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ASSESSING AGRICULTURAL PROGRESS AND THE COMMITMENT TO AGRICULTURE

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SUMMARY AND CONCLUSIONS

The main objective of this paper has been to critically assess the desirability of the agricultural productivity indicator cited in Public Law 94-161 as a measure of agricultural development and, to the extent it is found wanting, to suggest other, more appropriate indicators for this purpose. The indicator cited was to increase the productivity of land through small-farm labor-intensive agriculture.

Our major conclusions are as follows:

1. Assessing agricultural progress by what happens to the productivity of land is too restrictive in scope, and under some circumstances it can lead to misguided policy recommendations. Productivity growth should be focused on the resource that is limiting output expansion, and this will not always be land.
2. If a single partial measure of productivity is to be used, the growth in <u>labor</u> productivity or production per person employed in agriculture is a more appropriate measure of agriculture progress than is the growth in land productivity. Raising the productivity of rural people is an important means of raising their income, and this is clearly a goal of Congress. Increases in the productivity of land may not be translated into an increase in the productivity of labor. Moreover, the change in labor productivity is a more direct index of how much food is made available for the non-farm sector of the economy and for export.
3. The use of any partial index of average productivity should be done with care, since it may reflect nothing more than a shift in factor proportions induced by a change in relative factor prices. A

measure of total factor productivity, or an index of total output/ total input is likely to be a more desirable measure of agricultural progress.

4. In assessing agricultural progress, changes in total factor productivity can be evaluated without taking account of changes in the quality of inputs or of the public inputs supplied to the sector. Alternatively, measurements can be made of the factors known to give rise to changes in total factor productivity, such as investments in research and extension, in education and training of the labor force, and the other changes in the quality of inputs.

5. The possibility of factor intensity reversals casts doubt on the proposition that agricultural development should invariably follow a labor-intensive, small-farm approach. There is evidence, for example, that rice production is labor-intensive relative to the industrial sector at low wage/rental ratios in Asia, while it is relatively capital-intensive in the U.S.

6. A number of indicators associated with changes in productivity are suggested. Among these are expenditures on agricultural research, progress in providing education for the rural population, indices of adoption of improved varieties and other biological innovations, and the use of modern inputs such as fertilizer.

7. To the extent that Congress was concerned with the welfare of rural people, there is no substitute for examining the income of rural people as a measure of the progress being obtained. This is especially important in light of the fact that rapid progress in obtaining changes in productivity can actually lead to declines in the relative income position of rural people.

8. A common failing of all measures of productivity as an indicator of agricultural progress is that they provide an ex post indicator of government policy. Investments in agricultural research, for example, may not lead to an increase in measured productivity growth for from five to seven years. Such lags can penalize governments that are taking appropriate steps to improve their agriculture. To reduce this problem, attention should be given to measuring budget commitment and the quality of that commitment to the agricultural sector.

9. Economic policy is also an important indicator of the commitment a government has to its agriculture. In assessing this, special attention should be given to implicit and hidden taxes and distortions, and not just to the more overt and explicit policies.

10. Under rather general conditions it is the nature of economic development that labor has to be transferred from the farm to the non-farm sector. Under these circumstances it is misguided to attempt to retain all of present rural populations in agriculture, or to attempt to solve the more general employment problems of low income countries in agriculture. This points up the importance of appropriate employment policies, and to the removal of the anti-employment bias inherent in many economic policies.

11. Recent progress in estimating the underlying production function that describes world agriculture can provide a means of using estimates of inputs used in agriculture to estimate changes in total factor productivity. This reduces the need to estimate the parameters of a production function for every country of interest, and broadens the extent to which such a more desirable indicator can be used.

12. Careful monitoring of agricultural progress in most low-income countries will require additional investment in data collection and in the human capital to analyze and interpret these data. Such investments will have a high payoff both to the Agency for International Development and to the particular country involved.

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ASSESSING AGRICULTURAL PROGRESS AND THE COMMITMENT TO AGRICULTURE*

G. Edward Schuh and Robert L. Thompson**

In the 1975 amendments to the Foreign Assistance Act of 1961 the Congress directed that U.S. foreign aid should be concentrated on "countries and activities which effectively involve the poor in development, by expanding their access to the economy through services and institutions at the local level, increasing labor-intensive production, spreading productive investment and services out from major cities to small towns and outlying rural areas, and otherwise providing opportunities for the poor to better their lives through their own effort." [1/] Pursuant of this objective the Act requires the President among other things to "establish appropriate criteria to assess the commitment and progress of countries in meeting [these objectives]" ...and, "In establishing such criteria...[to] take into account their value in assessing the efforts of countries to....<u>increase agricultural productivity per unit of land through small-farm labor-intensive agriculture</u>..." (emphasis added).

The main objective of the present paper is to critically assess the desirability of the agricultural productivity indicator cited in Public Law 94-161 as a measure of agricultural development and, to the extent it is found wanting, to suggest other, more appropriate, indicators for this purpose. To anticipate some of our conclusions, we argue that productivity in general suffers from being an ex post measure of commitment, and that land productivity in

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1/ Public Law 94-161, Title III, Section 30/December 20, 1975.

particular has deficiencies that limit its general use as an indicator of progress. We therefore consider other indicators that reflect in an ex ante or concurrent way the commitment of governments to their agriculture, and propose alternative measures of productivity. The paper also contains a discussion of the feasibility of measuring the various indices proposed.

The paper is organized in three parts. Part I, the largest part of the paper, contains a rather comprehensive discussion of alternative indicators of agricultural progress, including comments on the theoretical complexities and problems associated with the agricultural productivity indicator suggested by Congress. Attention is also given to the different levels at which productivity may be investigated, and to the causes of observed differences in productivity. Considerations involved in choosing an indicator are discussed in the last section of this part.

Part II contains a discussion of indicators that provide a measure of the commitment a government may have to agricultural development. Such indicators are important, since changes in productivity may lag by a substantial margin certain changes in policy. Moreover, the most obvious reflection of a government's commitment to its agriculture may be its economic policy, and in the short term this may have little effect on productivity.

Finally, Part III contains an assessment of the availability, reliability, accuracy, and timeliness of the data required to measure the indicators recommended in Parts I and II. The focus here is on the countries to which USAID resources and programs are directed. Some attention is given to a proposed methodology for estimating indices of total factor productivity, and illustrative material on some of the proposed indicators are drawn from Brazil and India.

Strictly technical material is relegated to Appendices. There is also a Bibliography at the end of the Report.

PART I. INDICATORS OF AGRICULTURAL PROGRESS

Agricultural progress can be measured in a number of different ways, ranging from the change in gross agricultural output over time to sophisticated attempts to measure the rate of technological change in the sector. This part of the paper contains a rather broad ranging discussion of alternative indicators that might be used. The major part of the discussion focuses on alternative measures of productivity and the theoretical and definitional problems associated with measuring agricultural productivity. Other indicators are also considered, however, as well as a discussion of how both inputs and output should be specified and measured. The final section of this part addresses the specific question of a choice of an indicator or indicators for measuring agricultural progress.

Gross Output as a Measure of Agricultural Progress

Perhaps the simplest way to measure agricultural progress is in terms of the increase in gross agricultural output over time. Just increasing agricultural output in gross terms constitutes progress for many countries, and in a similar vein, for most countries a higher rate of output growth is preferred to a lower rate of growth. Moreover, given knowledge on the rate of increase in population, knowledge on the rate of increase in agricultural output, especially if it is broken down into broad categories such as food, export crops, and raw materials, can provide insight into whether per capita availability of food is increasing, whether there is potential for increases in earnings of foreign exchange, or whether agriculture is contributing to the expansion of the nonfarm sector by providing raw material products such as cotton in those cases where such products are relevant.

The advantage of using changes in the level of gross output as an indicator of agricultural progress, of course, is that it places minimal demands on data and

analytical capability. It does not require data on inputs as are required in calculating trends in resource productivity, nor does it require sophisticated analytical procedures to assume that estimators of the indicator are not biased in one form or another. By the same token, however, the concept of progress implied is a fairly limited one. Agricultural output can increase in the aggregate with no increase in productivity, and of course it is an increase in productivity (appropriately measured) that is often interpreted as economic progress, for it indicates the extent to which a greater output is obtained from the resources at hand.

The definition of the output variable itself is an important issue. The agricultural sector may be defined alternatively to include the conventional crop and livestock products, or it may include these plus fishery, or it may include crops and livestock plus fishery and forest products. Alternatively, the "conventional" agricultural products may be defined to include only food products, or it may be defined to include food products together with export products and products used as industrial raw materials.

For purposes of the analysis in this paper we will define agricultural output to include all the conventional agricultural products plus fish produced in fish farms. Hence, the concept is broader than food, and includes export crops and products produced as raw materials for the nonfarm sector. A conception broader than food is used in recognition of the fact that for low income countries agriculture will tend to be an important element in obtaining a more rapid rate of growth, and to do this progress in the food, export, and industrial raw material-producing sector are all important.

On the other hand, ocean - and river-based fishing and forestry are excluded. The reason for this is that they are sufficiently different both as products and in

their production processes to be treated differently. Both are generally beyond the common conception of agriculture, although both interact with agriculture. More importantly, they are sufficiently different in their production processes to compound analytical and measurement problems in assessing agricultural progress.

The Income of Farm People

Congress appeared to have a number of concerns in passing Public Law 94-161. One concern was with increasing agricultural output in the aggregate as a means of dealing with the emerging world food problem. A second concern was with income and participation of the poor in the economic life of the developing countries.

For some purposes, direct indicators of the incomes of farm people and of the quality of life thru experience are important as a measure of the progress that is being made in improving their situation and of the extent to which the mandate of Congress is being fulfilled. Such measures take on added importance when it is recognized that the relative income position of farm people can actually worsen in the face of rapid productivity growth in the agricultural sector, depending on the conditions in the product and factor markets.

There are a large number of measures of the quality of life that might be used. We want to focus herein on only per capita incomes, since it provides a summary measure of the welfare of individuals. If only one measure of welfare is to be considered, per capita income would be perhaps the best single indicator.

In considering differences or changes in this indicator, a number of different dimensions are important. In the first place, changes in the absolute income of the poor are important, independently of whether they are located in the rural or urban sector.[1/] Many contemporary discussions of income problems

[1/] A similar view is expressed by Gary Fields in a paper which we had access to after this paper was drafted. We of course subscribe to his position.

focus almost entirely on relative incomes. But changes in the absolute level of income are an important indicator of whether the goods and services available to a population group are increasing or decreasing, and that is important in assessing the progress of the poor.

In the second place, changes in the income of rural people relative to that of urban people are important, since incomes of rural people are often dramatically lower than those of urban people. Because of this wide disparity it is often a mistake to blindly argue that efforts should be made to increase employment in agriculture. The income differences suggest a need to transfer labor from the farm to the nonfarm sector. This becomes more obvious when it is realized that under fairly general conditions the nature of development is such that rural-urban migration has to take place. The sectoral income differences suggest that the transfer is not taking place at a sufficiently rapid pace.

This points up the importance of balanced development, in contrast to an exaggerated emphasis on either agricultural or industrial development. It also points up the importance of attacking the problem of rural poverty by means of appropriate labor market policies. The intersectoral labor market often functions quite inefficiently. It is a proper role of government to attempt to make these markets perform more efficiently. If productivity growth is the basis of development policy within agriculture, suitable labor market policies are an imperative. Only for countries with unusual trade possibilities is a relative income problem not likely to arise in the face of rapid productivity growth in agriculture, and trade possibilities for agriculture are at best uncertain.

Other dimensions of the income problem can be as important as the sectoral differential. In large countries such as Brazil and Mexico there are often large regional differences in per capita income. And within the agricultural sector

of many low income countries, the size distribution of income is often highly skewed, with a small proportion of the population receiving quite high incomes while the majority of the population receives very low incomes. This suggests that data on the size distribution of income can be an important complement to data on the sectoral and regional differentials.

An important aspect of the equity problem in all of its ramifications is the participation rates of both males and females in employment opportunities. With development, the opportunity cost of the housewife's time rises. As a result, female participation in the labor force rises. It may be that as males are pulled from agriculture into the nonfarm labor force, there is a substantial replacement of males in agriculture by females, involving an increase in participation rates of women in the labor force.

It is also important to catalog the changes in types of labor demanded by the nonfarm sector as development proceeds. If growth in nonfarm employment is heavily concentrated in relatively high skill-intensity jobs, the supply of skilled labor may not be forthcoming at a sufficiently rapid rate. If this occurs, wages will be bid up at the most skill-intensive end of the wage structure. When this occurs it reflects a failure in the educational system, and the failure of the government to invest in education and training at the appropriate levels. With more attention given to providing the appropriate skills to a larger fraction of the population, the wage rates will rise relatively less at the upper end of the distribution and relatively more at the lower end as labor is shifted out of the unskilled occupations and into the skilled occupations.

An important point to note here is that the bulk of additions to the nonfarm labor force often consists of migrants from agriculture and the entrance of women into the labor force. Neither group has been particularly blessed with educational

attainment in most developing countries. Educational attainment in the agricultural sector has been, and continues to be, substantially behind that of the nonfarm sector.

In measuring changes or differences in per capita incomes, a number of methodological problems arise. First, differences in relative prices faced by the population groups being compared may cause equal nominal income levels to reflect differences in real incomes. Second, population groups often differ in the share of their income they receive in kind. Consequently, measured income may suggest a difference in income when in fact none exists. Third, some income differences reflect differences in the demographic characteristics of the respective populations. Again, direct comparisons of measured income may be quite misleading as a guide to policy.

There are relatively standard procedures for dealing with these problems, and it is important that they be used. But in analyzing farm income one also faces a definitional problem. In most countries the structure of agriculture is such that the farm family household and the farm business comprise one inseparable whole. The residual income after all other claimants have been paid out of revenue from sales is available for family use and reinvestment in the business.

Coffey (pp. 1393-4) has suggested a useful accounting relation to analyze farm family income, as follows:

	Net receipts from farm sales
plus:	Non-money income (farm produced food and fuel; rental value of farmhouse)
plus:	Farm transfer payments
equals:	Net Farm Income
plus:	Real wealth gains (appreciation in real value of farm land and assets)

plus: Income from non-farm sources

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equals: Total Farmer's Income

less: Personal tax payments less personal transfer payments

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equals: Disposable Family Income

This accounting framework serves to focus attention on a number of important points with respect to rural incomes. First, while net receipts from farm sales may often be the dominant source of rural income, other sources are also important. There is often income in kind to the farm family in terms of farm produced food and fuel. In addition to net farm income, however, income from work off the farm by one or more family members may also be significant. In several high income countries, including Japan and West Germany, nonfarm sources of income have become at least as important as farm sources in rural areas. Villa-Issa has shown that even in countries such as Mexico, off-farm employment can be an important source of income for farm people.

When the availability of land per worker is limited by population pressure, off-farm income may be the only hope for achieving parity of farm with non-farm incomes in developing countries. Schuh (1976a) has argued that in light of the negative externalities imposed upon the rural areas by the departure of migrants, a case may be made for moving industrial and other off-farm employment opportunities to the rural areas. This further points up the importance of balanced development, and of being concerned with employment policy.

The above income accounting framework also includes real wealth gains as a source of farm income. Farmers who own agricultural land or other inputs in inelastic supply frequently enjoy real wealth gains from appreciation in land prices. However, while owner's equity increases in such cases, this "income"

can only be received when the asset is sold, i.e. when a given farmer leaves the business. This is one sense in which a farmer may live poor, but die a wealthy man. If this accounting framework were to be used to analyze family income, this change in asset values should be submerged for some purposes. Although it indicates what happens to the wealth position of the family, the gain may be difficult to realize in the short run. Hence, a more suitable measure of disposable family income would abstract from this.

Finally, the above accounting framework focuses attention on the family unit as a whole. Given the family farm organization of agriculture in most countries, household and farm business decisions cannot as a rule be logically separated.

Refined income data are typically not available for low income countries. However, gross estimates of the income of farm people can generally be made from the national income account data, or an estimate can be made from the output data. Although such estimates will have serious deficiencies, they can be useful in assessing changes over time.

In some cases data will be available on the wage rate within the agricultural sector. These data can also be used as an indicator of trends in the welfare of rural people, although it should be recognized that the wage rate itself only tells part of the story of what is happening to the income of farm people. If changes in it reflect competitive conditions in the labor market (in contrast to government-decreed increases), it can indicate how wage workers are faring. It will be less reliable as an indicator of the welfare of families who are farm owners.

Productivity Concepts

Economic theory suggests three basic concepts of productivity, with each

referring to a rather precise relationship between output and input(s). Marginal productivity refers to the increment in output that results from an increment in one of the inputs, holding the level of other inputs as well as the level of technology constant. Because the incremental changes are evaluated at the margin, the concept is referred to as marginal productivity.

Average productivity is the ratio of total output to the amount of a given input. Like the concept of marginal productivity, it is a partial index of productivity, since total output is related to only a single input. Unlike marginal productivity, however, an attempt is seldom made to hold the level of technology constant in measuring it. In fact, it is often incorrectly used as an index of technical change or technological progress.

Total factor productivity is the ratio of total output to an aggregate of all the inputs used in the production process. Measurement procedures differ in whether only within-the-firm inputs are considered or whether public inputs such as research and extension are included. Similarly, some attempt may be made to correct measured inputs for their changes in quality over time (such as the increased education of the labor force), or for differences in the quality of inputs from one region or area to another. Depending on the extent to which the inputs included are all-inclusive, and on the extent to which changes in quality are accounted for, an index of total factor productivity may be more or less suitable as an index of technical change (see below).

Each of these concepts of productivity has a different use in economics, and only rarely are any two of the three measures equal. Marginal productivity is used primarily in the analysis of the allocation of resources, and for the most part is beyond our present interests. Average productivity is the concept most frequently encountered in popular usage, and is frequently used as a measure

of efficiency or technological progress. The suggested use of land productivity in Public Law 94-161 is an example of just such a use.

The use of average productivity for this purpose can be quite mis-leading, and should be done with care. A rise in the productivity of land, for example, may reflect nothing more than a shift in factor proportions induced by a change in relative factor prices. In this sense it may reflect no "progress" at all, and may be associated with a concurrent decline in labor productivity. The trend in labor productivity, in turn, may be of interest in its own right.

For these and other reasons a measure of total factor productivity, or an index of total output/total input is likely to be a more desirable measure of agricultural progress or technical change. One of the most obvious reasons for this conclusion, of course, is that all inputs are used to produce the output. Hence it makes little sense to relate output to only one input in isolation in order to characterize what is happening in the agricultural sector.

The use of total factor productivity as a measure of progress in the agricultural sector also involves a number of problems, however. For example, total factor productivity is computed as the ratio of total output to an index of all factor inputs, where the individual inputs are summed together with an appropriate set of weights (often the factor shares). Increases in this productivity index therefore represent growth in total output which cannot be accounted for by increases in observed or measured inputs. That is, it represents a technological change, or a shift in the production function. Changes in total factor productivity over time may therefore be said to provide an index of technological progress in a country's agriculture, and in this sense serves as an indicator of the efforts that a country is making (or has made) to develop this sector.

Although often used for this purpose, this index also leaves one in a rather unsatisfactory situation. In a sense, the production function which relates the inputs used to the output produced is nothing more than an accounting equation. In this sense there should be no divergence between the output produced, on the one hand, and the sum of the inputs, on the other. To the extent that there is a divergence, it is because inputs that should have been included have been omitted, or because the inputs have not been correctly measured.

Considerable research has been done to investigate this problem, and the results have added to our knowledge on the sources of output expansion. This research has shown that an important source of measured productivity growth of this kind is due to public investments in agricultural research and extension, and to changes in quality of inputs. Changes in the quality of inputs may include a greater amount of education and training of the labor force, improvements in the quality of machinery and equipment, improvements in the varieties of plants, and improvements in other inputs. If all of these are taken into account, there should be no residual productivity growth to explain, except perhaps for a small amount of new production technology that is not imbedded in inputs of one kind or another.

