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AGRICULTURAL PRODUCTIVITY DIFFERENCES AMONG COUNTRIES

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The source of productivity growth over time, and of productivity differences among countries and regions have emerged as a central unifying theme of growth theory and development economics.[1] In recent years a concensus seems to have emerged to the effect that productivity growth in the agricultural sector is essential if agricultural output is to grow at a sufficiently rapid rate to meet the demands for food and raw materials that typically accompany urbanization and industrialization.[2] Failure to achieve rapid growth in agricultural productivity can result either in the drain of foreign exchange or in shifts in the internal terms of trade against industry, and thus seriously impede the growth of industrial production. Failure to achieve rapid growth in labor productivity in agriculture can also raise the cost of transferring labor, and other resources, from the agricultural to the nonagricultural sector as development proceeds.

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* Extract. The American Economic Review, Vol. LX, No.5, December 1970.

1 J.R. Hicks has suggested that growth theory and development economics have no connection. This view would seem to be invalid in view of Hicks' own criteria. See A.O. Krueger.

2 See articles by Irma Adelman and Cynthia T. Morris, Dale W. Jorgenson, Gustav Ranis and J.C.H. Fei, and V.W. Ruttan.

Extremely wide differences in agricultural productivity exist among countries. Agricultural output per worker in India is approximately one-fiftieth of that in the United States. Relatively few underdeveloped countries have achieved levels of output per worker one-fifth as high as in the United States. Furthermore, these differences have widened during the last decade.[3] This lag in the rate of productivity growth in agriculture represents a serious constraint on economic growth in many developing economies.

Recent empirical research supports a classification of the sources of productivity differences, or of productivity growth, into three broad categories, (a) resource endowments, (b) technology, as embodied in fixed or working capital, and (c) human capital, broadly conceived to include the education, skill, knowledge and capacity embodied in a country's population. Although this is clearly an oversimplification it does represent a substantial advance over the earlier emphasis on a single key or strategic factor.[4]

Our analysis indicates that the three broad categories outlined above account for approximately 95 per cent of the differences in labor productivity in agriculture between a representative group of Less Developed Countries (LDC's) and of Developed Countries (DC's). In this comparison the three factors are of roughly equal importance. When compared to the DC's of recent settlement (Australia, Canada, New Zealand, and the United States) favorable resource endowments account for somewhat more than one-third of the differences.

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3 See Hayami and associates.

4 See studies by Zvi Griliches, A.O. Krueger, R.R. Nelson, and T.W. Schultz.

Resource endowment is the major factor accounting for differences in labor productivity between the DC's of recent settlement and the older DC's. Nevertheless it seems apparent that the LDC's could, over time, achieve labor productivity levels in agriculture well over half as high as in the more recently settled DC's, roughly comparable to the levels achieved in the older DC's, through increased use of technical inputs supplied from the industrial sector and improvements in the quality of the labor force, even in the absence of substantial changes in man-land ratios.

I. The Method and the Data

The approach used in this study involves the estimation of a cross-country production function of the Cobb-Douglas type for thirty-eight developed and underdeveloped countries.[5] Differences in agricultural output per worker are accounted for by differences in the level of conventional and nonconventional inputs per worker, classified as (a) internal resource accumulation, (b) technical inputs supplied by the

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5 Countries included are : Argentina, Austria, Australia, Belgium, Brazil, Canada, Ceylon, Chile, Colombia, Denmark, Finland, France, Germany, Greece, India, Ireland, Israel, Italy, Japan, Mauritius, Mexico, Netherlands, New Zealand, Norway, Peru, Philippines, South Africa, Spain, Surinam, Sweden, Switzerland, Syria, Taiwan, Turkey, U.A.R., U.K., U.S.A., and Venezuela.

nonagriculture sector, and (c) human capital.[6] All the data used in this study are taken from a recent compilation of international agricultural production statistics by Yujiro Hayami and associates.[7]

Production functions were estimated for three different periods; 1955 (1952-56 averages), 1960 (1957-62 averages), and 1965 (1962-66 averages).[8] The analysis was conducted in gross output (net of seeds and feed) terms in order to include the effects of current intermediate inputs such as fertilizer. Individual agricultural commodities were aggregated by the farm gate (or import) prices of the United States, Japan and India, to produce three different output series. The series were then averaged geometrically into a single composite output series which [illegible]

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6 For a report on a preliminary attempt see Hayami (1969, 1970). Major extensions from the previous study include: (a) a comprehensive revision of data; (b) introduction of the livestock variable; (c) analysis on a per farm basis in addition to a national aggregate basis; (d) test of stability of the production function over time; and (e) refinements in the procedures used to account for productivity differences.

