.49038	.32308	.31018		
Machinery	.22054	.15085	.20799	.58072	.13346	.33762	.26179			
General Education	.71961	.00681	.03312	.26319	.59745	.22599				
Technical Education	.65482	.09364	.76091	.34625	.51423					
Per Capita Income	.67910	.60006	.53495	.48342						
Population	.89241	.61260	.40957							
Net Agric. Exports	.10107	.48296								
Trade Balance	.11712									

Labor

Land

Livestock

Fertilizer

Machinery

Gen. Educ.

Tech. Educ.

P.C. Income

Population

N.A.S.EXP.

Importing countries, periods 1957-61 and 1962-66.

Land	.84769	.90631	.59098	.92800	.24925	.74004	.49094	.40730	.37462	.71186
Livestock	.84512	.38057	.53455	.19707	.20747	.71014	.14261	.23309	.33058	
Fertilizer	.54375	.37016	.48679	.30239	.66084	.32096	.23797	.01087		
Machinery	.42595	.57903	.37247	.08242	.76031	.19780	.43651	.03146		
General Education	.57626	.57537	.35709	.76031	.39826	.04009	.20662			
Technical Education	.43398	.46251	.87169	.31777	.32804					
Per Capita Income	.64695	.77472	.23700	.21221						
Population	.92277	.10011	.21221							
Net Agric. Exports	.19246	.19246								
Trade Balance										

Labor

Land

Livestock

Fertilizer

Machinery

Gen. Educ.

Tech. Educ.

P.C. Income

Population

N.A.S.EXP.

Table 1 (continued).

Exporting countries, period 1957-61.

Land	.48342								
Livestock	.67902	.86404							
Fertilizer	.00321	.25895	.30374						
Machinery	.14204	.59246	.49819	.63310					
General Education	.74196	.24278	.36040	.44937	.42071				
Technical Education	.60008	.03784	.16428	.44670	.59129	.65141			
Per Capita Income	.66687	.08095	.07740	.55303	.75832	.84377	.74867		
Population	.91377	.62551	.79391	.26926	.17148	.54980	.34085	.37259	
Net Agric. Exports	.11385	.52333	.44525	.13517	.42585	.21168	.18802	.29780	.00562
Trade Balance	.03532	.33393	.26584	.48036	.46459	.27542	.29961	.38288	.14425

Labor Land Livestock Fertilizer Machinery Gen. Educ. Tech. Educ. P.C.Income Population N.Ag.Exp.

Exporting countries, period 1962-66.

Land	.37975								
Livestock	.54778	.86786							
Fertilizer	.08058	.23720	.31050						
Machinery	.30886	.54311	.45659	.64488					
General Education	.69122	.04599	.12053	.53449	.64499				
Technical Education	.73809	.14379	.26905	.53389	.52898	.74167			
Per Capita Income	.70023	.11537	.02147	.59644	.81782	.82808	.74750		
Population	.66512	.57105	.71746	.26440	.09040	.40807	.41166	.33571	
Net Agric. Exports	.07891	.73096	.66205	.50657	.74123	.44520	.39566	.52978	.26401
Trade Balance	.20502	.63182	.56635	.49961	.57980	.18420	.24647	.27430	.59382

Labor Land Livestock Fertilizer Machinery Gen. Educ. Tech. Educ. P.C.Income Population N.Ag.Exp.



Table D-1. Correlation coefficient matrix.

Exporting countries, periods 1957-61 and 1962-66.

Land	.43592						
Livestock	.62155	.86520	.30208				
Fertilizer	-.03918	.24452	.47489	.64290			
Machinery	-.22054	.56403	-.26170	.49186	.51917		
General Education	-.71961	-.15885	-.20799	.49610	.69344	.75425	
Technical Education	-.65482	.08681	-.03312	.58072	.78806	.83416	-.35187
Per Capita Income	-.67910	.09364	.76091	.26319	.13346	.49038	.44620
Population	.89241	.60006	.53495	.34625	.59745	.33762	.31018
Net Agric. Exports	-.10107	.61260	.53495	.48342	.51423	.22599	.26179
Trade Balance	.11712	.48296	.40957	.48342	.51423	.22599	.26179

Importing countries, periods 1957-61 and 1962-66.