Although this problem is rather serious in the context of growth accounting, it in effect provides one with a couple of alternative strategies when it comes to the somewhat simpler problems of measuring agricultural progress. One approach is to measure the conventional inputs of land, labor, and capital at the firm level, without correction for changes in quality of the inputs, and to relate this to changes in output. If the output/input ratio increases over time, one can infer that there is progress in agriculture, without being sure just what the nature of that progress is.

Alternatively, one can capitalize on the knowledge gained from the growth-accounting research and make separate measurements on the inputs identified as making up the difference between total output and the sum of the conventional inputs. Hence, rather than to measure changes in productivity, one could measure the factors known to affect productivity. These include expenditures on research and extension, expenditures on rural education or other measures of educational attainment, the number of improved plant varieties released, use of commercial fertilizers, and so forth. Measures such as these would be just as appropriate as measures of agricultural progress as would be measures of changes in productivity. Moreover, in some respects they may be more easily measurable.

Before turning to a discussion of the different levels at which production and productivity can be investigated and the issues involved at these various levels, there is one other technical point that should be noted about measuring changes in productivity. Each measure of productivity presupposes the existence of a specific production function that relates inputs in the production process to output (Christensen; Nadiri). Without specification of the form of this production function, no systematic analysis of productivity differences is possible. The functional form and the parameters of the function represent the technology underlying the production process. Recent research reported by Christensen (1975) has demonstrated that many productivity index number formulas exactly represent particular mathematical forms of production function. The choice of an index number formula then requires very specific assumptions concerning the degree to which factors of production may be substituted one for another. We shall return to this issue below. A discussion of the technical issues may be found in Christensen and Appendix A to this Report.

Levels at Which Productivity May be Investigated

Agricultural production and productivity can be investigated at three basic levels: (1) at the level of the biological production process, (2) at the level of the farm firm which combines and coordinates some set of biological and other processes, and (3) at the aggregate level, composed of the set of farm firms in some geographic region, which may in the individual instance be a country. A discussion of the various problems encountered at each of these levels brings out the complexities of productivity measurement.

The biological production process is, of course, the fundamental element of agricultural production. We therefore give more attention to this aspect of the production process than to the other two since it is the key to understanding problems at the other levels. Moreover, the issues which arise at this level indicate why comparisons of productivity among regions can be frought with difficulties, while at the same time bringing out the relationships between weather, climate, and productivity.

The investigation of productivity at the level of the biological production process involves attempts to discover the relationship between quantities of nutrient inputs and physiological growth under given environmental conditions for both plant and animal production.[1/] The production function which this relationship represents relates physical inputs to physical output over a given period of time.

The case of maize can be used to illustrate most of the issues involved. For example, in principle we could think in terms of a functional relationship which relates the yield from a given area of land to the amount of nitrogen, phosphorous, potash, micronutrients, water, carbon dioxide, light, and heat

[1/] Heady and Dillon treat this type of study in detail and review a number of empirical studies.

absorbed by the plants. The functional relationship would tell us how much yield would change if the amount of any of the inputs absorbed changed.

Two issues of economic significance immediately arise. The various inputs would differ in their substitutability, and this would be reflected in the mathematical form of the response function. Equally as important, different varieties of corn would in general differ in their responsiveness to variation in one or more inputs. This implies that there would be a different response function for each variety, and that the output per unit of input would vary among the varieties for a given level of input or outputs. This is important, for an important goal of biological research is to alter this relationship, especially in the direction of obtaining a larger response to given levels of plant nutrients and water.

In this framework we can think of the land or soil's role as that of physically supporting the plant (i.e., something for the roots to hold onto), and of providing a conduit for water and nutrients dissolved in the water to be absorbed through the plant's roots. Since soils differ in their capacity to do this, the yield of a crop grown in different soils, all other things held constant, may differ markedly. This is one reason why great care is needed in making comparisons of productivity.

Differences in soil structure may affect the capacity of the soil to hold the plants. However, differences in the capacity of soils to provide water and nutrients to the plants is probably more important. Very porous soils may permit the water from rainfall to move down out of reach of the plant roots. On the other hand, soils with a clay pan close to the surface may be so wet as to "drown" the plants.

The cation exchange capacity and base status of different soils also vary markedly. For example, many soils in the Tropics are of low base status and are highly leached relative to soils in termperate regions. Tropical soils are commonly deficient in bases and often present aluminum toxicity problems. The soils tend to be low in phosphorous available to the plants because the phosphate ions react with iron and aluminum hydroxides and are "fixed" in an insoluble or only slightly soluble form (Sanchez and Buol).

For the physiological growth of a plant, water is required in its own right, as well as as a conduit for nutrients required for plant growth. In nature this water is supplied by rainfall, which varies substantially across climatic zones and within climatic zones over time. There is an optimum amount of water at each stage of plant growth. More or less at any stage represents a movement along the biological response curve. Different varieties of the same plant and different species of plants have differing demands for water and drought tolerance. Productivity of a given variety then varies with rainfall regimes as it does with soil types.

By the same token, this illustrates how susceptible measures of productivity are to fluctuations in rainfall and the weather. If there should be cycles in the amount of rainfall - and there often are, a sustained decline in productivity may indicate nothing more than the down-side of a weather cycle. Similarly, a sustained rise in productivity may not indicate that a government is doing more for its agriculture, but rather that the area or region is on the upside of the weather cycle. Separating these differences in effects is one of the major challenges in the study of productivity growth. Empirical knowledge of the relationship between rainfall and yields is needed as a basis of knowing at a given point in time whether the observed change in productivity is due to

fluctuations in the weather or to changes in government policy.

While the distribution of light is fairly uniform around the globe, its availability to plants does vary with the amount of cloud cover. For example, rice yields in Southeast Asia are higher, other things (including water availability) held constant, in the dry season than in the wet season, due to the greater insolation.

In addition, variation in day length is an important element in triggering various vegetative phases of certain varieties and species of plants. This is referred to as photoperiod sensitivity. Plants which are photoperiod sensitive require changes in day length to trigger certain physiological processes, such as as flowering. For example, when rice varieties that are photoperiod sensitive are planted in the dry season under irrigated conditions in Southeast Asia, they go only so far in their vegetative cycle and then stop until the change in day-length in the following wet season signals the plant to resume its cycle.

Photoperiod sensitivity also limits the degree to which certain plants can be moved across latitudes. For example, maize, a native of the Tropics where there is relatively little change in day length around the year, tends not to be photoperiod sensitive and therefore is quite movable across latitudes. The soybean, on the other hand, a native of Northern China in the temperate zone, tends to be very photoperiod sensitive, and moves of any distance north and south require adaptive plant breeding. Moreover, soybean breeders doubt the viability of commercial soybean production within 10° north and south of the equator, due to the relative equality of day and night the year around.

These biological production relationships must ultimately be related to husbandry practices. In a primitive agriculture the services of the land with some labor input for planting represent the principal inputs to which the crop

output accrues. With some additional labor input for weeding and pest control, yields may be marginally raised, the returns to which accrue to that labor input. If a source of water for irrigation is available which can be tapped by gravity flow, additional output may be obtained by providing supplemental water in dry periods. Additional labor may also be expended to collect and spread manure, increasing the nutrient availability to the plants above that inherent in the soil.

The important point to remember in this context is that the underlying biological production function which relates plant uptake of nutrients, water, etc. is unchanged. We are merely adding a husbandry function through which greater labor input augments the naturally occurring availability of inputs or affects the timeliness of their delivery to the growing plants.

At a somewhat different level, the use of purchased inputs such as chemical fertilizers, lime, and irrigation pumps may augment the availability of nutrients to the plants. [1/] The use of herbicides and insecticides may also increase crop output. Each of these can be thought of as contributing directly to output, in part by reducing crop damage and in part by replacing labor to the extent that they reduce the amount of time consumed in pulling weeds and manual insect control.

Mechanization is in some respects similar, whether it be animal or tractor powered. It can be argued that an important part of mechanization is purely a substitution for labor and contributes little to output growth in its own right. However, mechanization may also improve yields due to more timely operations. When mechanization is just a substitute for labor, it is expected that its relative share in output will increase and that of labor will decline. To the extent that a productivity gain is realized from more timely operations, however, the share of capital may increase without the share of labor falling (or at least

[1/] Parallel examples can be given for livestock.

not by as much).

The thrust of this discussion is to argue that, given the underlying biological production function, the role of labor and mechanization is to create a more favorable environment than that which occurs naturally for plant growth. They do this by augmenting the availability of nutrients, water, etc, in as timely a manner as possible. It was suggested earlier, however, that different varieties of the same crop have different response functions to the inputs of these basic nutrients. Investment by society in plant breeding to engineer a plant with higher responsiveness to nitrogen, for example, or to breed in disease resistance (such as rust resistance in wheat), or to breed photoperiod sensitivity out of rice, or to develop biological fixation of nitrogen in non-legumes and the like, all serve to shift the biological response surface upwards, thereby raising production per unit of input in the process.

In addition to the input of physical labor, the human factor also provides an important management or coordination role in orchestrating the whole production process. Management skills are required to combine agricultural enterprises to make the most efficient use of a farm's endowment of land and labor. Differences in managerial skills constitute differences in the quality of the labor input.

Education is often used as a broad proxy for the quality of labor. The level of education of the farmer (broadly interpreted to include both formal schooling and vocational training of various kinds) has two basic effects in the production process according to Finis Welch. These include, first, a worker effect, which enables the worker to obtain more output from the same bundle of resources. This is a marginal product in the conventional sense. The second is an allocation effect, by means of which greater output is obtained from an

improved allocation of resources. Viewed from this perspective, the contribution of education is in enabling the worker to acquire and decode new information. This effect of education leads to an increase in output in the same sense that the worker effect does. It gives rise to differences in observed productivity among farmers in the same sense that differences in availability of new production technology gives rise to observed differences in productivity.

In addition to these biological and husbandry production relationships, production economics also postulates the existence of a firm-level production function that relates the physical quantities of input services used to maximum level of production that can be produced with those inputs. In the case of agriculture, each farm firm generally produces more than one product, often by more than one process. As indicated above, there is a coordination activity performed by the farm operator or manager. The comprehensive farm production function then represents an aggregation of partial production functions, including the biological functions, the husbandry functions, and other activities.

Sadan has suggested that if the various parts of the production process are assumed separable, such partial production functions may be aggregated into a comprehensive farm firm production function. Separability implies that the combination of inputs allocated in one activity and the combination of inputs allocated in another activity can be determined independently. In such cases one may estimate an "average" production function for the farm firm directly from cross-section survey data. [1] Studies of this kind are frequently employed to analyze resource productivity or the efficiency of resource allocation in some given group of farms.

The third level at which agricultural production may be investigated is

[1] Aigner and Chu have emphasized that such an "average" production function should not be misconstrued with the firm production function of microeconomic theory, which expresses, for a given state of the arts, the maximum product obtainable by a given firm from a given combination of resources.

at the aggregate (generally regional or national) level. This aggregate function is postulated to reflect the aggregate behavior of all firms in the industry. The aggregate production function should in principle imply the same level of total output for the sector as would be obtained by summing the production functions of the individual firms. While this point may seem esoteric, it is important with respect to productivity calculations because in the absence of some assumptions about the nature of the underlying production function, aggregate productivity calculations are meaningless. 1/

Causes of Observed Differences in Productivity

Differences in productivity may occur either in studying the changes that occur in a given region or country over time, or in comparing one region or country with another at a given point in time. Understanding the sources of these observed differences may be helpful on two counts. First, it will help in interpreting the observed differences in the context of determining whether one country or region is making more progress than another, or whether one country or another has done more for its agriculture. The point here is that differences or changes in productivity may occur for reasons that have little to do with economic policy.

Second, understanding the causes of differences in productivity helps to identify variables that may be used independently of productivity itself as a means of assessing a government's commitment to its agricultural sector. Often changes in these variables may be a more direct measure of the commitment to agriculture, or the changes in this commitment, than a change in productivity. Moreover, some of these variables may be more easily measurable than productivity itself.

1/ More detail on aggregation problems can be found in Theil, Green, and Fisher.

To start with, an analysis of the causes of observed differences in factor productivity (either over time or cross-sectionally at a point in time) requires consideration of the properties of the underlying production function which represents the production technology. Brown (pp. 12-20) has listed four characteristics of technology which are reflected in the technical form of the production function: [1/]

1) the efficiency of the technology, which determines how much output is produced from a given level of inputs;
2) the technologically determined returns to scale, which influences productivity as a function of size of firm;
3) the factor intensity or factor bias of a technology, which influences the proportions in which resources are used and in turn the relative average productivity of the individual factors of production; and
4) the ease with which one input is substituted for another.

A comprehensive analysis of observed changes over time in productivity, or their differences at a point in time, should consider which of these factors accounts for the difference. In practice, data limitations and/or the lack of suitable estimation procedures may limit the extent to which a production function which reflects all of these characteristics can be estimated. However, as will be argued below, consideration of the properties of the underlying production function is also necessary in selecting an appropriate formula for calculating indices of productivity.

In addition to these formal characteristics of the production function, there are other plausible explanations for observed differences in factor productivity. For example, differences in relative factor and product prices tend

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[1/] This discussion of the production function draws upon Nadiri (1970). It should be noted that Nadiri lists a fifth characteristic as being important - the homotheticity of the production function, or how input proportions are related to each other as output expands (p. 1141).

to result in differences in relative factor proportions and in the scale of operation. Anything which affects these relative prices will tend to affect the proportions in which resources are used and in turn the observed measures of productivity. For example, product price frequently varies inversely with the distance from market. This phenomenon results in more intensive production close to market, and hence higher levels of productivity. Marginal and average productivities of certain resources may then be expected to vary with distance to market (Moses, Nourse).

Differences in relative factor endowments among regions may result in differences in relative factor prices and therefore in different factor proportions. In a region where the relative price of labor was low compared to another region, we would expect to find a higher productivity of land since the price ratios would cause there to be more labor used relative to the land. Similarly, where the relative price of labor was high, the productivity of land would be relatively lower, since there would be less labor used relative to land, other things being constant.

A similar phenomenon often occurs when comparing resource productivity among farms of different sizes. For various reasons small farms may face a different set of factor price ratios than do large farms. The consequence is that they use their resources in different proportions, typically with the result that small farms will have a higher land productivity than large farms, while the large farms will typically have a higher labor productivity. 1/

The subtleties of these relationships should not be neglected. In the first place, when making cross-country comparisons, a high relative price for labor suggests a relatively more advanced level of development. Consequently, to the

1/ For a careful discussion of these issues, see Berry.

extent that comparisons among countries or within a country over time rest solely on changes in land productivity, they can be quite misleading. Similarly, the productivity of land may fail to rise over time in an individual country for the simple reason that the country is making progress in its development efforts and consequently the price of labor is rising, thereby inducing a shift in factor proportions.

In the second place, discussions of the changes in productivity as a result of changes in factor proportions often assume that the level of technology is constant. In practice there may be a change in the production technology associated with the changes in resource proportions. If this is the case, the productivity of all resources may rise, even though resource proportions are changing substantially.

There are also general equilibrium effects that must be taken account of in attempting to understand observed differences or changes in productivity. When large numbers of farmers change their production plans in response to changing price relatives or the general introduction of new production technology, at least some product and factor prices may be expected to undergo further changes. For example, except where there exist trade opportunities, agriculture confronts an inelastic demand, or one that is not very responsive to changes in price. If through technological change the supply of agricultural output increases more rapidly than the demand, the product price will decline, and in general will decline relatively more than the increase in output. Unless resources (especially labor) are especially mobile between the farm and nonfarm sectors, incomes of farm people can decline relative to those in the nonfarm sector at the very time that the greatest progress is being made in modernizing the agricultural sector. [1/] This

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[1/] Under these conditions the employment problem may become quite severe. Equally as important, the potential for solving it within the agricultural sector will be fairly limited, as will be noted below.

points up an important contradiction that often exists in development policy. Measures taken to increase agricultural output, which are beneficial for the economy as a whole, may actually cause the relative income position of rural people to worsen. Hence, in assessing agricultural progress it is important to specify the relative weights attached to output expansion versus the improvement in the welfare of rural people. Moreover, if policy-makers attach considerable weight to improving the welfare of rural people, the income indicator discussed in an earlier section takes on added importance.

There are also potentially important interactions between these general market effects and the nature of the production technology introduced into the agricultural sector. For example, it is often suggested that technology be introduced which increases the employment of labor in agriculture. However, even if there is success in that effort, in the sense that the resource proportions are shifted in the direction of using relatively more labor, the output-market effect, which can be negative, may more than offset the direct (positive) employment effect. The determining parameter, of course, will be the price elasticity of demand. If this elasticity is low, the (negative) price effect from productivity gains can be large. Unfortunately, the price elasticity of demand is often low for the subsistence food items, the very crops for which productivity gains are often important in order to measure food consumption. Crops with export potential, on the other hand, tend to have a higher price elasticity of demand and therefore offer greater employment potential.

Conditions in the factor markets can also cause these market effects to alter the relative proportions in which resources are used. Resources that are relatively inelastic in supply will suffer larger relative changes in prices in response to changing conditions in the product market, other things being equal.

The changes in factor proportions that result can induce changes in the observed indices of productivity.

Another possible explanation for observed differences in productivity is that the tenure system under which production is organized may affect the price perceived by the resource allocation decision-maker. Heady (1971), for example, argues that this may be the case for sharecropping, with the result that a predominance of sharecropping would cause productivity to be lower in relation to a system in which owner-operators prevailed. This is consistent with the commonly held view that share tenency is inefficient, as are leases of relatively short duration.

Cheung, however, has shown that both theoretically and empirically the ineffficiency argument is often illusory. He shows that the implied resource allocation under private property rights is the same whether the landowner cultivates the land himself, hires farm hands to do the tilling, leases his holding on a fixed rent basis, or shares the actual yield with his tenant. All that is required for this result is that the contractual arrangements themselves be aspects of the private property rights. Hence, whether tenure arrangements affect productivity or not depends on whether market forces can influence the tenure arrangements, and whether the government intervenes to fix these arrangements.

All of the factors discussed in this section may affect the factor-factor and/or factor-product price relatives, and thereby affect the optimum proportions in which inputs are used and the scale of production. They would in turn be reflected in measures of productivity.

Productivity differences may also be associated with failures in optimization on the part of the entrepreneur. A firm's decision maker has two optimization

problems. The first concerns combining inputs in such fashion that he operates on the production function, which in turn defines the maximum output attainable from given levels of a set of factors. Anything less than that maximum represents technical inefficiency. The second problem is to maximize profit by employing each input up to the point where the value of its marginal product equals its price. The degree to which the entrepreneur succeeds in doing this is referred to as price efficiency. The two types of efficiency together make up the economic efficiency of the firm (Farrell, Nerlove, Timmer, Yotopoulos).

Differences in economic efficiency may also contribute to observed productivity differences. This becomes empirically relevant when one compares a region with a feudal social structure, where optimization motives are not expected to prevail, with a region in which a capitalistic system predominates and entrepreneurs are expected to be optimizers.

In some instances, of course, observed productivity differences may be more apparent than real. Productivity differences may appear to exist if one takes as homogenous different qualities of land, or of labor, or different vintages of capital, and lumps them together without "correcting" for quality differences (Griliches (1960), Griliches and Jorgenson). Such "measurement" errors must be guarded against and corrected for whenever possible in the analysis of productivity, or the resulting indicators will be meaningless.

These measurement problems are related to the earlier discussion of whether there are changes or differences in the quality of inputs, and whether all inputs are considered in the calculation of the indices of resource productivity. Society may be attempting to improve its agricultural sector by investing in nonconventional inputs such as agricultural research and the education of its rural people. Such investments may not be picked up in the measurement of output and inputs, especially

if the latter are measured from farm survey data. If they are not, there will be observed changes or differences in productivity. If they are, there may be little or no change in observed productivity, especially if the emphasis is on an index of total factor productivity.