7 The basic data were collected from publications by the United Nations organizations (FAO, ILO and UNESCO), the Organization for Economic Cooperation and Development, and the governments of various countries. These data were processed by Hayami and associates to be consistent with the definitions of variables and, also, to be comparable among countries. Earlier estimates of agricultural outputs reported by Hayami and Inagi were substantially revised for this study.

8 Averages were taken for flow variables (output and fertilizer input). Stock variables were in principle measured by 1955, 1960, and 1965 levels. It would seem more consistent to have averages of 1953-57, 1958-62, and 1963-67, but the original estimates of agricultural output are of 1957-62 averages (see Hayami and associates) and, when we tried to extend the 1958-62 output series to 1955 and 1965, the FAO index of agricultural production was available only until 1966.

was used as the dependent variable.[9]

The independent variables used in the study include labor, land, livestock, fertilizer, machinery, education, and technical manpower. In summing up the effects of resource endowments, technology, and human capital on productivity per worker, land and livestock serve as proxy variables for internal resource accumulation; machinery and fertilizer for technical inputs; and general and technical education in agriculture for human capital.

Land(measured by hectares of agricultural land) used for agricultural production cannot be regarded as a mere gift of nature. It represents the result of previous investment in land clearing, reclamation, drainage, fencing, and other development measures. Similarly, livestock (as measured by livestock units) represents a form of internal capital accumulation. Thus, in our perspective, land and livestock represent a form of long-term capital formation embodying inputs supplied primarily by the agricultural sector.[10] Both high inputs of land and of livestock per worker tend to be associated with low levels of labor and high levels of land per unit of output. In contrast, fertilizer (as measured by the N + P_2O_5 + K_2O in commercial fertilizers) and machinery (as measured by tractor horsepower) represent inputs supplied by the industrial sector. Technical advances stemming from

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9 This procedure was applied for 1960 data. 1955 and 1965 output estimates were extrapolated from the 1960 estimates by using the FAO indexes of agricultural production by countries.

10 Perennial plants belong to the same category of inputs as livestock; but they are not included due to the lack of data.

both public and private sector research and development are embodied in or complementary to these modern industrial inputs. Mechanical innovations are usually associated with larger inputs of power and machinery. Biological improvements, such as the innovations embodied in high yeilding varieties, are typically associated with higher levels of fertilizer use. In this analysis these two industrial inputs represent proxies for the whole range of inputs which carry modern mechanical and biological technologies.

The proxies for human capital include measures of both the general educational level of the rural population and specialized education in the agricultural sciences and technology. Two alternative measures of the level of general education were attempted: (a) the literacy ratio and (b) the school enrollment ratio for the primary and secondary levels. Both sets of data are deficient in that they apply to the entire population and are not sensitive to differences in the quality of rural and urban education. Education in the agricultural sciences and technology was measured by the number of graduates per ten thousand farm workers from agricultural faculties at above the secondary level. These graduates represent the major source of technological and scientific personnel for public sector agricultural research and extension and for research development and marketing in the private agribusiness sector.[11]

A critical assumption in this approach is that the technical possibilities available to agricultural producers in the different countries can be described by the same

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11 In a sense this variable may be superior as the proxy for the level of research and extension to the "state average of public expenditure on research and extension per farm" used by Griliches, because our variable reflects the research and extension activities in the private sector as well as in the public sector.

production function. Cross-section production functions, using individual countries or regions as observations, have been widely used. Cross-country aggregate production functions for the agricultural sector were first estimated by Jyoti Bhattacharjee in 1953. An aggregate agricultural production function similar to that used in this study, using states in the United States as observations was employed by Zvi Griliches in an attempt to account for the impact of research and education on agricultural output. Anne Krueger's recent efforts to estimate the contribution of factor endowment differentials to variations in per capita income employs the assumption that all countries are subject to a uniform production function.