Land	.84769						
Livestock	.84512	.90631	.59098				
Fertilizer	-.54375	.38057	.53455	.92880			
Machinery	.42595	.37016	.48679	.19707	.24925		
General Education	-.57626	-.57903	-.37247	.24777	.20747	.74004	.49094
Technical Education	-.43390	.57537	-.35709	.08242	.30239	.71014	.40730
Per Capita Income	-.64695	.46251	.87169	.76031	.66084	.32096	.14261
Population	.92277	.77472	.87169	.76031	.66084	.19700	.23797
Net Agric. Exports	-.10011	.23708	.31777	.39826	.43551	.04009	.01007
Trade Balance	-.19246	-.21221	-.21733	-.32804	-.28662	.04009	.01007

Exporting countries, periods 1957-61 and 1962-66.

Labor

Land

Livestock • Fertilizer Machinery

Gen. Educ.

Tech. Educ. • P.C. Income

Population N.A.G. Exp.

Table 1 (continued).

Exporting countries, period 1957-61.

Land	.48342	.86404				
Livestock	.67902	.25895	.30374			
Fertilizer	-.00321	.49819	.63310			
Machinery	-.14204	.36040	.44937	.42071		
General Education	-.74196	-.03784	.16428	.59129	.65141	
Technical Education	-.60008	.00095	-.07740	.75832	.84377	.74867
Per Capita Income	-.66607	.62551	.79391	.17148	.54980	.34085
Population	.91377	.52333	.44525	.13517	.21168	.18802
Net Agric. Exports	-.11385	.33393	.26584	.46459	.27542	.29961
Trade Balance	.03532					

.00562  
.26513  
.37259  
.29780  
.38288  
Population N.A.S.Exp.

Exporting countries, period 1962-66.

Land	.37975	.86786				
Livestock	.54778	.23720	.31050			
Fertilizer	-.08058	.54311	.45659	.64488		
Machinery	-.30886	-.04599	.12053	.53449	.64499	
General Education	-.69122	.14379	.26905	.53389	.52098	.74167
Technical Education	-.70023	.11537	.02147	.59644	.81782	.82808
Per Capita Income	.06512	.57105	.71746	.26440	.09040	.41166
Population	-.07091	.73096	.66205	.50657	.74123	.44520
Net Agric. Exports	.20502	.63182	.56635	.49961	.57980	.16420
Trade Balance						

.26401  
.51638  
.59382  
Population N.A.S.Exp.

*Values are in millions of dollars and converted to U.S. dollars as reported in Table 1.*



Exporting countries, period 1957-61.

Land	.45159									
Livestock	.61620	.86073								
Fertilizer	.12027	.19765	.26462							
Machinery	.15652	.57600	.53437	.67590						
General Education	.68062	.15006	.20804	.58970	.53123					
Technical Education	.71128	.18591	.29622	.54443	.45693	.81229				.76108
Per Capita Income	.62589	.12588	.03030	.65375	.79830	.85546				.38333
Population	.87749	.60828	.75335	.20904	.22410	.42050				.2
Net Agric. Exports	.01565	.62118	.59630	.20836	.44334	.16390				.09648
Trade Balance	.23414	.44627	.44473	.58178	.53450	.19517				.31031

Labor

Land

Livestock

Fertilizer

Machinery

Gen. Educ.

Tech. Educ. P.C.

Exporting countries, period 1962-66.