As noted earlier, the analysis can proceed in either of two directions. One approach is to ignore these nonconventional inputs. Changes in observed total factor productivity may then reflect progress in the agricultural sector. Alternatively, these inputs may be included in the productivity accounting, and then progress will have to be measured by indices of whatever factors are at work in the sector - new varieties, fertilizers, education, etc.

In conjunction with observed resource-saving biases in technological change, it is important to recognize the possibility of factor intensity reversals. If a factor intensity reversal occurs, agriculture will be labor-intensive relative to industry at low wage/rental ratios, for example, while at high/wage rental ratios agriculture will be relatively capital intensive. Naya has provided empirical evidence that rice production at low wage/rental ratios in Asia is in fact labor-intensive relative to industry, while in the U.S., it is relatively capital-intensive. Agriculture as a whole in the United States is capital-intensive relative to industry, although for individual products it is relatively more labor intensive. To the extent that such reversals exist, they reinforce the argument made elsewhere in this paper concerning the need to move labor out of agriculture as development proceeds, and focus attention on the importance of employment and labor market policies. Similarly, the possibility of such reversals goes against the suggestion by Congress that agricultural development in low income countries should invariably follow a labor-intensive, small-farm approach.

There are at least two possible explanations for this observed phenomenon.

One is that relative factor proportions are inherently more rigid or fixed in industry than in agriculture. That is, the elasticity of substitution between capital and labor is higher in agriculture than in industry. An alternative explanation is that there is a stronger scarce factor-saving inducement mechanism in agricultural than in industrial research, so that the production technology for agriculture adapts more quickly to changes in the relative factor endowment.

A great deal of attention has been given recently to the possibilities of developing intermediate technologies for the industrial sector in developing countries. However, the evidence to date is not particularly convincing with respect to making industrial processes more labor-intensive, although greater labor intensity is often observed in peripheral tasks such as product packaging and moving. Even if the elasticity of substitution between capital and labor is inherently lower in industry than in agriculture, however, the cost mimimizing capital/labor ratio in every industry is not necessarily the same. This provides an opportunity for countries with the greatest labor absorption problems to focus their industrial growth efforts on those industries which tend to be inherently more labor-intensive. [1/]

If there is economic development in a given country, there will be a tendency for per capita incomes and therefore wage rates to rise over time. The above argument suggests that under these circumstances the capital-intensity of agriculture will tend to rise faster than that of the industrial sector. As long as the country remains relatively labor abundant so that the wage rate (or in particular the shadow wage rate) is low relative to the (shadow) rental price of capital, however, it is expected that agriculture will tend to be labor-intensive

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[1/] It should also be emphasized that certain agricultural activities are inherently more labor intensive than others. For example, animal husbandry (in particular, dairy cattle) and fruit and vegetable production tend to be more labor intensive than field crop production at the same wage-rental ratios.

relative to industry.

If the agricultural wage is also low relative to the rental price of land, we should also expect to find low land/labor ratios. When the industrial wage rate begins to rise as development proceeds, we expect the agricultural wage to begin to rise as well, unless the labor market is completely segmented. This will stimulate the substitution of capital for labor, raising the marginal and average product of labor, and inducing a transfer of labor out of agriculture. The exit of labor (and its absorption by the non-agricultural sector) becomes a necessary condition for raising rural per capita incomes. 1/ The extent to which labor will have to be transferred, however, will depend on the rate of technical change within agriculture, the extent to which that technical change increases or decreases labor requirements relative to the requirements of other resources, and the conditions of demand for the product. These factors were each discussed above.

As argued previously, the level of investments in human capital, including education and health, may affect the ability and speed of farmers to "decode" and adopt new technology (Becker (1964), Welch). This would affect measured productivity of conventional inputs in the same fashion as research and extension. But differences in human capital are also associated with differences in the quality of labor. Therefore, human capital may affect the productivity of labor independently of that of other factors.

Levels of investment in infra-structure, including roads and communications facilities, may also affect the rate of diffusion of new technology, and therefore also have an effect similar to that of extension. But, such investments may also

1/ To the extent that jobs exist or may be created in the nonagricultural sector in the same geographic area, this exit of labor from agriculture need not involve a physical relocation or move of the family out of the area.

affect price levels and, through this mechanism, the levels of factor use and productivity.

In studying the sources of productivity growth in American agriculture, Griliches found that education, research, and extension could explain much of the large "unexplainable" increase in output that could not be attributed to changes in traditional inputs (1963b, 1964). By including nonconventional inputs such as research, extension, and education in the production function, and correcting for quality changes in the conventional inputs, he transformed what was at that time a catch-all residual of unexplained productivity growth into movements along a more general production function and into identifiable changes in the quality of inputs.

Hayami and Ruttan used a similar approach to study the large productivity differences which exist among countries (1970a, 1970b, 1971). This study suggested three principal sources of productivity differences among countries: (1) resource endowments, (2) technology, as embodied in fixed or working capital, and (3) human capital, broadly conceived to include the education, skill, knowledge, and capacity embodied in a country's population. These three classes of variables together explain 95 percent of the observed differences in agricultural productivity among the 43 countries studied. The three classes of variables were about equally important in the explanation (1970a, pp. 895-6; 1971, p. 101).

These studies provide a source of hypotheses to explain interregional or intertemporal differences in productivity in agriculture, and should sensitize the reader to possible methodological problems. A maintained hypothesis is that one aggregate production function can represent the agricultural sector of a country, and that regional or intertemporal differences in the levels of the

respective inputs can explain most of the variation in output. If most of the disparities can be accounted for by differences in resource endowments or accumulation, this supports the application of resource accumulation models of economic development, as contrasted to institutional-constraint models. Depending on the relative contribution of individual variables, insights may be gained as to whether resources should be accumulated in conventional resources such as land and labor, or in nonconventional inputs such as education and other forms of human capital.

The inclusion of each variable in an aggregate production function is based on a hypothesis that that resource has a significant role in the generation of agricultural output. In an aggregate agricultural production function the value of gross agricultural output should be made a function of at least the land area in production, the labor force economically active in agriculture, the capital stock represented by the livestock herd, fertilizer use and the stock of machinery as proxies for the whole range of modern biological and mechanical technologies, the mean educational level of the rural sector as a proxy for human capital accumulation, and the number of agricultural and veterinary graduates occupied in agricultural research and extension.

Further implications of this aggregate production function approach to the development of alternative indices for measuring agricultural progress and the commitment to agriculture will be drawn in Part II. Alternative indices that can be used to measure changes in agricultural productivity in its own right are discussed in Appendix A, and suggestions on the specification and measurement of inputs and output for the measurement of productivity are presented in Appendix B.

Indicators Related to Productivity

Research such as that discussed above has advanced our knowledge of the sources of agricultural growth to the point where we can use measurements of the causes or sources of output growth to assess agricultural progress rather than the ex post consequence of such progress as reflected in changes or progress in productivity. One such important cause of productivity growth is investment in agricultural research. Such investments are fundamental to obtaining growth in productivity, and have also been found to have a high rate of payoff to society. Moreover, given the location specificity of agricultural production technology, most countries have to undertake such research on their own account. In general there are rather severe limits on the extent to which production technology can be borrowed from other regions or countries.

A direct measure of a government's attention to agricultural research would be the investment it makes through the public sector in research and extension. If cross-country comparisons are to be made, these expenditures need to be standardized by expressing them as a proportion of total agricultural output, or by expressing them in terms of expenditures per member of the farm population. If comparisons are made over time for a given country, a correction should be made for inflation or the change in the price level.

Given the costs of maintaining research and extension staffs varies from country to country, depending on the level of development, a "physical" measure of the research and extension input can be made by estimating the man-years of input directed to such activities. Ideally, these estimates would be adjusted for the level of training embedded in the staff. It is also useful to express the estimates as a ratio to agricultural output, or in relation to the farm population.

Other indicators of the research process may be available. These include the number of improved varieties that are released, the extent to which improved varieties are adopted, etc. Care should be taken when using such indicators that they actually represent improvements, and not just changes, however. Criteria for deciding whether a new variety represents an improvement includes such things as whether it has the potential for producing higher yields, whether it is more disease resistant, whether it is more resistant to climatic perturbations, or whether it has a shorter growing season, thereby permitting double cropping, for example.

Successful agricultural development efforts generally involve the introduction of modern inputs, or inputs produced in the nonfarm sector, into the production process. Hence, data on the use of commercial fertilizers, or mechanical inputs, and on pesticides and herbicides can often be used as indicators of agricultural progress. Ideally, these will also be expressed on some standardized basis in order to facilitate comparisons. Some caution is required in the use of such indicators since economic conditions may not be appropriate for their use. For example, undiscriminating mechanization in the presence of a serious employment problem may reflect bad economic policy rather than agricultural progress. The same applies to the use of herbicides under certain circumstances.

Finally, the educational attainment of the agricultural population and labor force may be a good measure of the efforts of the government to modernize its agricultural sector and improve the lot of its rural people. Formal education and vocational training are important elements in obtaining a more rapid diffusion of production technology in the agricultural sector. It is also an important means of facilitating the transfer of the agricultural labor force to nonfarm employment, and hence of raising the incomes of farm people.

Education can be measured in a number of different ways. Total expenditures on education and training is one index that is often available from government budget data. Less frequently available, but in some cases more pertinent, are data such as literacy rates, average years of schooling, number of educational opportunities created, numbers of people given vocational skills, or class attendance in vocational programs.

Choice of an Indicator of Agricultural Progress

A rather wide range of indicators has been discussed to this point that can serve as a measure or measures of the progress that is occurring in agriculture and the commitments that governments have made to their agricultural sector. These indicators have included changes in gross agricultural output, changes in the per capita income of farm people, changes in the average productivity of individual input categories such as land and labor, changes in an index of total factor productivity, and changes in indices of variables known to be generally associated with progress and modernization such as expenditures on research, extension, and education, the production and diffusion of improved varieties and techniques of production, and the adoption of modern inputs such as fertilizers, mechanical inputs, pesticides and herbicides.

This wide range of possible indicators implies a problem of choice. Congress, of course, suggested that the productivity of land be used in assessing the commitment and progress of countries in meeting the objectives of improving the welfare of the rural poor in low income countries. Our analysis suggests that other indicators might be used, and that under certain circumstances other indicators might be more desirable. We now turn to a consideration of the factors involved in making a choice.

To anticipate our conclusions, we shall argue that to limit the indicator to

a consideration of land productivity alone would be inappropriate and in some cases lead to wrong policy conclusions. Our analysis suggests that there is value in an eclectic approach to assessing agricultural progress, in contrast to resting the evaluation on one indicator alone. The choice of indicator in the individual instance depends on the goals and objectives of policy makers, the economic environment, and the availability of data. Each of these will differ among countries, and within an individual country they will change over time.

Ideally, we believe there is considerable merit in measuring progress by an index that measures the change over time in total factor productivity within the sector, or an index of output over total inputs. If lack of data preclude such a choice and resort has to be made to a partial measure of productivity such as land or labor productivity, we would opt for an index of labor productivity under most circumstances. Both the indices of partial productivity and total factor productivity can be usefully complemented with data on changes in output and in the use of modern inputs. Data on the trend in per capita income of farm people would indicate the extent to which people in the agricultural sector are benefitting from whatever progress is being realized in the sector. Considerable progress can be made, of course, with the bulk of the benefits transferred to those outside the sector rather than inside it.

The advantage of using an index of total factor productivity is that under certain rather general conditions it can be interpreted as a proxy for the rate of technical change that is taking place within the sector. Under certain circumstances an increase in output by almost any means will be an important policy goal, and in these cases an increase in output alone can serve as an appropriate measure of "progress". But more generally, progress refers to the modernization

of the agricultural sector, with modernization assumed to be highly correlated with technical change.

Technological progress is desirable because it has been shown to be an important means of increasing the output from a given stock of resources. Moreover, in Professor Schultz's framework it is an important means of raising the rate of return to capital, thereby increasing both savings rates and investment rates, and it increases the incentive price to labor. To the extent that progress in agriculture is associated with technical change, the desired indicator would be one that would reflect technological progress. For reasons elaborated above, an index of total factor productivity more generally measures this than does an index of either land or labor productivity.

If data are not available to estimate an index of total factor productivity, then one logically turns to a partial measure of productivity such as the average productivity of land or labor. Our view is that the indicator suggested by Congress, the productivity of land, is too restrictive in scope, and that under some circumstances it can lead to misguided policy recommendations. Moreover, we shall argue that if a single partial measure of productivity is to be used, the growth in <u>labor</u> productivity or <u>production per person employed in agriculture</u> is a more appropriate measure of agricultural progress than is the growth in land productivity.

There are a number of reasons for our position. The first is rooted in the objectives or reasons for desiring agricultural progress or development. One such objective is to increase the per capita output of food compared to some base period. If efficiency considerations were ignored, one would be indifferent between whether the increase in output were obtained by means of an increase in labor productivity, an increase in land productivity, or an increase in output per standardized unit

of all inputs used in agriculture.

However, a second objective of agricultural progress or development is to obtain an increase in the income or well-being of rural people. Raising the productivity of rural people is an important aspect of raising their income. Hence, to the extent that we are concerned with alleviating rural poverty, priority should be given to raising labor productivity. As will be shown below, raising the productivity of land is one means of doing that under certain circumstances. But to focus entirely on that indicator can result in a neglect of other important policy measures, and in some cases can in fact be counter-productive.

Another reason for focusing on labor productivity is that it provides a proximate indicator of the extent to which agricultural progress and development is contributing to the more general development of the economy. Agriculture contributes to the development of the nonfarm sector by producing a "surplus" above the consumption within the sector. [1] To the extent it does, it provides growing food supplies for the urban population and under certain circumstances a "surplus" for export.

Given these reasons for desiring to focus on labor productivity, perspective can be obtained on the relationship between land and labor productivity by means of an accounting identity that relates one to the other. The relationship can be expressed formally as

$$\frac{Q}{N} = \frac{Q}{A} \cdot \frac{A}{N}$$

where Q is the quantity of food or agricultural output produced, N is the man-years of labor employed or used in agriculture, and A is the area of land in

[1] The "surplus" referred to here is not that which accumulates in government hands when prices are set above market clearing levels. Rather, it is the amount which is available for consumption and use outside the agricultural sector. (Nicholls).

production. Thus, labor productivity is the product of output per unit of land (or land productivity) and the land/man ratio. Labor productivity can be increased by increasing land productivity, or by increasing the land/man ratio, or by some combination of the two.

To increase either ratio generally involves an increase in the use of non-traditional inputs purchased from the nonfarm sector and which embody improved agricultural technology. However, the particular technological package which is involved in each case is quite different. This implies a problem of choice, and if progress and development are to be efficient, the choice must be conditioned by the relative price of the factors of production or the conditions prevailing in the input markets. To choose the wrong path can lead to a slower growth rate over time.

The most efficient path for a country to choose is that which uses relatively more intensively those resources which are relatively more abundant, and to economize on or use sparingly those inputs that are relatively more scarce. general, relative resource scarcity will differ among countries. Some countries will have more land relative to labor, while for others the reverse will be true. To focus only on increasing land productivity as a means of raising labor productivity is to neglect these important differences in economic conditions among countries, and consequently to make erroneous policy recommendations.

Technological innovation should in general be directed to facilitating the substitution of relatively abundant resources for relatively scarce resources. In this way it will ease the constraints to output growth, and do it in an efficient manner.

Agricultural technologies can be classified into two general types that provide a means of understanding this instrumental role that technical change can

play in the development process. On the one hand, there are mechanical or labor-saving innovations which facilitate the substitution of power and machinery for labor. Such innovations are often relevant in countries where land is abundant relative to labor, such as in some parts of Africa and Latin America. Under these conditions labor productivity can be increased by increasing the land/man ratio.

On the other hand, there are biological and chemical innovations that are land-saving in the sense that their primary direct impact is in raising the productivity of land. [1] Such innovations include improved varieties of plants, commercial (inorganic) fertilizers, and pesticides. These innovations or modern inputs tend to be more relevant when land is scarce relative to labor, or when there are low land/man ratios, such as in large parts of Asia. Under these circumstances labor productivity can be raised by increasing the productivity of land.

This classification of the types of agricultural technologies or innovations shows the extent to which there is a problem of choice in deciding how to modernize and develop an agricultural sector, and how limiting the choice of a productivity indicator to land productivity can result in a failure to focus on the correct policy variable, thereby leading to an inefficient or slow growth process. The two classic examples of countries that have followed quite divergent paths to the modernization of their agricultural sectors are Japan and the U.S. [2] Japan historically was the epitomy of a land scarce, densely populated country. Hence,

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[1] Not all biological or chemical innovations are land-saving, of course. For example, herbicides tend to be strongly labor-saving. By the same token, some mechanical innovations can be land-saving by increasing land productivity and by permitting double cropping through more timely operations. If these caveats are kept in mind, the view of mechanical innovations as generally labor saving and biological and chemical innovations as generally land saving can be a useful way of thinking about the agricultural development process.

[2] The development of the agriculture in these two "success stories" has been carefully analyzed by Hayami and Ruttan (1971). The concepts of technological change and the underlying theory outlined above are taken from their important book.

early in its modernization process it concentrated on raising land productivity by the adoption of improved crop varieties and the intensive use of fertilizers. The United States, on the other hand, was well endowed with land but had a labor scarce economy. Consequently, it concentrated on mechanization in order to economize on labor and to ease the constraint to output expansion imposed by a limited supply of labor. Both countries are outstanding examples of successful modernization, but they did it by quite different means.

More recent development experience in both countries shows how important the technological choice can be, and how it can change over time. The closing of the frontier in the U.S. gave impetus to raising land productivity. Hence, a gradual process of plant improvement and the expanded use of fertilizers began. Further impetus to this process was given after World War II by two successive technological breakthroughs in the fertilizer industry which lowered the price of fertilizer relative to land. Increasing use of fertilizer therefore sustained a rise in the productivity of land, which in the absence of these breakthoughs might have declined due to the rapid increase in the land/man ratio as a result of out-migration from agriculture.

The recent experience of Japan has been just the opposite. Rapid and sustained industrialization induced a rapid outmigration from agriculture and a rise in the land/man ratio. Mechanization was then induced in order to permit and facilitate the increase in the land/man ratio - an important source of increasing labor productivity in Japanese agriculture.

The important point to note from this discussion is that there is no easy classification of countries into those in which land or labor is the prevailing constraint to output expansion. In large countries such as Brazil, the requirement may be to ease a labor constraint in one region, such as the Central West

or the South, while it may be to ease a land constraint in another region, such as the East and the Northeast.

Similarly, there are important interactions between the two components of productivity growth. For example, Project Pueblo in Mexico is an intensive rural development project based on the diffusion of land augmenting biological and chemical fertilizers among the farmers. The small size of the farms (approximately 2.5 hectares) and the high population density in the project region make it appear on the surface that land is limiting and that the goals of development policy should be to raise land productivity. However, research at Purdue University (Villa-Issa) suggests that a scarcity of labor is imposing a constraint to the adoption of the new technology, and that simple or small scale mechanization could facilitate the adoption of the biological technology which would raise the productivity of land. The point is that the population in the region has access to a rather active off-farm labor market, contrary to what casual observation might suggest, and participates actively in this labor market. Since the use of fertilizer and the other cultural practices which would raise the productivity of land also increase labor requirements, the farmers who work off the farm tend not to adopt these practices. Emphasis on land productivity will cause a neglect of this important aspect of the development process, and as in the case of Project Puebla, lead in turn to disappointment and frustration.

Uma Lele has found similar problems in her evaluation of agricultural development projects in Africa (Lele (1975), especially Chapter II). She found that "compared to Asia, labor availability in Africa is frequently a greater constraint to increasing agricultural productivity than is the availability of land" (p. 23). As a result, she argues that technological innovations which

require intense labor input (i.e., the kind often viewed as desirable because of its supposed employment generating effects), often may not result in the full realization of potential production increases. At the same time, however, she argues that there is some prima facie evidence of surplus labor in African agriculture. Thus there is the seeming paradox of a farm labor shortage combined with an apparent labor surplus. The explanation in this case lies in the seasonality of labor usage, in the allotment of time between farm work, nonfarm work, and leisure, and in the division of labor between the sexes. Whatever the explanation, an emphasis on land productivity alone would cause policy makers to neglect the importance of raising labor productivity under certain circumstances, and therefore to fail to fully realize the potential of their development policies.