In a recent paper Richard Nelson has argued that the assumptions of a common production function "... get in the way of understanding international differences in productivity--particularly differences between advanced and underdeveloped countries" (p.1229). Nelson's objections appear directed primarily to the empirical results obtained from use of relatively primitive two-factor production functions, where intercountry differences in value-added per worker are related to the capital-labor ratio. He insists, as a result of differential diffusion of new technology, that "... at any given time one would expect to find considerable variation among firms with respect to the vintage of their technology, certainly between countries, but even within a country" (p.1230).

We share the Nelson perspective. Agricultural producers in different countries, in different regions of the same country, and on different farms in the same region are not all on the same micro-production function. This reflects differences among producers in their ability to adopt new technology. More importantly, it is also the result of differential diffusion of agricultural technology, and, to an even greater degree, of differential diffusion of the scientific and technical capacity to invent and develop new mechanical, biological, and chemical technology specifically adapted to the factor endowments and prices in a particular country or region.

We may call the envelope of all known and potentially discoverable activities a secular or "meta-production function". The full range of technological alternatives described by the meta-production function is only partially available to individual producers in a particular country or agricultural region during any particular historical "epoch".[12] It is, however, potentially available to agricultural scientists and technicians.

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12 In the short run, in which substitution between capital and labor is circumscribed by the rigidity of existing capital and equipment, production relationships are best described by an activity with relatively fixed factor-factor and factor-product ratios. In the long run, in which the constraints exercised by existing capital disappear and are replaced by the fund of available technical knowledge, including all alternative feasible factor-factor and factor-product combinations, production relationships can be adequately described by the neoclassical production function. In the secular period of production, in which the constraints given by the available fund of technical knowledge are further relaxed to admit all potentially discoverable knowledge, production relationships can be described by a meta-production function which describes all potentially discoverable technical alternatives. The meta-production function can be regarded as the envelope of neoclassical production functions. Although the term is not employed, the meta-production function concept is implicit in the work of Murray Brown and of W.E.G. Salter. We have discussed the rationale for the metaproduction function concept in Japanese and U.S. agricultural development in greater detail elsewhere (see Hayami and Ruttan). The elasticity of substitution among factors increases continuously as the time period increases from the short run to the secular period.

We view the common or cross-country production function which we have estimated as a meta-production function. It is assumed that the invention and diffusion of a new "location specific" agricultural technology through the application of the concepts of physical, biological, and chemical science and of engineering, craft, and husbandry skills, is capable of making the factor productivities implicit in the cross-country production function available to producers in less developed countries. It is also assumed that the capacity of a country to engage in the necessary research, development and extension is measured by the two proxy variables for human capital, namely general education and technical education in agriculture. It appears to us that this effort, and that of Griliches and Krueger, are not inconsistent with the perspective presented by Nelson in his criticism of the empirical results obtained from two factor cross-country production functions.

The production function employed in this study was of the Cobb-Douglas type. It was used mainly because of its ease in manipulation and interpretation. A test presented in the Appendix* indicates that the unitary elasticity of substitution implicit in the Cobb-Douglas production function is an acceptable assumption. The ordinary least squares estimation procedure was used. The possibility of simultaneous equation bias seems small because all inputs, except fertilizer, are measured in stock terms and can be treated as predetermined. In a few cases, however, the method of instrumental variables was tried to see if any different inferences might be drawn. The assumption of a common production function among countries is a testable hypothesis. However,

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* Appendix is not reproduced here.

it appears that the data used in this study are too crude to be employed for such a test.[13]

II. Estimation of the Production Function

We conducted an especially detailed analysis for 1960 because of (a) better comparability of output data and (b) availability of data for the number of farms in that year.[14]. The estimation was made both on per farm data (output and conventional inputs deflated by the number of farms) and on national aggregate data. The results from these two sets of data are not sufficiently different to lead to different inferences regarding the agricultural production structures among countries.