Land	.45345									
Livestock	.59520	.86834								
Fertilizer	.09201	.25600	.32010							
Machinery	.27450	.51639	.44077	.67352						
General Education	.67400	.12441	.16888	.57192	.62137					
Technical Education	.77094	.13142	.26273	.53261	.56062	.79651				.78660
Per Capita Income	.68525	.06258	.01105	.62449	.80765	.81723				.42333
Population	.86573	.62163	.74549	.26123	.12063	.39410				.5
Net Agric. Exports	.03833	.71765	.65372	.52715	.72893	.41257				.41921
Trade Balance	.22964	.63137	.56157	.50619	.57679	.16605				.25423

Labor

Land

Livestock

Fertilizer

Machinery

Gen. Educ.

Tech. Educ. P.C.

1962-66, 6 months and continuing

Table C-1 (continued).

Exporting countries, period 1957-61.

45159											
61520	86073										
12027	19765	26462									
15652	57600	53437	67590								
6A062	15006	20804	58970	53123							
71128	18591	29622	54443	45693	81229						
62589	12588	03030	65375	79830	85546	76108					
87749	60828	75335	20984	22410	42060	38333	25915				
01565	62118	59630	20836	44334	16390	09648	24197	14869			
23414	44627	44473	58178	53450	19517	31031	33530	51118	09147		

Labor Land Livestock Fertilizer Machinery Gen. Educ. Tech. Educ. P.C. Income Population N.Ag.Exp.

Exporting countries, period 1962-66.

45345											
59520	86834										
09201	25600	32010									
27450	51639	44077	67352								
67400	12441	16888	57192	62137							
77094	13142	26273	53261	56062	79651						
68525	06258	01105	62449	80765	81723	78660					
86573	62163	74549	26123	12063	39410	42333	31978				
03833	71765	65372	52715	72893	41257	41921	50679	29545			
22964	63137	56157	50619	57679	16605	25423	26163	53241	59020		

Labor Land Livestock Fertilizer Machinery Gen. Educ. Tech. Educ. P.C. Income Population N.Ag.Exp.