To summarize, under rather general conditions it may be as important or more important to raise the productivity of labor as it is to raise the productivity of land if the goal is to increase agricultural output in an efficient manner. Moreover, an increase in the productivity of land may not be translated into an increase in the productivity of labor. Hence, to focus on land productivity alone may lead to wrong signals to policy makers. Given that part of the concern with rural development is a result of a desire to raise the incomes of rural people, a case can be made for concentrating instead on labor productivity, since the income of rural people is determined primarily through their role as laborers rather than as a return to land. In addition, labor productivity is the key to determining how much of a production surplus is available for release to the nonfarm sector or as exports. With the emphasis on labor productivity, there is a relationship between it and the productivity of land and the land/man ratio. This relationship enables the policy maker

to focus on the alternative ways that technical change can ease the constraints to output expansion, and puts the goal of raising land productivity in perspective with other means that can be used to raise labor productivity.

This conceptualization of the problem, of course, puts the emphasis on efficiency considerations and implicitly assumes that the labor market is efficient and functioning. If the labor market is not performing efficiently because of government intervention or whatever, it would be possible to raise the productivity of those employed (the variable we used above), without raising the average productivity of the total agricultural population. In fact, if the agricultural labor market were segmented and effectively isolated from the nonfarm labor market, as it often is, an increase in the productivity of those employed would worsen the distribution problem within the agricultural sector, since it might create additional unemployed. This brings the equity problem to the fore.

One way to gain perspective on this problem is through another accounting identity:

$$\frac{Q}{L} = \frac{Q}{N} \cdot \frac{N}{L}$$

where Q and N are defined as before and L refers to the rural population rather than the labor force actually employed. Hence, the left hand variable refers to the average productivity of the rural population and not the productivity of those employed, and is a product of the labor productivity of those employed and the labor force participation rate. Under certain circumstances we might be interested in the average productivity of the rural population rather than just those employed, and this accounting identity indicates how an increase in the productivity of those employed could be completely offset, or more, by a compensating change in the labor force participation rate.

This view of the problem brings the importance of employment and labor market policies to the fore. In general such policies would tend to focus on raising labor force participation rates, $\frac{N}{L}$, thereby broadening the participation in the development process. The advantage of this formulation of the problem is that it focuses on the importance of labor market policies, and makes explicit the respective roles of technical change and employment policies.

This is not to argue that science and technology policy should be oblivious to the employment problem. In fact, it should be noted that if the labor is indeed trapped in agriculture, then there will be no incentive to economize on the use of labor unless the government imposes such incentives artificially, and the tendency would be to raise land productivity. By the same token, labor market problems should be addressed as such. The failure to deal with these problems can condemn those in the rural sector to perpetual poverty. Although attention is often focused on the distribution problem <u>within</u> the agricultural sector, more generally the fundamental equity problem is the imbalance between per capita incomes in the rural and urban sectors.

Our emphasis on labor productivity logically raises the question of when an index of land productivity would be an appropriate indicator of agricultural progress. The answer can be found in the above formulation. If land is limited or relatively more scarce than labor, then an index of land productivity may be an appropriate indicator of agricultural progress. But it should be kept in mind that land may be the relatively more scarce resource only because labor market policies have trapped labor in agriculture. Moreover, an observed increase in the productivity of land may occur only because the man/land ratio is rising. In this case the marginal product of labor will be declining, and with it the wage or salary of rural workers.

If the productivity of land is rising because of the adoption of new production technology, this may not be the case. The problem, of course, is that the index of land productivity alone cannot separate these two cases. For this reason we are reluctant to accept or recommend this index as the sole indicator of agricultural progress. An index of labor productivity carries more policy information if only one index is to be used. Ideally, of course, an index of total factor productivity would be the best indicator of progress, since if appropriately measured it would provide an index of technical change in the sector, and that is what progress and modernization is all about.

PART II. THE COMMITMENT TO AGRICULTURAL DEVELOPMENT

Most of the measures of agricultural progress discussed in the previous part of this paper have the disadvantage of being ex post indicators of change. Although useful for some purposes, changes in such ex post indicators may suffer a sizeable lag from the time the government actually changes its policy, and hence will be less useful as a measure of commitment or policy. For example, if the appropriate commitment is assumed to be investments in agricultural research, there is strong evidence to indicate that there is something like a 5-7 year lag between increased expenditures on research and an eventual increase in output (Evenson, 1971). In countries where a capability for agricultural research has to be built, or considerable strengthening of the system is required before a payoff is forthcoming, the lag could be even greater. To focus only on observed changes in productivity could therefore be quite unfair to countries that were taking important steps in the right direction.

Equally as important, the view that governments take toward their agriculture may be represented in forms other than what could be easily detected by changes in productivity, even under the best of circumstances. For example, even though

productivity may be growing, policy makers may place price ceilings on food and agricultural products, or discriminate against the agricultural sector by means of export quotas and export taxes (Schuh, 1975). Perhaps even more importantly, governments discriminate severely against their agricultural sector by means of implicit taxes, such as an over-valued exchange rate, a differential tariff structure, and other differentials in policy variables - many often associated with import-substituting industrialization.

For these reasons we turn in this section to a discussion of what we choose to call ex ante measures of the commitment of governments to their agricultural sector. We discuss (1) the budget commitment to agriculture, (2) the share of external resources that are channeled to agriculture, (3) the share of public-sector credit going to agriculture (and the terms on which it is extended), and (4) the stance of economic policy.

Budget Commitment to Agriculture

Two aspects of the budget commitment to agriculture are important: (1) the quantity of resources, and (2) the quality or composition of the investments. There is no hard and fast rule for what fraction of public investments or consumption should be directed to agriculture. It will depend a great deal on the particular stage of development of the country, and on the particular constellation of problems that the country faces. However, the budget commitment to agriculture, or changes in the budget commitment, can be an important leading indicator of a government's attitude towards its agricultural sector.

The "quality" of the government expenditures is almost as important as the quantity of expenditures. There are a number of different dimensions to the quality of government expenditures. In the first place, there is the question of whether the expenditures are on longer-term investments, or whether it comes under

the rubric of government consumption. For example, the government might be making large expenditures for the acquisition of agricultural products for distribution in school lunch or welfare programs. This will have a quite different effect on the agricultural sector than if the same amount of expdenditures were made on agricultural research. Similarly, expenditures on a government bureacracy can have a quite different effect than expenditures on an irrigation project.

At a different level, government investments in their own right can differ a great deal in their "quality". There is a growing consensus that the high pay-off investments for agricultural development are those that have to do with non-conventional capital - research, extension, and education. However, one should not be dogmatic on this. The sequencing of agricultural investments may be as important as their particular make-up at a given point in time. For example, it makes little sense to invest in raising agricultural productivity if there are no roads to haul the produce to markets. Neither is it rational to invest in agricultural extension if there is no research capability.

The problem of sequencing and relevance of investments means that an evaluation of the quality or composition of investments can be made only in the context of a sound diagnostic of the investment needs of the sector. To the extent such diagnostics are required as a regular part of external investment decisions, this does not impose any extra burdens. It is important, however, that the diagnostic be sound.

Measuring the budget commitment to a sector such as agriculture is not an easy task. Resources that contribute to agricultural development often come from Ministries other than agriculture. Roads, for example, are often financed through the Ministry of Interior or Public Works, as are irrigation projects and other

physical infrastructure. The investments in rural education, or even in research and technology, may be financed through the Ministry of Education. And subsidies and taxes may be implemented through the Ministry of Commerce, as for example when marketing boards are subordinated in this ministry, or the control and allocation of exchange confiscation is centered here.

This caveat on measurement does not mean that the task is impossible. It does mean that the subtleties of budget-making do have to be appreciated, and the attempt made to identify and separate the particular component of a larger budget that goes to agriculture.

Share of External Resources

The use made of resources obtained through foreign aid is also a good indication of a country's commitment to its agricultural sector. Many of the same comments made with respect to the domestic budget apply here. There are both quantitative and qualitative dimensions to the problem, and an evaluation of the appropriateness of the use made of the resources must be made in the context of the problems faced by the agricultural sector, and with an eye to the appropriate sequencing of investments. However, countries that are willing to borrow abroad, even on concessional terms, to train people and to build an agricultural research capability must be given high marks for their commitment to agriculture. Such investments can be expected to have a high payoff in the future.

Share of Public Credit

Many countries establish special public banks for development purposes. Some of these are designed to deal with special regional development problems (such as the Northeast of Brazil), while others have a sectoral focus. The willingness of a government to establish and sustain specialized banks or credit

facilities for agriculture is a measure of their commitment to agriculture. More generally, the share of public credit extended to agriculture is an index of commitment, as is the terms on which that credit is extended.

The terms on which credit is extended to agriculture have a number of different dimensions. Some countries extend such credit at high negative real rates of interest as a logical consequence of rates of inflation that are greater than the nominal interest rate. Although overtly this appears as a subsidy to the agricultural sector, the effective consequence may be rather different. At a negative real rate of interest the demand for credit is almost unlimited since the price of credit loses its rationing role. Under these circumstances the credit will often be allocated to friends and relatives of the banker. At one level, these may not be the people best able to use the credit productively within agriculture. Often such credit goes only to large producers, and not to small producers who might be able to make better use of it. At another level, the credit may do little more than displace internally generated funds, with the latter channeled to nonfarm uses.

A second dimension to the terms on which credit is extended has to do with the length of time for which the credit is made available. Many productive investments in agriculture have gestation periods of two to four years. If credit is available only for a crop year, the chance of such investments being made at the appropriate level is less.

Finally, credit may be ear-marked for special purposes. For example, credit may be amply available for mechanization, while not available for terracing or irrigation. Clearly, this can have important income distribution consequences.

The Stance of Economic Policy

Finally, many governments discriminate against their agricultural sector with

economic policy. This discrimination can take many different forms. The more obvious forms of discrimination include cheap food policies, such as price ceilings for urban consumers, and export quotas to keep domestic prices from rising. Export taxes are also fairly overt and easily detected, as are marketing boards that buy at low prices from farmers and sell at high prices on world markets, with the differential transferred to the public treasury.

All such measures constitute a tax on agriculture in one form or another, and constitute strong discrimination against the expansion of output. But there are implicit taxes on agriculture that are equally as important and perhaps more pervasive in their effects on agriculture. For example, development policy often results in shifts in the price relatives of capital and labor. Social welfare and education and training programs are often financed by means of payroll taxes. Such taxes raise the cost of labor to the firm relative to what it would be in the absence of the tax, and cause the firm to reduce its employment of labor.

Similarly, subsidies are often provided for the use of capital so long as its use is consistent with the development goals of the government. If inflation is a part of the economic environment, such subsidies can often result in negative real rates of interest, with the result that the government is in effect paying the firm to use its capital. The combination of low relative prices for capital and high relative prices for labor gives development policy a strong anti-employment bias. Although generally applied primarily in the non-farm sector, such policies act to keep labor dammed up in agriculture and thereby lower the incomes of farm people.

An over-valued exchange rate is another implicit tax, and its incidence is on the export sector. To the extent that agriculture is either an actual or potential export sector, it will bear the burden of such taxes. If the country

is relatively unimportant in world markets, an over-valued exchange rate will cause the domestic price of its exportables to be lower than their true opportunity cost on world markets. An over-valued exchange rate also makes imports cheaper than they otherwise would be, and this often gives foreign agriculture an advantage over the domestic sector, thereby driving domestic prices lower because of "cheap" imports. In fact, a number of observers of the Brazilian scene, for example, have argued that Brazil maintained an over-valued exchange rate for a long period of time primarily in order to keep the cost of living down (e.g., Bergman).

Finally, governments discriminate against their agricultural sector by means of their tariff structure. Import-substituting industrialization policies typically involve high levels of protection for the industrial sector, and zero or negative protection for the agricultural sector. When evaluated in terms of effective protection, the level of protection for the industrial sector can be of the order of 70-90 percent or higher, while that for agriculture may be from zero to 10 percent (Bergman). Even though much of the protection is redundant, it is not difficult to see that the tariff structure can markedly shift the internal terms of trade away from agriculture. This will provide strong disincentives to the modernization and development of the agricultural sector.

To summarize, a number of variables can be used to assess the government's commitment to its agricultural sector. These range from an evaluation of government expenditures on agriculture, to an assessment of the use of foreign assistance and the shares of public credit channeled to agriculture, to the discrimination against agriculture by means of economic policy. In the latter case, discrimination is fairly easily identified and observed when it is in overt or explicit form. Distortions in factor price ratios can also be fairly

easily detected by means of rather straightforward procedures. The discrimination through trade policy, however, requires the use of more complex procedures such as the estimation of the shadow price of foreign exchange and the level of effective protection.

The use of such indicators can often complement either the direct measures of productivity or their proxies. More importantly, they can often serve as leading indicators, and in this sense often are of more value in evaluating policy than the more immediate evaluation of productivity change.

PART III. DATA REQUIREMENTS AND AN ILLUSTRATION

Parts I and II of this document have outlined a number of indicators of progress on agricultural development in low income countries. The data requirements for implementations of many of these are indeed demanding. In choosing an operational indicator the merits of conceptual purity must be weighed against the costs of gathering data and the deficiences if available data.

This part of the paper is divided into three sections. The first section contains a discussion of the raw data available for estimating changes in productivity. This is followed by a brief summary of available estimates of the underlying production function for agriculture. Estimates of the parameters of this production function are required to estimate indices of total factor productivity. Finally, illustrations of particular progress indicators are presented for India and Brazil.

The Raw Data Available for Estimating Agricultural Productivity Indicators

There exist two basic sources of data on annual agricultural production by commodity for effectively all countries of the world. These are maintained by the Food and Agrciultural Organization (FAO) of the United Nations and the U.S. Department of Agriculture (USDA). Both are based primarily upon official

government statistics. The FAO attempts to estimate area and production of major crops and livestock production when no official figures are available from the countries themselves. The USDA also utilizes agricultural attache reports to supplement official data. Some attempt is made to "correct" for known errors or obvious discrepancies. In general these data series are very similar, and the measurement of productivity change is likely to be little affected by the choice of data base.

The FAO data on area, yield and production of each crop, livestock population and production by species and indices total agricultural production by country are published annually in the FAO Production Yearbook. These data are also available on computer tape from the FAO in Rome. Data on seed and feed use of individual crops can be found in FAO's Food Balance Sheet.

The Economic Research Service of the USDA makes available time series data on the area, yield and production of field crops by country from 1950 to date on a computer tape. The list of commodity coverage includes:

Food Grains	Feed Grains	Other
Rice	Corn	Rye
Wheat	Oats	Oilseeds
	Barley	Cotton
	Grain sorghum/millet	

The countries for which these data are available are listed in Table 1. This data tape is available from the Data Services Center, Economic Research Service (ERS), USDA.

A second data set, which is maintained by the Foreign Agricultural Service (FAS), contains basically the same data on area, yield, and production, but also includes data on imports, exports, domestic consumption, and change in stocks, for all countries for which data are available. (There exist rather large gaps in these data series for several low income countries.) This data tape is sold

Table 1

Country Groupings

ERS Grains Data Tape

Developed

UNITED STATES:
Excludes Hawaii, Puerto Rico, and the Virgin Islands

CANADA:
Excludes Newfoundland

EUROPEAN ECONOMIC COMMUNITY:

Denmark	Netherlands	Italy
United Kingdom	Belgium	France
Ireland	Luxembourg	West Germany

REST OF WESTERN EUROPE:

Iceland	Finland	Spain
Sweden	Austria	Portugal
Norway	Switzerland	Greece
		Cyprus

JAPAN

AUSTRALIA/NEW ZEALAND/SOUTH AFRICA:

Australia	New Zealand	South Africa

Centrally Planned

EASTERN EUROPE:

East Germany	Poland	Romania
Czechoslovakia	Yugoslavia	Bulgaria
Hungary	Albania	

SOVIET UNION:

P.R.C./COMMUNIST SOUTH EAST ASIA:

Peoples Republic of China	Outer Mongolia	North Vietnam

Less Developed Countries

LATIN AMERICA/CARIBBEAN:

Mexico	Dominican Republic	Columbia
Guatemala	Leeward-Windward Islands	Venezuela
Belize	Antigua	Guyana
El Salvador	St. Kitts	Surinam
Honduras	Grenada	Ecuador
Nicaragua	Barbados	Peru
Costa Rica	Trinidad-Tobago	Bolivia
Panama	Netherlands Antilles	Chile
British West Indies	Aruba	Brazil
Bermuda	Bonaire	Paraguay
Cuba	Curacao	Uruguay
Jamaica	Guadeloupe	Argentina
Haiti	Martinique	Falkland

NORTH AFRICA/WEST ASIA:

Turkey	Jordan	Afghanistan
Syria	Kuwait	Morocco
Lebanon	Saudi Arabia	Algeria
Iraq	Yemen	Tunistia
Iran	Southern Yemen	Libya
Israel		Egypt

CENTRAL AFRICA:

Fernando Po	French Equitorial Africa	Central African Republic
Cape Verde Islands	Senegal	Gabon
Portuguese Guinea	Mali	Chad
Sao Tome - Principe	Guinea	West Africa
Comoro Islands	Sierra Leone	Upper Volta
Reunion	Ivory Coast	Benin
French North Africa	Ghana	Angola
Sudan	Gambia	Congo - Brazzaville
Spanish Africa	Niger	Liberia
Equitorial Guinea	Togo	Zaire
Cameroon	Kenya	Burundi
Rwanda	Tanzania	French Indian O. Are
Somoli Republic	Mauritius	Botswana
French West Africa	Rhodesia-Nyasaland	Zambia
Ethiopia	Mozambique	Swabiland
Afars-Issas	Malagasy Republic	Malawi
Uganda		Lesotho

SOUTHERN ASIA:

Pakistan	Nepal	Bangladesh
India		Sri Lanka

SOUTH EAST ASIA/PACIFIC ISLANDS:

Burma	Sabah	Taiwan
Thailand	Singapore	New Guinea
South Vietnam	Indonesia	Papua
Indochina	Burnei	West Somoa
Laos	Philippines	New Hebrides
Khmer Republic	Portuguese Timor	Fiji
Sarawak	North Korea	British Pacific Islands
Malaysia	South Korea	New Caledonia
	Hong Kong	

Source: Tape documentation

through the National Technical Information Service of the U.S. Department of Commerce. The grains data have been published in USDA, Foreign Agricultural Service, "Reference Tables on Wheat, Corn and Total Coarse Grains Supply-Distribution for Individual Countries", Foreign Agricultural Circular-Grains, FG9-76 (May 1976), and "Reference Tables on Rice Supply-Distribution for Individual Countries", Foreign Agricultural Circular Rice, FR 1-76 (May 1976).

Indices of agricultural production in foreign countries have been prepared since World War II by both the Economic Research Service, U.S.D.A., and the F.A.O. The F.A.O.'s indices are reported annually in the Production Yearbook, and the ERS's are published in periodic Statistical Bulletins. Expressed on a per capita basis these indices suggest whether the agriculture of a country is keeping up with population growth or not.

The E.R.S. recently revised its country indices of agricultural production. They have been published together with the production of each product (in metric tons) in three E.R. S. Statistical Bulletins:

1. Indices of Agricultural Production in Africa and the Near East, 1956-75, No. 556, July 1976.
2. Indices of Agricultural Production for the Far East and Oceania, Average 1961-65 and Annual 1966-75, No. 555, June 1976.
3. Indices of Agricultural Production for the Western Hemisphere, Excluding the U.S. and Cuba, 1966 through 1975, No. 552, May 1976.

Table 2 summarizes the indices of total agricultural food production for current U.S. aid recipient countries for the decade 1966-75, as reported in these publications.

Since the mid-1950's the USDA has had a special arrangement with the U.S.A.I.D. to prepare annual reports on the volume of agricultural production

Table 2A. Indices of Total Agricultural Production of Aid Recipient Countries with Under $500 Per Capita Annual GNP, 1966 - 1975, 1961 - 65 = 100.

	1975 Per Capita GNP (U.S. $)	1966	1967	1968	1969	1970	1971	1972	1973	1974	Preliminary Estimate 1975
Africa											
Mali	90	101	107	99	117	110	105	91	86	97	97
Rwanda	90	109	134	133	138	147	149	145	152	136	149
Upper Volta	90	98	101	99	97	96	88	86	84	102	100
Burundi	100	112	116	116	120	127	131	130	129	108	127
Ethiopia	100	107	110	114	116	117	119	112	109	113	103
Chad	120				NOT AVAILABLE						
Guinea	130	96	109	119	122	120	124	126	127	127	129
Niger	130	109	120	113	117	117	112	95	71	97	91
Benin	140	99	106	106	106	111	109	113	121	129	132
Zaire	140	114	117	129	137	140	133	134	140	144	142
Malawi	150	136	138	119	129	129	148	160	151	161	175
Tanyania	170	123	110	114	116	120	123	126	124	113	122
Lesotho	180				NOT AVAILABLE						
Malayasy Republic	180	110	117	119	120	127	126	129	122	135	137
Gambia	190				NOT AVAILABLE						
Sierra Leone	200	100	103	107	104	109	117	118	117	120	128
Kenya	220	113	115	118	119	125	123	139	145	148	149
Cent. Africa Republic	230				NOT AVAILABLE						
Togo	270	116	116	132	128	125	123	124	117	124	128
Sudan	290	104	121	111	124	136	140	136	131	139	139
Mauritania	310				NOT AVAILABLE						
Egypt	310	104	101	105	114	113	117	119	119	118	121
Botswania	330				NOT AVAILABLE						
Cameroon	330	109	115	117	117	113	121	120	119	129	128
Nigeria	330	102	97	94	119	113	114	119	113	120	124
Senegal	370	94	116	92	106	78	112	79	95	121	138
Liberia	410	109	113	114	120	135	131	141	149	157	146
Ghana	460	108	112	105	111	108	116	109	115	120	126
Morocco	470	95	104	160	124	128	143	144	119	146	118
Swaziland	470				NOT AVAILABLE						
Congo	500				NOT AVAILABLE						
Ivory Coast	500	105	126	120	136	134	149	151	146	168	176

Table 2A. Continued.

	1975 Per Capita GNP (U.S. $)	1966	1967	1968	1969	1970	1971	1972	1973	1974	Preliminary Estimate 1975
Asia & Near East											
Bhutan	60				NOT AVAILABLE						
Bangladesh	110	99	114	113	121	114	100	101	116	108	120
Nepal	110				NOT AVAILABLE						
Afghanistan	130				NOT AVAILABLE						
Pakistan	140	113	124	139	149	158	156	155	159	163	155
India	150	95	104	111	117	124	127	119	129	122	136
Sri Lanka	150	103	111	110	123	128	122	119	117	122	112
Indonesia	180	110	104	120	121	130	132	129	142	150	158
Yemen, AR.	210				NOT AVAILABLE						
Malta	350				NOT AVAILABLE						
Thailand	350	126	109	121	129	133	141	131	161	159	169
Philippines	370	111	115	117	126	130	137	133	142	146	158
Jordon	460	77	128	78	108	69	107	134	66	166	84
Latin America											
Haiti	180	94	94	89	94	99	100	103	103	104	104
Bolivia	320	107	105	107	115	113	117	121	133	130	128
Honduras	350	117	125	131	127	127	144	138	141	139	105
El Salvador	450	101	109	105	116	117	133	119	131	159	131

Sources: USDA, ERS Statistical Bulletins No. 552, 555, and 556, 1976.

Table 2B. Indices of Total Agricultural Production Aid Recipient Countries with Over $500 Per Capita Annual GNP, 1966-75, 1961-65 = 100.

	1975 Per Capita GNP (U.S. $)	1966	1967	1968	1969	1970	1971	1972	1973	1974	Preliminary Estimate 1975
Africa											
Zambia	540	98	99	75	96	97	103	102	90	94	110
Mauritius	580				NOT AVAILABLE						
Tunisia	760	105	111	144	114	126	77	90	122	105	103
Gabon	2240				NOT AVAILABLE						
Asia & Near East											
Korea, Rep. of	550	122	114	115	131	129	129	136	138	142	157
Syria	660	79	94	87	95	78	83	127	73	124	123
Lebanon	1117	107	135	117	105	115	152	159	150	176	153
Cyprus	1180	111	145	132	140	124	163	156	121	155	128
Portugal	1610										
Greece	2360	114	122	108	109	128	126	132	132	147	149
Singapore	2510				NOT AVAILABLE						
Spain	2700										
Israel	3010	111	128	134	134	138	156	170	179	189	177
Latin America											
Colombia	550	106	111	116	119	121	123	133	134	144	149
Ecuador	550	110	108	110	116	133	133	139	140	141	147
Guyana	560	99	99	98	104	97	104	90	83	114	113
Paraguay	570	100	107	103	108	123	104	108	111	116	119
Guatemala	650	102	113	116	115	121	139	143	151	165	156
Dominican Republic	720	98	98	94	114	119	129	130	132	137	126
Nicaragua	720	118	116	117	109	118	136	130	148	143	147
Chile	760	117	117	123	116	127	128	116	103	116	119
Peru	810	100	101	94	99	105	108	101	104	105	104
Costa Rica	910	117	124	128	141	148	147	158	170	157	171
Brazil	1010	106	112	115	120	121	127	133	131	148	147
Panama	1060	120	124	144	155	147	155	158	143	134	145
Jamaica	1290	108	99	94	88	85	88	90	85	89	86
Uruguay	1330	94	83	97	95	108	89	85	91	100	100

Sources: USDA, ERS Statistical Bulletins No. 552, 555, and 556, 1976.

in most countries which are aid recipients. The country indices presented in Table 2 are calculated by Laspayre's base price-weighted aggregate formula. [1/] Estimated base-period average prices received by farmers, expressed in U.S. dollars per metric ton, are used for weighting. When farm prices were not available, export or wholesale prices adjusted to make them comparable to farm level are employed. These base period prices for each country are also published in the Statistical Reports cited above.

Indices for individual countries are based on statistics from various sources, and are of widely varying reliability. Statistics on livestock products generally tend to be less reliable than data on the output of the principal commercial crops. Periodic commodity reports published by the F.A.S. give data for the most recent years. This source is supplemented by publications of foreign governments and international organizations such as the F.A.O.

Indices include all major cash crops and subsistence crops for which current estimates of production are obtainable for each country. Hay and other crops grown on the farm for feeding are omitted. Output of milk, eggs, poultry meat, honey, skins and wool are included to the extent permitted by the quality of the data. Meat production is estimated in a crude manner in many cases, because livestock herd data tend to be subject to wide margins of error in many developing countries.

The annual indices of total and per capita agricultural and food production are calculated as follows. For each country the production of each commodity is multiplied by its price weight and the resulting aggregates are summed for each year. The total aggregate for a given year is then divided by the average aggregate for the base period (1961-65) to obtain the index number. The per capita

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[1/] See Appendix A for a discussion of certain deficiencies with using a Laspeyre's index.

indices for each country are calculated by dividing the indices of total agricultural production by mid-year population indices. Food production indices are calculated in the same fashion and differ only by the exclusion of inedible commodities, coffee, tea, and spices.

To avoid double counting of livestock products and feed in certain countries, a fraction of the aggregate value of output of livestock products is subtracted to determine total agricultural output. In deriving this deduction the agriculture of each country is regarded as consisting of essentially two farms: one with no livestock which produces only crops, and one with grazing land but no crops which produces livestock products from pasture and from feed purchased either from the domestic crop farm or from abroad. Aggregates are reported separately for crops and livestock, referring to the gross output of these two farms. When the two aggregates are combined, a deduction is made for livestock feed. This deduction is a fixed percentage of the livestock aggregate and represents the feed purchased by the national livestock farm. This measure of gross crop production plus value added in livestock production is conceptually similar to the index of net U.S. agricultural output used by the E.R.S.

A subindex for crops is also published. When divided by an index of cropland harvested it provides a measure of the change over time in crop output per hectare. (Note that this is not an index of yields, since the relative importance of the different crops is not held constant.)

It should be noted that not all crops and livestock products produced in a country are included. Only those products with "significant production" or for which "reasonable estimates" of production could be made are included.

In the last few years several studies have been carried out using basically the same data set as that employed above to calculate compound rates of growth

in food production, which are then compared to rates of growth in population, usually by region of the world (FAO, ERS, University of California, and the International Food Policy Research Institute (IFPRI). The IFPRI study expressed all cereals and tubers in terms of wheat equivalents in calories rather in value terms using price weights to aggregate. This permitted comparison of the rate of growth in food production and population.

Land in crops is the only agricultural input for which annual time series data are available for most countries of the world. The area planted or harvested of each crop is readily available from the above-cited USDA and FAO sources, as well as national statistical sources. These data permit calculation of trends in yields of individuals crops or aggregates of crops for most countries. This in itself provides a strong argument for use of this indicator, subject of course to all the caveats presented above in Section I.

The principal source of annual data on inputs other than land is the FAO's annual Production Yearbook. The coverage here is rather spotty. For example, the population economically active in agriculture is reported only at ten-year intervals (i.e. in the census years). Annual estimates are published, however, of consumption of nitrogen, phosphorous, and potash, a number of pesticides, and the stocks of large agricultural tractors, garden tractors, harvester-threshers, and milking machines by country, however the time series tend to be rather short. An alternative source of data on the economically active population in agricultural occupations (defined as agriculture, forestry, hunting and fishing) is the International Labor organization's annual Yearbook of Labor Statistics.

Additional data on the agricultural labor force could be synthesized. Data are available on population growth rates for most countries. These data can be combined with benchmark data on share of the labor force in agriculture to produce

annual estimates of the agricultural labor force. The sectoral distribution changes rather slowly and extrapolation should not be subject to major errors if done with some care. To the extent data are available on modern sector employment, or on urban population, additional adjustments can be made.

Two caveats should be kept in mind in using agricultural employment data, however. First, as noted by Burton in a paper parallel to this one, labor force concepts differ rather widely from one country to another. Hence, inter-country comparisons in labor productivity should be made with considerable care until broadly similar concepts of employment have been developed.

Second, estimating the trends in the agricultural labor force by sectoral shifts in population can over-estimate the actual reduction in labor input. The seasonality of agricultural activities, plus their sporadic nature in some parts of the year, cause the actual reduction in labor input to be less than the data on migration or even on employment might suggest. This will give an upward bias to estimates of labor productivity.

With respect to nontraditional agricultural inputs such as rural education and agricultural scientific manpower, the UNESCO Statistical Yearbook provide some useful data. For example, these contain data on school enrollment ratios and on the number of graduates from agricultural colleges.

In their recent analysis of international differences in agricultural productivity, Hayami and Ruttan assembled data on agricultural output, labor, land, livestock herd, fertilizer use, tractor stock, level of rural education, and scientific manpower in agriculture for 43 countries at all levels of development for 1955, 1960, and 1965. The data have been extended to 1970 by Yamada and Ruttan. The countries included in this data set are listed in Table 3. For the countries listed this set of data provides a valuable point of departure for assessing

Table 3

Country Coverage in Hayami-Yamada-Ruttan
Data Set

Argentina	Taiwan
Australia	Turkey
Austria	United Arab Republic
Bangladesh	United Kingdom
Belgium-Luxembourg	United States
Brazil	Venezuela
Canada	Yugoslavia
Chile	
Colombia	
Denmark	
Finland	
France	
Germany, Federal Republic	
Greece	
India	
Ireland	
Israel	
Italy	
Japan	
Libya	
Mauritius	
Mexico	
Netherlands	
New Zealand	
Norway	
Pakistan	
Paraguay	
Peru	
Philippines	
Portugal	
South Africa	
Spain	
Sri Lanka	
Surinam	
Sweden	
Switzerland	
Syria	

Source: Hayami and Ruttan (1971).

agricultural progress.

To estimate indices of total factor productivity, comprehensive data on all inputs used in agriculture are required. This makes the calculation of such indices somewhat more difficult than the indices of partial productivity for land and labor. However, to the extent that benchmarks are available for census years, indices of change in other inputs are what is required. Often, resident staff can synthesize these data for the modern inputs from data on inputs and production from the local modern sectors. In the final analysis, such estimates - if done with care - may be no worse than the available estimates of land, labor, and output. This of course represents only an interim solution until improved data collection capability is created. Careful monitoring of agricultural progress in most low income countries will require additional investment in data collection and in the human capital to analyze and interpret these data. Such investments will have a high payoff both to the Agency for International Development and to the particular country involved.

Factor Weights for Output/Input Indices

A problem that has limited the more general use of indices of total factor productivity is that they require appropriate weights to aggregate the various input categories. These weights can be obtained either from direct estimates of the parameters of the underlying production function, or from estimates of the functional shares if the base period can be assumed to represent equilibrium in the factor markets. (Other assumptions such as the neutrality of technical change and constant returns to scale are also required.)

Needless to say, there have been only limited attempts to estimate the parameters of the aggregate agricultural production function, or to estimate the

functional distribution of income within agriculture for the low income countries. However, we believe that recent attempts to understand the sources of cross-country differences in agricultural development, especially as undertaken by Hayami and Ruttan, provide an alternative means of arriving at these factor weights. In particular, there is a somewhat surprising convergence in alternative estimates of the parameters of the underlying metaproduction function specified by Hayami and Ruttan. It appears that for countries near the means of the data set employed by Hayami and Ruttan, these parameters - if used with care - can serve as the weights for estimating indices of total factor productivity.

Hayami and Ruttan postulated that world agriculture could be described by one underlying production function (which they call a metaproduction function) if shift variables representing human capital and the capacity to produce and absorb new production technology were included in the function. 1/ The satisfactory statistical results which they obtained for their estimate of this underlying production function provide support for their hypothesis. However, more robust support is provided by the fact that independent estimates of this underlying production function, using quite different sets of data, give quite similar results.

A comparison of six alternative estimates of the aggregate production function for agriculture is presented in Table 4. Four of the studies represent attempts to fit the metaproduction function, while one (Bhattacharjee) represents estimates of the conventional production function. (The original Hayami-Ruttan

1/ Hayami and Ruttan studied the large productivity differences which exist among among countries (1970a, 1970b, 1971). Their study suggested three principal sources of productivity differences among countries: (1) resource endowments, (2) technology, as embodied in fixed or working capital, and (3) human capital, broadly conceived to include education, skill, knowledge, and capacity embodied in a country's population. These three classes of variables together explain 95 percent of the observed differences in agricultural productivity among the 43 countries studied, and the three classes of variables were about equally important in the explanation (1970a, pp. 895-6; 1971, p. 101).

Table 4. A Comparison of Estimates of the Coefficients of the Metaproduction Function.

Researcher/ Location	Variables						
	Labor	Land	Livestock	Fertilizer	Machinery	Education	Research & Extension
Bhattacharjee[1/] / international	.3	.3-.4		.3			
Griliches[2/] / U.S.	.4-.5	.1-.2		.1-.2	.1-.2	.3-.5	.04-.1
Akino & Hayami[3/] / Japan	.30-.40	.25-.37		.08-.20	.15-.25	.15-.30	.03-.12
Hayami & Ruttan[4/] / international	.34-.49	.07-.12	.17-.25	.10-.17	.04-.21	.35-.37	.15-.20
Ogg[5/] North America	.54	.04	.28	.20	.13	.29	.03
Thompson[6/] / Brazil	.37	.13	.15		.10	.33	.24

[1/] J.P. Bhattacharjee, "Resource Use and Productivity in World Agriculture", Journal of Farm Economics, 37:57-71, February 1955.

[2/] Z. Griliches, "Research Expenditures, Education, and the Aggregate Agricultural Production Function", American Economic Review 54:961-974, December 1974.

[3/] M. Akino & Y. Hayami, "Sources of Agricultural Growth in Japan, 1880-1965", Quarterly Journal of Economics 88(3): 454-479, August 1974.

[4/] Y. Hayami & V.W. Ruttan, "Agricultural Productivity Differences Among Countries", American Economic Review 60(5): 895-911, December 1970.

[5/] C. Ogg, "Sources of Agricultural Productivity Differences in North America", Unpublished Ph.D. Dissertation, University of Minnesota, June 1974.

[6/] R.L. Thompson, "The Metaproduction Function for Brazilian Agriculture: An Analysis of Productivity and Other Aspects of Agricultural Growth", Unpublished Ph.D. Dissertation, Purdue University, May 1974.

estimate is included as equation 4.). Of the five that attempted to estimate the more extended function, the scope of the respective studies range from Griliches' estimate of the function for U.S. agriculture, through Akino and Hayami's study of Japanese agriculture, Ogg's attempt to estimate a function that could describe the agriculture of Mexico, the U.S., and Canada, and Thompson's study of Brazilian agriculture, to the Hayami-Ruttan study which drew upon data from 43 different countries at all levels of development.

It should be noted that the variables are defined somewhat differently in each of these studies, the overall "quality" of the data probably varies, and the specification of the model itself differs in important details. The consistency of the results provides rather strong support for the existence of an underlying metaproduction function. This gives us some confidence that a total factor productivity index for agriculture might be constructed using the weights from Hayami and Ruttan's study in countries in which adequate data are not available to estimate their own set of weights. One might also utilize their coefficient estimates as a constant set of weights to be utilized for more extensive cross-country analysis in the same manner as they did.

To implement studies of total factor productivity, the goal would be to measure changes in the productivity of conventional inputs used at the farm level, abstracting from changes in the quality of the inputs used over time. For the most part it will be such crude data (or indices thereof) that are available.

Interest will therefore focus on the coefficients of the conventional inputs, and not those for education and research and extension. The sum of these coefficients should be constrained to sum to one, to be consistent with the implicit assumption of constant returns to scale at the farm level. The statistical results presented in Table 4 are for the most part consistent with this

assumption.

Although there is surprising agreement on the various estimates of the production elasticities, some care should be used in applying to individual countries. With the exception of the results for Japan, the sample data refer to rather diversified and large agricultural sectors. In the case of a highly specialized, small farm agriculture, there could be a divergence from these results. In such cases, adjustments of the weights can be made on an a priori basis, drawing on judgments about relative factor shares and other information. Until experience is accumulated with this approach, sensitivity analysis can be used with the weights to determine to what extent the estimate of changes in total factor productivity are influenced by the weights chosen.

To conclude this section, we note that Yamada and Ruttan recently reviewed the literature on studies of total factor productivity in developing countries and found a number for Asia, including Taiwan, Korea, Philippines, and India.[1/] This suggests that while the data requirements do tend to be great, such studies are feasible. Moreover, the studies referred to made independent estimates of the underlying production function, while we propose to draw on recent advances in our theoretical and empirical knowledge to use a common set of weights for factor aggregation, or to make corrections of the weights based on a priori knowledge.

[1/] See Y. Hayami, V.W. Ruttan, and H. Southworth, eds. Agricultural Growth in Japan, Taiwan, Korea and the Philippines (Honolulu: University Press of Hawaii, 1976) for total factor productivity studies of Taiwan (Lee and Chen), Korea (Ban) and the Philippines (Christomo and Barker). The Indian case is covered in Tara Shukla, Capital Formation in Indian Agriculture (Bombay: Vora, 1965), and in R.E. Evenson and D. Jha, "The Contribution of the Agricultural Research System to Agricultural Production in India", Indian Journal of Agricultural Economics 27(4): 212-230, Oct.-Dec. 1973. A cross-section analysis for Asian countries is made in S. Yamada, A Comparative Analysis of Asian Agricultural Productivities and Growth Patterns (Tokyo: Asian Productivity Organization, 1975).

Illustrations of Progress Indicators and Commitment

The material in this section includes a cursory look at the progress and commitment indicators suggested above for two countries: India and Brazil. The goal is to indicate feasibility and to illustrate problems, and not to provide a detailed analysis of the growth performance of the individual countries.