*Handwritten notes:* 47-66, 67-68, 69-70, 71-72, 73-74, 75-76, 77-78, 79-80, 81-82, 83-84, 85-86, 87-88, 89-90, 91-92, 93-94, 95-96, 97-98, 99-100, 101-102, 103-104, 105-106, 107-108, 109-110, 111-112, 113-114, 115-116, 117-118, 119-120, 121-122, 123-124, 125-126, 127-128, 129-130, 131-132, 133-134, 135-136, 137-138, 139-140, 141-142, 143-144, 145-146, 147-148, 149-150, 151-152, 153-154, 155-156, 157-158, 159-160, 161-162, 163-164, 165-166, 167-168, 169-170, 171-172, 173-174, 175-176, 177-178, 179-180, 181-182, 183-184, 185-186, 187-188, 189-190, 191-192, 193-194, 195-196, 197-198, 199-200, 201-202, 203-204, 205-206, 207-208, 209-210, 211-212, 213-214, 215-216, 217-218, 219-220, 221-222, 223-224, 225-226, 227-228, 229-230, 231-232, 233-234, 235-236, 237-238, 239-240, 241-242, 243-244, 245-246, 247-248, 249-250, 251-252, 253-254, 255-256, 257-258, 259-260, 261-262, 263-264, 265-266, 267-268, 269-270, 271-272, 273-274, 275-276, 277-278, 279-280, 281-282, 283-284, 285-286, 287-288, 289-290, 291-292, 293-294, 295-296, 297-298, 299-300, 301-302, 303-304, 305-306, 307-308, 309-310, 311-312, 313-314, 315-316, 317-318, 319-320, 321-322, 323-324, 325-326, 327-328, 329-330, 331-332, 333-334, 335-336, 337-338, 339-340, 341-342, 343-344, 345-346, 347-348, 349-350, 351-352, 353-354, 355-356, 357-358, 359-360, 361-362, 363-364, 365-366, 367-368, 369-370, 371-372, 373-374, 375-376, 377-378, 379-380, 381-382, 383-384, 385-386, 387-388, 389-390, 391-392, 393-394, 395-396, 397-398, 399-400, 401-402, 403-404, 405-406, 407-408, 409-410, 411-412, 413-414, 415-416, 417-418, 419-420, 421-422, 423-424, 425-426, 427-428, 429-430, 431-432, 433-434, 435-436, 437-438, 439-440, 441-442, 443-444, 445-446, 447-448, 449-450, 451-452, 453-454, 455-456, 457-458, 459-460, 461-462, 463-464, 465-466, 467-468, 469-470, 471-472, 473-474, 475-476, 477-478, 479-480, 481-482, 483-484, 485-486, 487-488, 489-490, 491-492, 493-494, 495-496, 497-498, 499-500, 501-502, 503-504, 505-506, 507-508, 509-510, 511-512, 513-514, 515-516, 517-518, 519-520, 521-522, 523-524, 525-526, 527-528, 529-530, 531-532, 533-534, 535-536, 537-538, 539-540, 541-542, 543-544, 545-546, 547-548, 549-550, 551-552, 553-554, 555-556, 557-558, 559-560, 561-562, 563-564, 565-566, 567-568, 569-570, 571-572, 573-574, 575-576, 577-578, 579-580, 581-582, 583-584, 585-586, 587-588, 589-590, 591-592, 593-594, 595-596, 597-598, 599-600, 601-602, 603-604, 605-606, 607-608, 609-610, 611-612, 613-614, 615-616, 617-618, 619-620, 621-622, 623-624, 625-626, 627-628, 629-630, 631-632, 633-634, 635-636, 637-638, 639-640, 641-642, 643-644, 645-646, 647-648, 649-650, 651-652, 653-654, 655-656, 657-658, 659-660, 661-662, 663-664, 665-666, 667-668, 669-670, 671-672, 673-674, 675-676, 677-678, 679-680, 681-682, 683-684, 685-686, 687-688, 689-690, 691-692, 693-694, 695-696, 697-698, 699-700, 701-702, 703-704, 705-706, 707-708, 709-710, 711-712, 713-714, 715-716, 717-718, 719-720, 721-722, 723-724, 725-726, 727-728, 729-730, 731-732, 733-734, 735-736, 737-738, 739-740, 741-742, 743-744, 745-746, 747-748, 749-750, 751-752, 753-754, 755-756, 757-758, 759-760, 761-762, 763-764, 765-766, 767-768, 769-770, 771-772, 773-774, 775-776, 777-778, 779-780, 781-782, 783-784, 785-786, 787-788, 789-790, 791-792, 793-794, 795-796, 797-798, 799-800, 801-802, 803-804, 805-806, 807-808, 809-810, 811-812, 813-814, 815-816, 817-818, 819-820, 821-822, 823-824, 825-826, 827-828, 829-830, 831-832, 833-834, 835-836, 837-838, 839-840, 841-842, 843-844, 845-846, 847-848, 849-850, 851-852, 853-854, 855-856, 857-858, 859-860, 861-862, 863-864, 865-866, 867-868, 869-870, 871-872, 873-874, 875-876, 877-878, 879-880, 881-882, 883-884, 885-886, 887-888, 889-890, 891-892, 893-894, 895-896, 897-898, 899-900, 901-902, 903-904, 905-906, 907-908, 909-910, 911-912, 913-914, 915-916, 917-918, 919-920, 921-922, 923-924, 925-926, 927-928, 929-930, 931-932, 933-934, 935-936, 937-938, 939-940, 941-942, 943-944, 945-946, 947-948, 949-950, 951-952, 953-954, 955-956, 957-958, 959-960, 961-962, 963-964, 965-966, 967-968, 969-970, 971-972, 973-974, 975-976, 977-978, 979-980, 981-982, 983-984, 985-986, 987-988, 989-990, 991-992, 993-994, 995-996, 997-998, 999-1000.