Brazil

Table 5 provides regional data on Brazil which points up the importance of looking at labor productivity, and which illustrates what can be gained from examining land and labor productivity in conjunction with the land/labor ratio. Brazil is a very large country, covering approximately half of South America, and has distinct regional economies comparable in size to the total economies of other countries. The regional differences in development are quite great, and within agriculture, per capita incomes in the South were approximately double those in the East and Northeast in 1970.

An important point to note from the table is that, although substantial, the variation in land productivity among regions is much less than the variation in labor productivity. Clearly, the lowest land productivity is in the Northeast, where the lowest incomes are. But the difference in land productivity between the Northeast and the South falls far short of reflecting the differences in per capita income of the agricultural population, whereas the difference in labor productivity brings the difference to the fore. Similarly, land productivity was the highest in the East, whereas per capita incomes in agriculture in that region are second to the Northeast; land productivity in the Central West is quite low, whereas the per capita incomes of farm people in that region are relatively high. Hence, data on land productivity alone can be quite misleading as an indicator of the welfare (as measured by per capita incomes) of the people

Table 5. Regional Distribution of Agricultural Product, Labor Force and Crop Land, and Indices of Labor Productivity, Land Productivity, and Land/Labor Ratio, Brazil, 1969-70.

	Percentage Distribution of:			Indices of:		
Region	GDP of Agricultural sector (1969)	Agricultural Labor Force (1970)	Crop Land (1970)	Average Labor Productivity	Average "Land Productivity"	Cropland/ Labor Ratio
North	2.06	5.37	1.80	.38	1.14	.34
Northeast	23.01	43.05	30.31	.53	.76	.70
East	17.23	14.72	14.34	1.17	1.20	.97
South	51.84	31.61	46.50	1.64	1.11	1.47
Central West	5.86	5.25	7.05	1.12	.83	1.35
Brazil	100.00	100.00	100.00	1.00	1.00	1.00

Note: Regions are defined as follows:

North = Rondônia, Acre, Amazonas, Roraima, Pará, and Amapá.

Northeast = Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia.

East = Minas Gerais, Espírito Santo, Rio de Janeiro, and Guanabara.

South = São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul.

Central West = Mato Grosso, Goiás, and Distrito Federal

Source: Gross Domestic Product (GDP) of the agricultural sector (including crops, livestock, and vegetative extraction) from official national account data as published in Conjuntura Economica 25(9):112-114, set. 1971.
Agricultural labor force and crop land data from: Fundacao IBGE, Sinopse Preliminar do Censo Agropecuario - 1970---Brasil e Unidades de Federacao, Rio de Janeiro, set. 1973.

in the agricultural sector.

Further insights into Brazilian agriculture can be gained from Tables 6, 7, 8 and 9. Table 6 provides annual data on the growth in agricultural and food production by commodity and in aggregate index form over the decade 1965-75. Table 7 builds upon the identity presented earlier that labor productivity $\frac{Q}{N}$, equals land productivity, $\frac{Q}{A}$, times the land: man ratio, $\frac{A}{N}$. Observe that the growth in labor productivity through time was associated with increasing land productivity and a marginal decline in the land: labor ratio over the 15-year period, 1955-70.

Tables 8 and 9, which are based upon a different data set, provide estimates of the geometric growth rates in the several components for Brazil and on a regional basis, respectively. These data again illustrate how misleading a measure of land productivity can be as an indicator of land productivity, and in turn the welfare of the agricultural population and the contribution that agriculture is making to the total economy. For Brazil as a whole, there was a strong correlation between land and labor productivity between 1940 and 1950. However, in the period from 1950-60 the growth rate in land productivity almost quadrupled compared with the earlier period, while the growth rate of labor productivity only doubled. In the more recent period, the productivity of land grew at a still more modest rate, while the productivity of labor grew at a rate quadruple that of the previous period, and roughly double that of the productivity of land. Of course, the land/man ratio was changing at a more rapid rate in this period.

The regional data show similar relationships. Especially notable is the decline in labor productivity in Sao Paulo in the decade of the 1950's, despite a fairly large growth rate in the productivity of land. The growth rate in labor

Table 6. Brazil

PRODUCTION BY COMMODITY, VALUE AND INDICES OF TOTAL AGRICULTURAL AND FOOD PRODUCTION, AVERAGE 1961-65, ANNUAL 1966-75

COMMODITY	PRICE WEIGHT	AVERAGE 1961-65	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
	DOLLARS	-1,000 METRIC TONS-										
WHEAT	99	574	615	629	856	1,374	1,844	2,011	693	2,031	2,820	1,600
RYE	30	18	17	17	19	19	19	20	16	16	19	19
RICE, PADDY	63	6,123	5,802	6,792	6,652	6,394	6,648	5,394	6,132	6,632	6,421	6,500
CORN	31	10,112	11,371	12,824	12,814	12,693	14,216	14,130	14,891	14,109	15,000	15,000
BARLEY	25	26	35	31	29	31	27	20	26	13	26	27
OATS	20	20	23	21	26	26	27	29	27	38	27	28
BEANS, DRY	97	1,928	2,148	2,548	2,420	2,200	2,211	2,364	2,688	2,229	2,238	2,271
POTATOES	44	1,178	1,329	1,467	1,606	1,507	1,583	1,649	1,589	1,337	1,672	1,669
CASSAVA	8	21,900	24,710	27,268	29,203	30,074	29,464	30,258	29,829	26,559	24,715	26,683
SWEETPOTATOES	17	1,534	1,913	2,226	2,120	2,175	2,134	2,155	2,140	1,814	2,200	2,150
ONIONS	92	216	277	250	273	275	285	246	282	306	341	349
SUGARCANE	4	65,577	75,787	77,087	76,600	75,250	79,753	79,754	85,000	91,877	96,412	88,412
TOBACCO	195	162	136	145	152	188	193	196	191	181	226	286
COTTON	350	490	561	445	606	705	581	595	682	660	517	510
JUTE	115	48	44	40	51	49	38	35	35	62	32	41
COTTONSEED	40	1,133	1,119	1,015	1,200	1,266	1,173	1,200	1,480	1,400	1,130	1,100
SOYBEANS	59	353	595	716	654	1,057	1,509	2,077	3,666	5,012	7,700	9,700
PEANUTS, IN SHELL	78	610	895	751	754	754	928	945	893	650	530	350
CASTOR BEANS	53	268	329	355	370	378	349	362	265	449	540	290
TOMATOES	57	502	679	745	775	700	764	820	892	809	1,036	801
BANANAS	13	6,287	7,117	8,056	8,453	9,266	9,860	10,100	10,900	7,128	6,974	7,068
PINEAPPLES	84	188	197	225	225	260	283	333	357	325	369	344
GRAPES	49	463	523	501	539	483	598	502	564	394	564	587
COFFEE	280	1,655	1,200	1,380	990	1,140	585	1,416	1,470	858	1,650	1,440
COCOA BEANS	195	128	173	145	166	202	192	165	159	245	267	237
COCONUTS	79	237	343	412	345	328	350	363	322	274	254	239
SISAL	128	186	202	199	190	193	210	210	260	302	293	313
BEEF AND VEAL	420	1,404	1,452	1,505	1,694	1,827	1,845	1,838	2,020	2,000	2,100	2,250
MUTTON AND LAMB	325	48	56	52	57	56	55	61	58	58	58	58
PORK	395	468	545	557	634	642	679	674	645	701	725	750
MILK	58	5,742	6,889	6,904	7,116	7,244	7,346	7,323	7,146	7,310	8,497	8,827
WOOL, GREASY BASIS	545	29	27	31	40	37	41	34	37	36	34	34
AGGREGATES OF PRODUCTION		-MILLION DOLLARS AT CONSTANT PRICES-										
CROPS		2,496.3	2,597.6	2,800.5	2,782.5	2,913.8	2,896.2	3,129.6	3,280.2	3,205.2	3,671.6	3,565.4
LIVESTOCK		1,139.1	1,257.6	1,286.3	1,414.9	1,479.5	1,509.4	1,501.2	1,556.8	1,579.4	1,698.6	1,790.7
LIVESTOCK FEED DEDUCTION (.16)		-182.2	-201.2	-205.8	-226.3	-236.7	-241.5	-240.1	-249.0	-252.7	-271.7	-286.5
TOTAL AGRICULTURE		3,453.2	3,654.0	3,881.0	3,971.1	4,156.6	4,164.1	4,390.7	4,588.0	4,531.9	5,098.5	5,069.6
TOTAL FOOD		2,727.3	3,032.0	3,244.7	3,380.6	3,483.4	3,687.2	3,679.1	3,829.0	3,936.2	4,323.1	4,354.0
INDICES OF PRODUCTION		(1961-65 = 100)										
CROPS		100	104	112	111	117	116	125	131	128	147	143
TOTAL AGRICULTURE		100	106	112	115	120	121	127	133	131	148	147
TOTAL FOOD		100	111	119	124	128	135	135	140	144	159	160
PER CAPITA AGRICULTURE		100	98	100	100	102	100	102	104	99	109	105
PER CAPITA FOOD		100	102	107	108	108	111	108	109	109	117	115
INDEX OF POPULATION 1961-65 POPULATION= 78,016,000		100.0	108.5	111.5	114.7	117.9	121.3	124.8	128.4	132.0	135.7	139.5

Source: U.S. Dept. of Agriculture, Economic Research Service, Indices of Agricultural Production for the Western Hemisphere, Excluding the U.S. and Cuba, 1966 through 1975, Statistical Bulletin No. 552, May 1976.

Table 7. Elements of Agricultural Productivity, Brazil, 1955, 1965, and 1970.

	1955	1965	1970
$\frac{Q}{N}$	8.06	10.42	11.97
$\frac{Q}{A}$	.481	.627	.781
$\frac{A}{N}$	16.75	16.63	15.32

Note: Output measured in thousands of wheat units (5 year average), land in thousands of hectares, and labor in thousands of male workers.

Source: Calculations by authors based upon data in Hayami and Ruttan, and Yamada and Ruttan.

Table 8. Geometric Growth Rates in Elements of Productivity Growth, Brazil, 1940-1970.

	1940-50	1950-60	1960-70
Q/A	0.49	1.77	2.03
A/N	0.93	0.54	2.96
Q/N	0.46	0.95	3.98
N	1.55	3.53	1.36
Q	2.97	5.84	5.35

Source: Affonso Pastore

Table 9. Geometric Growth Rates in Elements of Productivity Growth, Selected Regions of Brazil, 1950-70.

	Sao Paulo		Northeast		Central West	
	1950-60	1960-70	1950-60	1960-70	1950-60	1960-70
Q/A	3.76	4.79	0.48	0.62	1.55	2.09
A/N	- .05	0.62	0.16	3.14	1.62	1.99
Q/N	- .19	2.97	0.08	1.95	2.51	4.16
N	1.21	-1.32	4.39	1.64	3.39	1.68
Q	4.92	4.09	5.03	5.40	4.13	5.76

Source: Affonso Pastore

productivity in the Northeast was fairly large in the 1960's, despite a fairly modest growth rate in land productivity, and this because of a substantial change in the land/man ratio. And of course the growth in labor productivity in the Central West has been quite large because there has been a sizeable growth rate in both land productivity and the land/man ratio.

We now turn to some of the ex ante measures of commitment to agricultural development and to measures of policy discrimination. Schuh (1970) made an attempt to pull together the various data on budget support for Brazilian agriculture. Brazil typifies most developing countries in that the budget support is diffuse and multi-faceted, and hence has to be gleaned from various sources. The following discussion shows that estimates can be made even in the absence of a unified budget, and illustrates the problems as well.

Data on Federal support for agriculture through the Ministry of Agriculture are provided in Table 10 for the 5-year period 1960-64. Such data were synthesized in Schuh (1970) for the period 1944 through 1965. They show that the Ministry of Agriculture received only between 2.26 and 5.00 percent of the Federal budget. When it is realized that agriculture provided over half of the employment of the country in this period, and produced over 25 percent of the GNP, the lack of commitment to agriculture during that period is quite clear.

Table 10

Budget Resources of the Ministry of Agriculture, 1960-1964

Year	Total Federal Budget (billion Cr$)	Budget of Ministry of Agriculture (billion Cr$)	Percent of Total
1960	194	12	5.9
1961	302	15	4.8
1962	572	22	3.9
1963	1,023	45	4.4
1964	2,110	122	5.7

Source: Anuário Estatístico do Brasil (Rio de Janeiro: IBGE, various issues).

Because support for agriculture comes from many sources other than the Ministry of Agriculture, Table 11 was prepared. This shows that the Ministry represents only half the total expenditure. Moreover, even these estimates neglect the expenditures on higher education for agriculture.

To supplement these data, other information was provided on the sectoral allocation of loans by the National Development Bank, on the disparity between rural and urban education, and on the sectoral allocation of credit - all from generally available sources. A sectoral allocation of foreign aid funds for science and technology was also developed (Table 12), and within agriculture, an allocation of how such funds were used (Table 13). These data provide some indication of both the quantity and quality of the investments.

Data of a similar kind were developed for the poverty-stricken Northeast as well, and can be found in the original sources. Analyses were made of the sectoral allocation for foreign aid funds for this region, as well as for funds provided through the regional development banks. A comparable analysis of the "quality" of the investments could also be made.

In turning to economic policy and the extent to which it has encouraged agriculture or discriminated against it, a number of different kinds of studies can be drawn upon. The overt policy is the easiest. Price ceilings were maintained on food products for a rather long period of time, and these can be rather easily documented. Similarly, the extent to which minimum prices are above or below realized market prices can be documented, as can the terms on which credit is extended to agriculture.

Implicit taxation and other policies that discriminate against agriculture are somewhat more difficult to arrive at, but are also feasible. In some cases the evidence is rather direct, as in the case of multiple exchange rates,

Table 11. Federal Budget for Agriculture, 1966 (thousand NCr$).

Govt. Organ	Admin.	Research, Technological Experimentation	Promotion, Ag. Extension	Ag.	Mechanization	Disease, Pests	Ag. Inspection	Renewable Nat. Resources	Meteorology, Climatology	Agrarian Reform	Training	Studies, Research	Total	Percent
President	.02	-	.01	-	-	.01	-	.21	-	51.53	-	-	51.58	19.0
Coordination of Regional Organs	1.47	1.54	12.14	.64	2.17	.48	-	-	-	-	.01	.60	19.15	6.8
Min. of Aeronautics	-	-	.04	-	.04	-	-	-	-	-	-	-	.08	-
Min. of Agriculture	32.50	21.73	58.07	4.00	-	5.91	5.18	14.0	1.64	-	-	3.97	147.00	52.0
Min. of Education, Culture	-	.22	.18	-	-	-	-	.01	.06	-	.21	.08	.76	-
Min. of War	-	-	.15	-	-	-	-	-	-	-	-	-	.15	-
Min. of Mines and Energy	-	-	-	-	-	-	-	-	-	-	-	.05	.05	-
Min. of Transportation and Public Works	11.04	-	11.00	35.62	-	-	-	3.12	-	-	.13	2.38	63.30	22.4
Total	45.03	23.49	81.59	40.26	2.21	6.40	5.18	17.34	1.70	51.53	.35	7.08	282.07	100.0
Percentage	16.0	8.3	28.9	14.3	.08	2.3	1.8	6.1	0.6	18.3	0.0	2.5	-	-

Source: Ministry of Planning and General Coordination, Orçamento Programa (1965).

Table 12. Distribution of Funds[a] by Organization and Field, 1962-1965[b] (thousand U.S.$)[c]

	IDB	World Bank	UN	OAS	US AID	US AEC	Natl. Inst. Health	Natl. Sci. Found.	Mili-tary	USDA	Ford	Kel-logg	Rocke-feller	Total
Agr.	13,750		3,323	191	11,808			411		726	3,500		337	34,072
Oceanog.			835		90						2		548	1,475
Med. & Biol. Sci.			1,089			142	1,111	19	208			509	685	3,762
Dental Sci.			11									128		135
Math.								91	20					111
Chem.			4						48		490		24	566
Eng.			721		1,760						160			2,641
Physics			22		16	122		101	213		100		1	575
Meteorology			170		38									208
Geophys.									20					20
Nat. Res.			716		76,622			155						77,494
Ind. + Manpower	2,650		163		244									3,057
Power	41,900	79,500	2,571		31,575									155,536
Trans.			34		12,044									12,078
Eco. + Plan.	340		314	237	1,188						1,172		14	3,264
Pub. + Bus. Admin.			5		5,852						905			6,762
Ed.	4,000		1,519	4	3,761						4,562			13,843
Sociology			17	4	445									466
Total	62,640	79,500	11,514	436	145,443	264	1,111	777	509	726	10,891	637	1,609	313,974

[a]Loans and grants combined.
[b]Some amounts include years before 1962 or after 1965.
[c]Due to rounding, columns and rows may not add up to total.

Source: "Science and Brazilian Development," Part I of a Report of a workshop on Contributions of Science and Technology to Development, April 11-16, 1966, Itatiaia, Brazil. Workshop was under the auspices of the National Research Council of Brazil and the U.S. National Academy of Sciences in cooperation with USAID.

Table 13. Breakdown of Loans and Grants for Agriculture and Plant Sciences, 1962-1965[a] (thousand U.S.$).

	IDB	OAS	UN	USAID	USDA	NSF	Ford	Rocke-feller	Total
Land Reform, Colonization	2,000	6	277	194					2,427
Machinery, Equipment	9,000								9,000
Development Programs, Productivity	2,750		63	1,910					4,723
Extension, Education, Curriculum Planning, Related Institutional Development		186	2,844	9,210			2,795	41	15,076
Agricultural Economics			147	494			705		1,346
Research, including Materials & Equipment			42		726	411		297	1,476
Total	13,750	192	3,323	11,808	726	411	3,500	338	31,978

[a]Approximately.

Source: "Science and Brazilian Development," Part I of a Report of a Workshop on Contributions of Science and Technology to Development, April 11-16, 1966, Itatiaia, Brazil.

differential rates between exports and imports, and quotas on both exports and imports. Inspection of the system can in many cases identify whether agriculture is suffering discrimination, or whether it is being favored by trade policy. Similarly, export subsidies will often be provided at a differential rate among sectors.

If a single exchange rate is in effect, evaluating the degree of distortion will be more difficult. But rather straight-forward procedures are available for estimating the shadow rate of foreign exchange. In the case of Brazil, studies have shown that the cruzeiro has persistently been over-valued by as much as 20 percent or more. (Schuh (1976(c), Bergman, von Doellinger). An over-valued exchange rate is an implicit export tax. To the extent that agriculture either is, or has the potential to be, an export sector, this tax will be on the agricultural sector. Moreover, its effect is such as to have a rather strong disincentive to production, since it distorts relative price ratios.

Brazil has also used explicit export taxes and the confiscation of exchange earnings. The confiscation has been extensively used on coffee. Explicit export taxes have been imposed on beef, soybeans, and in some cases cotton. When a country is a dominant seller in international markets, as Brazil was for a time with coffee some fraction of both implicit and explicit export taxes can be passed on to the foreign consumer. In general, however, the bulk of the tax will be paid by the domestic producer.

Finally, the system of tariffs provides an important means of shifting price incentives and of influencing the structure of production. When development policy is oriented towards import-substituting industrialization, the system of tariffs becomes an important set of policy tools. For the most part the tariffs will be set so as to discriminate against the agricultural sector.

The modern way of analyzing the effects of tariffs is through effective protection, which takes account of the fact that an industry may use inputs that are also protected. Bergman has made an extensive study of the effective protection implied by Brazilian trade policy. As an example of the size of the distortion, he found that as of April, 1967, agricultural crops in Brazil experienced a -5 percent level of effective protection, while the average effective protection for all sectors was 55 percent, and that for all manufacturing was 91 percent. Clearly, the discrimination against agriculture was severe.

If the goal is to evaluate the commitment of a government to its agriculture, surely these ex ante evaluations of policy are of more value than an ex post evaluation of trends in productivity. Moreover, it is especially important to note that in many instances the implicit taxes and discrimination are more important than the explicit and more overt forms of taxes and discrimination.

Identifying and evaluating the consequences of such policies are not as easy as measuring ex post changes in productivity. But a well-trained economist can do much, if even in only a qualitative way. More importantly, the true test of commitment is in government policy. It is here that the analysis has to focus if the goal is to assess commitment.

India

In turning to the case of India, a number of comparable kinds of evidence and studies can be turned to, although we are not as familiar with either Indian policy or the literature on India. Therefore, this section on India draws heavilily upon the research of John W. Mellor, particularly that reported in his New Economics of Growth - A Strategy for India and the Developing World (Ithaca: Cornell University Press, 1976), and his article "The Agriculture of India" in Scientific American, Volume 235, No. 3, September 1976, pp. 154-163).

Table 14 provides annual data on the growth in agricultural and food production by commodity and in aggregate index form over the decade 1966-75. India, which is the fourth largest grain producing country, increased its production of food grains at about 2.8 percent per year from 1950 to 1976. [1/] This rate of growth was significantly higher than the population growth rate of about 2.1 percent per year over the same period. Around this upward trend, however, substantial year-to-year fluctuations in grain production have occurred due to changing weather. This makes estimation of trend rates of growth in Indian food production extremely precarious. By choosing an appropriate base and terminal year, one can demonstrate almost any trend desired. This suggests that one must exercise care in matching years of comparable weather when choosing base and terminal years.[2/]

Table 15 presents data on labor productivity, land productivity, and the land:labor ratio in Indian agriculture for 1955, 1965, and 1970. It should be noted that while land productivity has followed a steady upward trend over the period, labor productivity has moved somewhat erratically. It was lower in 1965 than 1955. By 1970 it had not quite regained the level of 1955. The data reveal a fairly steady decline in the land:labor ratio in Indian agriculture over the period. To better understand the development of Indian agriculture over this period, we draw upon Mellor's analysis in the following paragraphs.

1/ Years of good harvest include 1949-50, 1954-55, 1961-62, 1964-65, 1970-71, and 1975-76. Poor harvests occurred in 1957-58, 1965-67, and 1972-73.

2/ Note that the output measures employed are 5-year averages centered on 1955, 1965, and 1970 respectively. Each contains one of the bad crop years listed in the previous footnote.

Table 14. India, Production by Commodity, Value and Indices of Total Agricultural and Food Production, Average 1961-65, Annual 1966-75.

COMMODITY	PRICE WEIGHT	AVERAGE 1961-65	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
	DOLLARS	-1,000 METRIC TONS-										
WHEAT	66	11,192	10,394	11,393	16,540	18,651	20,093	23,832	26,410	24,735	21,778	24,235
RICE, PADDY	53	52,864	45,703	56,474	59,701	60,706	63,401	64,667	58,926	66,143	60,438	69,069
CORN	55	4,599	4,894	6,270	5,701	5,674	7,486	5,101	6,388	5,804	5,723	5,800
BARLEY	52	2,601	2,382	2,348	3,504	2,424	2,716	2,784	2,577	2,379	2,371	3,150
MILLET	61	7,729	7,587	8,976	7,254	9,176	12,172	9,196	7,404	11,557	7,085	9,700
SORGHUM	61	8,845	9,224	10,048	9,804	9,721	8,105	7,722	6,968	9,097	10,221	10,700
CHICKPEAS	59	5,535	4,224	3,622	5,973	4,309	5,546	5,199	5,081	4,537	4,099	4,055
PIGEON PEA	68	1,668	1,733	1,130	1,74[illegible]	1,816	1,842	1,883	1,683	1,928	1,408	1,818
OTHER PULSES	77	4,512	3,987	3,595	4,390	4,293	4,303	4,736	4,330	3,442	4,500	4,525
POTATOES	41	3,023	4,076	3,522	4,232	4,726	3,913	4,807	4,826	4,451	4,861	6,171
CASSAVA	20	2,295	3,467	3,817	4,644	4,636	5,214	5,130	5,939	6,371	6,358	6,630
SWEETPOTATOES	39	984	991	1,297	1,588	1,764	1,444	1,750	2,267	2,082	2,000	2,300
SUGARCANE	8	106,403	123,990	92,826	95,500	124,676	135,024	126,368	113,570	124,867	140,804	140,196
TOBACCO	436	338	293	353	369	361	337	362	419	372	462	395
COTTON	281	1,032	997	1,149	1,062	1,052	972	1,296	1,129	1,161	1,251	1,332
JUTE	130	1,022	964	1,138	528	1,018	889	1,023	896	1,120	808	792
COTTONSEED	51	2,064	1,994	2,298	2,124	2,104	1,944	2,592	2,241	2,320	2,502	2,664
FLAXSEED	89	432	331	260	438	329	459	453	530	428	471	550
PEANUTS, IN SHELL	99	5,048	4,411	5,731	4,631	5,130	6,111	6,181	4,092	5,932	4,991	7,000
RAPESEED	114	1,277	1,298	1,228	1,568	1,347	1,564	1,976	1,433	1,808	1,704	2,211
SESAME SEED	152	444	416	445	422	448	562	450	385	484	408	400
CASTOR BEANS	83	107	80	110	121	116	123	136	175	229	216	225
COFFEE	555	43	64	78	57	74	69	115	74	97	92	98
TEA	532	357	376	385	402	396	422	433	456	472	491	492
RUBBER	438	38	55	65	71	82	92	101	112	123	128	142
AGGREGATES OF PRODUCTION		-MILLION DOLLARS AT CONSTANT PRICES-										
CROPS		8,453.2	8,046.3	8,779.3	9,356.3	9,849.0	10,519.6	10,718.8	10,041.6	10,929.9	10,313.3	11,532.8
LIVESTOCK		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL AGRICULTURE		8,453.2	8,046.3	8,779.3	9,356.3	9,849.0	10,519.6	10,718.8	10,041.6	10,929.9	10,313.3	11,532.8
TOTAL FOOD		7,604.9	7,217.4	7,845.8	8,502.8	8,937.1	9,629.0	9,673.8	9,030.7	9,880.0	9,227.2	10,437.3
INDICES OF PRODUCTION						(1961-65 = 100)						
CROPS		100	95	104	111	117	124	127	119	129	122	136
TOTAL AGRICULTURE		100	95	104	111	117	124	127	119	129	122	136
TOTAL FOOD		100	95	103	112	118	127	127	119	130	121	137
PER CAPITA AGRICULTURE		100	89	95	99	103	106	107	98	104	96	105
PER CAPITA FOOD		100	89	94	100	103	109	107	98	104	95	105
INDEX OF POPULATION 1961-65 POPULATION=484,432,000		100.0	106.8	109.1	111.6	114.1	116.6	119.2	121.8	124.5	127.3	130.1

Source: U.S. Dept. of Agriculture, Economic Research Service, Indices of Agricultural Production for the Far East and Oceania, Average 1961-65 and Annual 1966-75, Statistical Bulletin No. 555, June 1976, p. 15.

Table 15. Elements of Agricultural Productivity, India, 1955, 1965, and 1970

	1955	1965	1970
$\frac{Q}{N}$	2.397	2.19	2.35
$\frac{Q}{A}$	.936	1.129	1.290
$\frac{A}{N}$	2.562	1.940	1.824

Note: Output measured in thousands of wheat units (5 year average), land in thousands of hectares, and labor in thousands of male workers.

Source: Calculations by authors based upon data in Hayami and Ruttan, and Yamada and Ruttan.

In analyzing the growth in India's food grain production, Mellor divides the period 1950-76 into 3 phases: the decade 1950-60 of accelerated growth based on traditional technology, a five-year period of transition (1960-65), and a period of increasing dependence on new technology for raising production since 1965 (1976a, p. 157).

During the 1950's about a fifth of the production increase was due to expansion of irrigation, two-fifths to increased utilization of labor, and a third to a greater area under cultivation. In the early 1960's the food-grain production growth rate slackened, and a shift in sources of agricultural growth began. The growth in land area under cultivation became less significant and the use of fertilizer grew in importance. Increases in fertilizer use accounted for nearly 40 percent of the increase in grain production in 1961-65, but only 10 percent of the increase in the previous decade. During 1965-1970 with the coming of the Green Revolution in the form of higher yielding varieties of wheat and rice, the increased use of fertilizer and other modern inputs gained an even higher payoff. Sixty percent of the increased grain production in that period was attributable to the greater use of fertilizer and other modern inputs. From 1971 to 1975 Indian agriculture was first hit with two years of drought and then a worldwide shortage of fertilizer. With the increased world fertilizer production capacity and lower prices of fertilizer and favorable growing conditions, the 1975-76 crop broke all previous records. In addition to the year to year variablity in growth in grain production, there is also substantial regional variation in growth in grain production. Mellor points out that "the Green Revolution achieved its greatest success in the Punjab of northwestern India which showed faster growth rates than Taiwan, often regarded as the model of agricultural success."

(1976a, p. 157) Parts of Gujarat in the west and Andhra in the South also achieved rapid growth rates while Bihar, West Bengal and Madhya Pradesh have lagged substantially behind the others. This demonstrates how dangerous it is to generalize concerning the agriculture of any large country.

Evenson and Jha have utilized a total factor productivity approach to analyze growth in agricultural output by state in India over three periods (1953-56 to 1958-61, 1958-61 to 1963-65, and 1963-65 to 1969-71). Rather than directly estimating the aggregate agricultural production function to obtain the input aggregation weights they utilized production cost data to estimate factor shares for each input. (It is explained in Appendix A that these are equivalent under certain assumptions.) These are presented in Table 16. Using these as input aggregation weights indices of total inputs were developed and divided into the respective indices of output to yield indices of total factor productivity by state (Table 17). This illustrates that given an adequate data base the use of total factor productivity as an indicator of agricultural progress is indeed viable, even on a state level.

From their study Evenson and Jha concluded:

1. that total factor productivity gains in some parts of Indian agriculture have been truly extraordinary, but that large regional disparities have emerged over time;

2. that the gains realized have not been associated exclusively with wheat and rice production or with the extent of irrigated acreage, and

3. that the major determinant of productivity change in Indian agriculture has been the Indian agricultural research system, and the investment in the research system has yielded social rates of return far in excess of those realized in other development activities (pp. 212-213).

Whether or not the rather impressive growth performance of Indian agriculture

Table 16. Estimated Factor Shares Indian State Agricultural Production 1960 and 1971.

		Land	Labour	Animal power	Implements	Pump-sets	Tractors	Fertilizer
Andhra Pradesh	1960	·336	·451	·127	·012	·061	·003	·010
	1971	·307	·407	·088	·008	·158	·008	·024
Assam	1960	·185	·683	·124	·006	—	·001	—
	1971	·316	·570	·102	·009	—	·001	·002
Bihar	1960	·265	·569	·138	·010	·001	·002	·003
	1971	·353	·510	·095	·013	·008	·006	·014
Gujarat	1960	·329	·574	·079	·009	·003	·002	·003
	1971	·373	·539	·055	·006	·008	·005	·015
Haryana	1960	·335	·516	·125	·010	·004	·009	·002
	1971	·379	·530	·040	·007	·016	·010	·020
Kerala	1960	·301	·595	·077	·007	·005	—	·014
	1971	·394	·478	·053	·005	·044	·001	·024
Madhya Pradesh	1960	·343	·457	·158	·016	·023	·001	·002
	1971	·423	·425	·114	·012	·015	·001	·007
Maharashtra	1960	·385	·441	·155	·011	·002	·001	·004
	1971	·412	·453	·096	·007	·013	·003	·016
Mysore	1960	·378	·501	·092	·012	·009	·002	·006
	1971	·412	·390	·060	·009	·020	·034	·027
Orissa	1960	·535	·319	·135	·005	—	—	·002
	1971	·640	·197	·082	·008	·001	—	·004
Punjab	1960	·373	·430	·151	·020	·007	·011	·003
	1971	·369	·489	·045	·012	·015	·029	·043
Rajasthan	1960	·466	·430	·089	·010	·002	·001	·001
	1971	·565	·342	·062	·008	·013	·002	·007
Tamil Nadu	1960	·257	·497	·140	·016	·074	·002	·015
	1971	·301	·443	·095	·009	·095	·003	·053
Uttar Pradesh	1960	·308	·479	·185	·017	·001	·014	·005
	1971	·382	·404	·135	·012	·006	·036	·025
West Bengal	1960	·255	·589	·137	·012	—	—	·006
	1971	·345	·525	·105	·007	·003	·005	·011

Source: Evenson and Jha, p. 229.

Table 17. Output, Input and Total Factor Productivity Indexes by State: 1952-53 to 1970-71.

Year	Gujarat			Rajasthan			Punjab			
	O	I	TFP	O	I	TFP	O	I	TFP	
1952-53	68.6	88.7	77.3	74.2	84.5	85.4	77.6	87.4	88.1	Combined Punjab-Haryana
1953-54	99.5	91.6	108.6	97.1	86.2	112.6	85.3	90.1	94.8	
1954-55	115.9	95.2	121.7	94.2	92.3	101.9	90.7	95.4	95.1	
1955-56	92.0	97.0	94.8	93.1	96.4	96.6	86.1	98.7	87.2	
1956-57	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
1957-58	90.0	100.3	90.1	95.0	99.3	95.7	100.8	103.0	97.9	
1958-59	130.4	103.8	125.6	108.8	103.0	105.6	112.0	103.9	107.8	
1959-60	89.7	105.3	85.2	108.1	106.5	101.5	106.8	105.5	101.2	
1960-61	116.7	107.1	108.9	104.7	106.2	98.6	119.4	105.3	113.4	
1961-62	134.5	111.4	120.7	123.6	110.0	112.4	121.0	109.2	110.8	
1962-63	128.9	110.5	116.7	122.8	109.2	112.5	126.5	114.6	110.4	
1963-64	131.8	109.7	120.1	93.6	107.9	86.7	119.2	116.5	102.3	
1964-65	153.3	115.3	133.0	121.6	111.9	108.7	142.2	121.1	117.4	
1965-66	123.6	116.9	105.8	90.6	108.8	83.3	127.7	121.4	105.2	
1966-67	120.6	119.8	100.7	101.2	111.2	91.0	144.9	126.0	115.0	
1967-68	150.0	123.9	128.3	152.3	112.7	135.1	182.6	138.0	132.3	
1968-69	121.1	123.0	98.5	93.2	114.4	81.5	201.6	144.3	139.7	
1969-70	152.3	125.6	121.3	107.5	115.1	93.4	221.9	150.9	147.1	
1970-71	191.5	128.2	149.4	225.0	117.6	191.3	231.7	155.6	148.9	

Year	Haryana			Uttar Pradesh			Bihar			
	O	I	TFP	O	I	TFP	O	I	TFP	
1952-53	Combined Punjab-Haryana			91.3	93.1	98.1	112.4	95.0	118.3	
1953-54				91.3	95.2	95.6	119.2	95.3	125.0	
1954-55				100.4	96.9	103.6	88.2	95.5	92.3	
1955-56				92.7	98.4	94.2	105.5	98.4	107.2	
1956-57				100.0	100.0	100.0	100.0	100.0	100.0	
1957-58				96.8	101.0	89.9	78.4	100.2	78.3	
1958-59				101.4	103.1	98.4	129.8	105.7	122.8	
1959-60				102.2	104.3	98.0	117.1	107.1	109.6	
1960-61				113.0	105.9	106.7	134.6	109.6	122.8	
1961-62	121.0	107.1	113.0	112.8	107.3	105.1	132.5	111.6	118.7	
1962-63	126.5	110.2	114.8	103.6	108.5	95.0	131.9	113.9	115.8	
1963-64	119.2	111.3	107.1	95.0	110.2	86.2	138.0	116.0	119.0	
1964-65	120.2	114.6	104.9	121.8	111.7	109.0	139.9	117.3	119.3	
1965-66	117.3	114.9	102.1	113.9	112.0	101.7	129.3	119.0	108.7	

Table 17. Continued.

Year	Gujarat			Rajasthan			Punjab		
	O	I	TFP	O	I	TFP	O	I	TFP
1966-67	130.8	118.8	110.1	94.5	113.9	83.2	84.5	119.2	71.0
1967-68	184.1	128.7	143.0	122.4	117.5	104.2	153.0	125.3	122.1
1968-69	143.9	126.2	114.1	125.8	120.6	104.3	152.5	125.9	121.3
1969-70	217.7	134.3	162.1	137.4	122.8	111.8	140.0	129.9	107.8
1970-71	223.8	140.2	159.6	147.2	124.8	118.3	147.9	132.2	111.9

Table 17. Continued.

Year	West Bengal			Assam			Maharashtra		
	O	I	TFP	O	I	TFP	O	I	TFP
1952-53	109·3	90·1	121·0	94·2	88·1	106·9	72·5	91·8	79·0
1953-54	118·7	93·4	127·0	93·4	90·7	102·9	91·7	94·9	96·6
1954-55	97·3	94·5	102·9	96·4	93·3	103·3	99·7	97·1	102·7
1955-56	105·4	98·3	107.2	95·7	96·6	99·0	86·8	98·6	88·1
1956-57	100·0	100·0	100·0	100·0	100·0	100.0	100·0	100·0	100·0
1957-58	98·2	101·7	96·6	100·0	103·3	97·1	100·6	100·7	99·9
1958-59	103·6	104·4	99·2	103·0	107·5	95·8	105·8	102·3	103·4
1959-60	104·7	107·7	97·2	102·9	110·8	93·0	97·5	103·4	94·3
1960-61	123·3	110·5	111·6	98·9	114·1	86·9	125·1	104·7	119·5
1961-62	123·3	112·7	109·4	107·3	115·1	93·2	107·1	107·1	100·0
1962-63	115·7	113·7	101·8	98·3	116·5	84·7	110·9	108·5	102·2
1963-64	127·8	115·0	111·1	105·1	117·7	89·4	113·1	110·3	102·5
1964-65	139·8	118·0	118·5	113·1	119·0	95·0	114·3	112·7	101·4
1965-66	109·4	120·0	91·2	111·7	120·4	92·8	84·1	112·4	74·8
1966-67	115·6	121·7	95·0	112·6	121·9	96·4	100·4	116·1	86·5
1967-68	135·5	124·4	108·9	123·7	124·5	99·4	116·3	119·5	97·3
1968-69	115·2	125·8	91·6	120·5	127·3	94·7	122·4	122·1	100·2
1969-70	149·9	130·6	114·8	135·6	129·2	105·0	120·6	124·3	97·1
1970-71	139·6	132·9	105·1	130·2	127·7	101·9	99·3	124·6	80·1

Year	Madhya Pradesh			Orissa			Andhra Pradesh		
	O	I	TFP	O	I	TFP	O	I	TFP
1952-53	76·6	89·1	85·9	99·7	93·4	100·7	85·1	90·8	93·8
1953-54	83·8	92·0	83·3	99·2	95·3	104·1	92·4	93·5	98·9
1954-55	85·6	94·9	90·2	97·7	97·2	100·5	96·9	95·2	101·9
1955-56	86·7	97·1	89·3	95·6	98·7	96·9	94·5	97·9	96·7
1956-57	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
1957-58	77·2	100·7	76·7	78·8	101·6	77·6	99·5	100·7	98·7
1958-59	104·2	104·7	99·5	95·2	103·4	92·1	106·0	102·8	103·1
1959-60	100·4	107·3	93·6	108·1	109·4	98·8	107·3	104·1	103·0
1960-61	107·1	108·9	98·3	109·0	116·1	93·9	104·4	105·5	98·0
1961-62	99·6	109·9	90·6	112·4	120·4	93·4	111·9	107·8	103·8
1962-63	92·2	110·2	83·7	112·9	125·7	89·8	107·7	111·9	96·2
1963-64	102·3	111·3	91·9	127·3	122·9	103·5	115·7	113·6	101·8
1964-65	113·5	112·1	101·2	131·5	123·7	106·3	122·4	114·2	107·2
1965-66	73·9	112·1	65·9	120·2	125·4	93·8	95·3	111·2	85·5
1966-67	69·0	114·4	60·3	135·1	127·1	106·3	117·2	116·6	100·6
1967-68	109·8	118·3	92·8	139·8	128·5	108·8	117·2	114·0	102·9
1968-69	101·3	122·2	82·9	154·7	129·6	119·4	110·7	121·0	92·3
1969-70	105·2	122·8	85·9	144·9	133·4	108·6	120·0	121·7	98·6
1970-71	113·2	124·8	90·7	146·7	136·3	107·6	115·7	121·7	95·1

Table 17. Continued.

Year	Kerala			Mysore			Tamil Nadu		
	O	I	TFP	O	I	TFP	O	I	TFP
1952-53	89·3	95·5	93·5	75·2	85·4	88·1	67·9	85·7	79·3
1953-54	92·5	97·8	94·6	95·6	92·1	103·8	83·2	91·2	91·2
1954-55	95·8	100·0	95·8	100·8	95·1	106·0	95·5	94·5	101·1
1955-56	98·6	100·0	98·6	105·4	97·2	108·5	96·0	96·5	99·5
1956-57	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
1957-58	101·3	100·9	100·4	111·7	101·6	109·9	102·9	102·7	100·2
1958-59	104·9	101·7	103·2	113·2	104·9	111·4	102·3	106·5	96·1
1959-60	111·0	103·1	107·7	116·7	108·2	107·8	108·5	110·0	98·6
1960-61	111·8	104·4	107·1	113·2	112·5	100·6	116·5	115·1	101·2
1961-62	110·1	107·3	102·6	118·7	113·6	104·5	119·6	117·2	102·6
1962-63	114·5	110·2	103·9	126·2	115·8	109·0	120·1	120·0	110·0
1963-64	116·6	112·3	101·2	123·9	117·9	105·1	121·5	123·2	98·6
1964-65	116·1	115·9	100·2	134·4	119·6	112·4	120·1	126·7	94·8
1965-66	104·8	118·1	88·8	99·1	122·9	81·0	113·4	128·1	88·5
1966-67	113·4	121·4	93·4	119·7	124·3	96·3	121·1	129·5	93·5
1967-68	116·9	124·0	94·3	115·4	124·0	93·1	120·7	131·1	92·1
1968-69	142·6	132·9	107·3	141·8	127·4	111·3	111·4	130·5	85·4
1969-70	124·4	129·9	95·8	137·5	128·3	107·2	130·6	135·4	96·5
1970-71	128·4	132·8	96·7	140·1	129·1	108·5	141·8	138·5	102·4

Source: Evenson and Jha, pp. 224-227.

over the past 25 years continues, accelerates, or declines will depend to no small degree on the continued commitment of the Indian government to agricultural progress in the form of adequate resources.

Data on the budget for a country such as India are somewhat easier to work with than in a country like Brazil because the successive five year plans provide a unified budget which, even if not completely fulfilled, at least gives a measure of the intent of policy makers.

Data on the first four plans of the Indian government are summarized in Table 18 (from Mellor, p. 298). The changing emphasis of the government can be detected from the data. In the 1950's and early 1960's India chose not to make a major commitment to agriculture. Irrigation and power received major emphasis in the First Plan, with agricultural programs receiving approximately 10 percent of the budget. In the Second Plan, the share for agricultural programs declined to 6 percent of the total, and irrigation and power declined from 28 percent to 19 percent. Industry and minerals experienced a large increase in its relative share.

The share for agricultural programs went up again in the Third Plan, and increased still further in the Fourth Plan. These last two plans had specific line items - for the first time - for agricultural production. As Mellor notes in his discussion of the successive plans, these shifts in budgetary commitment reflect changes in the performance of the agricultural sector, and changes in the policy to do something about it.

Table 18. Planned Financial Provisions, First Four Five-Year Plans, India, 1950-51 to 1970-71.

Planned provisions	First Plan		Second Plan		Third Plan		Fourth Plan	
	Rupee crores	Percent	Rupee crores	Percent	Rupee crores	Percent	Rupee crores	Percent
Agricultural programs	233	9.9	294	6.1	688	8.5	1,944	12.2
Agricultural production					226	2.8	720	4.5
Minor irrigation	197	8.3	170	3.5	177	2.2	520	3.2
Soil conservation					73	0.9	218	1.4
Animal husbandry	22	1.0	56	1.1	54	0.7	142	0.9
Dairying and milk supply					36	0.4	59	0.4
Forests	10	0.4	47	1.0	51	0.6	122	0.8
Fisheries	4	0.2	12	0.3	29	0.4	113	0.7
Warehousing, marketing, and storage	-	-	9	0.2	42	0.5	50	0.3
Community development and cooperation	124	5.2	274	5.7	403	5.0	466	2.9
Cooperation	8*	0.3	47	1.0	80	1.0	206	1.3
Community development	90	3.8	200	4.1	294	3.6	260	1.6
Panchayats	26	1.1	27	0.6	29	0.4		
Irrigation and power	661	28.1	913	19.0	1,680	20.7	2,994	18.7
Irrigation	384	16.3	381	7.9	599	7.4	849	5.3
Flood control	17	0.7	105	2.2	61	0.8	115	0.7
Power	260	11.1	427	8.9	1,020	12.6	2,030	12.7
Industry and minerals	179	7.6	890	18.5	2,147	26.5	4,306	26.9
Industries and minerals	149	6.3	690	14.4	1,882	23.2	3,936	24.6
Village and small industries	30	1.3	200	4.1	264	3.3	370	2.3
Transport and communication	557	23.6	1,385	28.9	1,655	20.4	3,010	18.8
Social services	533	22.6	945	19.7	1,416	17.5	3,210	20.1
Miscellaneous	69	3.0	99	2.1	110	1.4	70	0.4
Grand total	2,356	100.0	4,600	100.0	8,099 †	100.0	16,000	100.0

* Includes Rs. one crore for "miscellaneous" agricultural programs.

** Excludes a provision of Rs. 200 crores for "inventories".

Note: One crore is equal to 10 million.

Sources: First and Second Plan periods: Second Five-Year Plan (New Delhi: Government of India, Planning Commission, 1956), p. 51; Third Plan period: Third Five-Year Plan (New Delhi: Government of India, Planning Commission, 1961), pp. 85-88; Fourth Plan provision: Fourth Five-Year Plan: A Draft Outline (New Delhi: Government of India, Planning Commission, 1966), pp. 41-72-74, 185, 219, 227, 242, 257, 297, as reported in Mellor (1976), p. 298.

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APPENDIX A

INDICES FOR THE MEASUREMENT OF CHANGES IN AGRICULTURAL PRODUCTIVITY 1/

This appendix expands upon the material presented in the text on the measurement of changes in total factor productivity in somewhat more technical terms. Most official index number computations made by U.S. government agencies use base period weighting schemes. 2/ For example, a common input quantity index is the Laspeyres index, which can be written as: 3/

$$\frac{X_1}{X_o} = \frac{\sum P_{io} X_{i1}}{\sum P_{io} X_{io}} = \sum W_{io} \left(\frac{X_{i1}}{X_{io}}\right),$$

where

$$W_{io} = \frac{P_{io} X_{io}}{\sum P_{jo} X_{jo}}, \text{ and}$$

where the subscript zero refers to the base period and one to the comparison period. By holding prices constant in the base period, the Laspeyres index purports to tell us how much of the change in total input resulted from pure quality changes.

More recently, the Laspeyres index has been subject to criticism, and a number of studies in the theory of index numbers have argued that the Divisia index is preferable to the Laspeyres index. In continuous time the Divisia

1/ The Appendix draws heavily upon the work of Christensen (1975).

2/ For example, U.S.D.A. computations of total farm output and input for the U.S. and other countries (as described in Section III of this document).

3/ On the assumption that producers equate factor prices with value of marginal products, prices are used to weight input quantities.

index is defined as:

$$\frac{X(t)}{X(0)} = \exp\left\{\int\left(\sum W_i(t)\left(\frac{\dot{X}_i(t)}{X_i(t)}\right)\right)\right\}$$

where $W_i(t) = \dfrac{p_i(t)\,X_i(t)}{\sum p_j(t)\,X_j(t)}$.

Several discrete time approximations to the Divisia index have been proposed, but the most common in current research appears to be the (arithmetic average) weighted log-change index:

$$\log\left(\frac{X_1}{X_0}\right) = \sum \bar{W}_i \log\left(\frac{X_{i1}}{X_{i0}}\right),$$

where $\bar{W}_i = \dfrac{W_{i1} + W_{i0}}{2}$

This is known as the Tornqvist approximation to the Divisia index.

Jorgenson and Griliches have demonstrated that the much criticized Laspeyres index itself can be interpreted as a discrete approximation to the Divisia index. This turns arguments about the attractiveness of the Divisia over the Laspeyres index meaningless. However, other recent work (Afriat, Diewert, Pollak, Samuelson and Swamy) has demonstrated that many index number formulaes represent <u>exactly</u> particular production functions. The Laspeyres index has been shown to be exact for a linear production function. That is, when the Laspeyres index is used, it carries the implicit assumption that all inputs are perfect substitutes in the production process. The Tornqvist approximation is exact for the homogeneous trans-log production function (Christensen, Jorgenson, and Lau). This functional form is referred to as flexible in that it can approximate any arbitrary twice differentiable homogenous production function. No a priori restraints are imposed upon the substitution possibilities among inputs.

Production economics theory demonstrates that the firm maximizes profits when each input or factor of production is used up to the point where the value of its marginal product equals its purchase price. This simultaneously determines the optimum proportions in which factors are employed, given the technologically determined substitution possibilities. The linear production function is considered an inappropriate analog of most real world phenomena. As Christensen has argued, perfect substitutability among inputs implies that any change in relative price causes complete substitution of one input for another. There would be no reason for using any of a higher priced perfect substitute. So, if all inputs are used in both the base and the comparison periods, the relative prices must be unchanged. But then there would be no reason to employ base period price weights because they must necessarily be unchanged. The important point is that users of Laspeyres input quantity indices are implicitly assuming perfect substitutability among inputs. This suggests that use of some other index number formula which is at least equivalent to a production function which assumes less than perfect factor substitutability would be preferable.

As indicated above, the translog function does not require inputs to be perfect substitutes. Therefore, prices from both the base and the comparison period enter the Tornqvist index to represent marginal productivities in both periods. Particularly when the time period between the base period and the comparison period is not short, or there have been substantial changes in relative prices, it is argued here that the Tornqvist approximation is at least preferable to the Laspeyres index. [1/]

[1/] Diewert has shown that Fisher's ideal index (the geometric mean of the Laspeyres and Paasche indexes) is exact for the quadratic production function, which is also flexible.

Solow proposed a measure of total factor productivity based upon the Cobb-Douglas production function with constant returns to scale and autonomous and neutral technological change. This index formula is preferable to the Laspeyres index because the Cobb-Douglas production function assumes inputs are less than perfect substitutes. On the other hand, it is more restrictive than the Tornqvist approximation to the Divisia index, because the Cobb-Douglas function forces an elasticity of substitution of one between all pairs of inputs (in contrast to the translog function which imposes no a priori restriction on the degree of substitutability among inputs.) For a production function,

$$Y = AX_1^{b1} X_2^{b2} \ldots X_n^{bn}, \qquad \sum b_i = 1.0,$$

the Solow index is:

$$A = Y - \sum_{i=1}^{n} b_i \hat{X}_i,$$ where the "^" represents the percentage change in a variable, and the b_i represent factor shares. In a competitive equilibrium the b_i could be obtained by statistically estimating the production function or by direct calculation from cost data. The result should be the same. However, consistent with the Divisia index discussion above, the input aggregation weights, b_i, should be calculated or estimated for short time periods because the appropriate productivity index is a "chain-linked index" with the aggregation weights changed often.

Each of the index number formulas discussed in detail above assumes the production function is homogeneous of degree one, i.e. constant returns to scale prevail. If the production function is homogeneous of degree other than one, then part of the measured change in total factor productivity is due to scale economies or diseconomies rather than to technological change.

Christensen (1975) has argued that the usual approach to calculating total factor productivity may not be completely correct when the factor - saving bias of technological change is induced by relative factor prices. Further research will be required to assess what errors this may introduce in conventional measures of total factor productivity in agriculture.

APPENDIX B

SPECIFICATION AND MEASUREMENT OF INPUTS AND OUTPUTS

The study of changes or differences in aggregate productivity generally requires either an aggregation over heterogeneous inputs or an aggregation over heterogeneous outputs. In this Appendix we briefly review certain considerations that need to be taken into account in measuring inputs and outputs for purposes of productivity analysis.

As a starting point, consider the output variable, which generally represents gross output of the sector. Gross output is used rather than net output, since intermediate outputs (inputs) such as seed, fertilizer, livestock feed and the like are important in agricultural production. 1/ If all intermediate inputs were used to the point where the value of their marginal products equalled their respective prices or marginal factor costs, working with net output might be equally correct. However, if this were not the case, the intermediate inputs should be explicitly included when doing productivity accounting in order to take account of contribution to production of these inputs.

The most common procedure for aggregating outputs of various products is to use product prices as weights. The sum is simply the total value of agricultural output.

1/ Much of the empirical research on productivity, particularly that dealing with research on the industrial sector (for example, that of Kendrick and of Kravis), has utilized a value-added measure of output, and considers capital and labor to be the only inputs utilized in generating this value-added. However, as Domar (1967) has argued, "It seems to me that a production function is supposed to explain a productive process such as the making of potato chips from potatoes (and other ingredients, labor, and capital). It must take some ingenuity to make potato chips without potatoes". (p. 471).

Mundlak has pointed out that aggregate output, properly measured, should be the same at all points on a given transformation curve (which represents given quantities of the various factors of production). For the production function to be a single-valued function of inputs, there will be one and only one output (1963b, p. 433).

The value of the composite output is not invariant under changes in relative prices, however. As a consequence, one is restricted to a comparison of outputs which correspond to the same price relatives. To circumvent this problem, some "base-state" or mean set of prices is often utilized to aggregate the output. [1/] The price weights chosen should ideally represent as close to an equilibrium situation as possible. Although such a set of "alien" price weights does not represent the prices on which the resource allocation decision was made in a given situation, it has the advantage of using weights that are subject to random disturbances.

The measurement of inputs gives rise to other classes of problems. It should first be observed that there are two basic classes of inputs in agriculture: durables, such as machinery and equipment, which generate a flow of services over time, and current inputs that are fully utilized in the production cycle, e.g. fertilizers and livestock feed. The latter present few problems, and the total physical quantities used may be entered as inputs in the production function. However, only the flow of services, and not the stock, of a durable input is relevant as a measure of the input when it is a durable good.

[1/] Alternatively, the composite output of each state (region) could be "deflated" by an appropriate price index, so that output is evaluated at fixed prices. It should be emphasized that both procedures assume that all products are homogeneous between states and that product price differences do not represent different qualities of the respective products.

The assumption that the flow of services from an input is proportional to the stock implies that both the stock of the input and the flow of services from it must be homogeneous. Every unit of the stock must have the same durability, and there must be no deterioration of the current flow of services with age. That is, the stock renders the same regular stream of services every period until it is retired. Under these conditions the flow of services is proportional to the stock. (This was demonstrated by Yotopoulos (p. 116).

The land input satisfies these requirements as long as different qualities are defined as different inputs or the area of each quality of land is adjusted by some index of quality, and if land is assumed to have infinite durability. In this case, the flow of services of land would be proportional to the stock.

The relevant measure of land services in a perfect market would be the rental price per hectare per production period (usually considered one year) in agricultural uses. However, the land market is far from perfect, and land has alternative non-agricultural uses. 1/

We turn now to consideration of the second large class of durable inputs —

1/ An "hedonic price index" (Griliches (1963a)) might be constructed by estimating implicit prices per unit of certain quantitative dimensions of land which are assumed to influence its prices. The price of land or the annual land rental cost could be regressed on the quality dimensions for which data are available. The list might include: percent organic matter, parts per million P_2O_5, parts per million K_2O, pH, average slope (percent), mean annual precipitation (mm), standard deviation of annual precipitation (millimeters), distance to an asphalt road (kilometers). (With time series data, the sale price of land would also be influenced by the rate of inflation (percent) and the rate of acceleration of inflation (percent).)

The implicit prices of agriculturally associated quality dimensions so obtained from the multiple regression could be used to create an index of land quality, with the implicit prices taken as weights. This index might then be used to adjust the data on land area to put it in constant quality units.

capital. Some of the problems that occur in measuring this input can be avoided by disaggregating capital into a number of relatively homogeneous inputs. However, to the extent that aggregation of capital does occur, there are two basic measurement problems. First, it is incorrect to aggregate capital of the same vintage without adopting some form of weighting system to allow for differences in the productivity of capital in different activities. Second, capital may vary in productivity because it is not of the same vintage.

If capital services were bought and sold in a similar fashion to say, labor services, one could construct a quantity index of total capital input from data on the value of transactions in each type of capital service. Each such transaction would represent a price of capital service or rental and a quantity of capital service in, say, machine-hours. A quantity index of total capital input could then be constructed using the relative shares of the rental value of each capital service in the rental value of all capital services to weight the quantitites of each type of capital service. However, this procedure is rarely feasible since capital goods are usually owned by the firm which utilizes their services. As a result, the consumer of the capital service is usually also the supplier of the service. [1/]

Griliches has argued that it is incorrect to measure capital services by the net value of the capital stock on the assumption that the flow of services is proportional to the stock. The value of the stock of capital at any point in time is the current valuation of current and all future services expected from the stock, whereas current productivity is only the value of current services from the stock. He points out that, "The two measures will diverge if the average age

[1/] This paragraph draws upon Griliches and Jorgenson and Jorgenson and Griliches.

of equipment is changing...and if there are anticipations of future price changes or technical advances." (1960) (p. 1417).

The net measure of capital, i.e. net of depreciation, is incorrect since it reflects only the age of the capita. If a machine yields identical services every year of its life, it should have the same value regardless of the net worth of the machine. Gross capital is more satisfactory, especially if corrected to take into account the decline in efficiency of a piece of equipment as it ages, rather than the decline in its value.

As a measure of the services of capital equipment in agriculture, Griliches suggests that one assume there is no deterioration with age and that the service flow is constant over the life span of a machine. In this case the flow of services is constant and equal to the sum of interest and depreciation charges. As the machine ages, the interest charges will fall and the depreciation charges will rise, with their total remaining constant. Given these assumptions, the service flow is a constant fraction of the original value of the machine throughout its life. So, if all machinery had a fixed life of 15 years, for example, a 15-year moving sum of past gross investments would be the relevant 'stock' figure to be converted at a constant rate into the flow of services concept in time-series analysis (1960) (p. 1417).

The third large class of inputs to be considered is labor. The stock of labor in the sector is measured by the number of people economically active in the sector. The associated flow concept is man-hours of labor services. If all labor were of homogeneous quality, it would be a simple matter to use man-hours of labor services as a measure of the labor input (or number of people economically active, assuming each works the same number of hours per period.)

However, the assumption that all labor is of homogeneous quality appears

rather strong. The quality of labor services rendered may vary due to the differences among workers in education (formal or on-the-job), nutrition, sex, age, motivation, etc. One means of adjusting labor force data for quality differences would again be to use an "hedonic price analysis" to derive relative implicit market prices which could be used as weights for "correcting" the data. [1/] A simplified approach is to consider education as the only (or principal) factor associated with differences in wages, and then to take the relative wage or income of persons in each educational strata as weights.

Whether one wants to correct for such differences in quality depends, of course, on the particular approach taken to measuring productivity. However, even when the approach is to let changes or differences in productivity reflect the progress being made in agriculture, care must be taken to correct for those differences that are not due to the control of policy makers. Hence, differences in demographic characteristics such as age and sex should be taken into account.

[1/] An hedonic price index of labor can be derived by regressing the wage rate on various measurable characteristics of the labor force assumed to be associated with its quality, such as education, age, and sex. This is really nothing more than estimating a so-called "income generating function", such as has been utilized to test the hypotheses of human capital theory, (Becker (1964), Griliches (1970)).