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13 In order to test the assumption that farmers in different countries face the same production function, the production function was estimated separately for the two different groups of countries (DC and LDC's). The estimation was tried for various groupings of DC's and LDC's, but the results are all implausible with most of the coefficients statistically nonsignificant or negative in sign. It seems that measurement errors in our observations (especially of nonconventional variables) are too large to make it possible to estimate the influences of variables for the groups of countries within which the ranges of data variations are relatively small. The basic assumption is, therefore, not testable on the presently available data. All we can claim is that differences in agricultural productivity among countries can be explained well with this assumption.

14 The 1960 World Census of Agriculture provides the data of the number of farms for a large number of countries. Comparable data are available for only a small number of countries for 1955 and 1965. See also fn.9.

Considering the crudeness of data, the levels of statistical significance of the estimated coefficients seem satisfactory in most cases. The coefficients stay fairly stable when nonconventional variables are added or subtracted, though the coefficients for labor and livestock tend to move opposite to the coefficient for machinery. The results of estimation by the method of instrumental variables (denoted as IV) compared with the least square estimates provide no prima facie evidence against the use of least squares.

Attempts to include other variables, e.g., the ratio of irrigation land to total land area and the ratio of cropland to pasture land, were tried in an attempt to adjust for differences in the quality of land input; but it turned out that the coefficients for such variables are either negative or nonsignificant.[15]

Plausibility of the estimates may be checked by a comparison with the results of earlier attempts to estimate aggregate production functions in various countries. Bhattacharjee obtained aggregate production elasticities for his cross-country production function (including only conventional variables) centered on 1950 of around 0.3 for labor; 0.3 to 0.4 for land; and 0.3 for fertilizer. The coefficients for livestock and tractors were not significant at commonly accepted levels. The Bhattacharjee results indicate higher production elasticities for land and fertilizer than the results obtained in our study. It would appear that

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15 This does not necessarily mean that such variables have no significant influence, but rather it means that the presently available data are too crude to estimate the influences of such variables.

our model is somewhat better specified in that we obtained statistically meaningful coefficients for livestock and machinery as well as for the two proxy variables for human capital.

The aggregate production elasticities of U.S. agriculture were estimated by Griliches as 0.4 to 0.5 for labor; 0.1 to 0.2 for land, fertilizer and machinery; 0.3 to 0.5 for education; 0.04 to 0.1 for research and extension. It is rather surprising that the Griliches' estimates, despite the completely different nature of the data used, coincide so well with the ones in this study.

The production elasticities estimated for Japanese agriculture by Yasuhiko Yuize in value-added terms are in the ranges of 0.4 to 0.6 for labor and 0.2 to 0.4 for land. Such figures are consistent with the estimates in this study since according to the social account study by the Japanese Ministry of Agriculture and Forestry the ratio of value-added to gross output was around 0.7 in Japanese agriculture in the period when Yuize's study was made. In the less developed countries we do not have comparable estimates of the aggregate agricultural production function. Theodore Schultz has, however, inferred from the impact of the 1918-19 influenza epidemic that the production elasticity of labor in Indian agriculture was 0.4. This is consistent with our estimates. Such consistency with other studies gives support to the results of estimation in this study.

Griliches has found that in U.S. agriculture, a given percentage increase in education, which improves the quality of labor, has the same output effect as an equal percentage increase in labor itself. In order to test whether the same assertion holds in the international dimension, we have estimated the production function by combining labor

L and general education E in a multiplicative form L x E; this resulted in little change (compare regressions 2 with 4, 3 with 5, 7 with 9, and 8 with 10). Furthermore, the analysis of variance provides evidence in support of the equality in the coefficients of labor and general education.[16]

Judging from the sums of coefficients of conventional inputs, compared with the standard errors of those sums (shown in parentheses below the sums of coefficients), constant returns seem to prevail both on the farm firm level and on the national aggregate level. Note, however, that increasing returns prevail when both private and socially controlled inputs are allowed to vary. The constant returns at the farm firm level may explain the existence of farms of extremely different sizes producing the same commodities.. The constant returns at the national aggregate level might be one of the distinctive characteristics of agricultural production and, if so, would have important implications for the intersectoral investment priorities for national economic development.

The stability of the agricultural production function over time is tested on the 1955, 1960, and 1965 cross-country samples. Because comparable data on the number of farms were not available for 1955 and 1965, we assumed the linear homogeneity in the Cobb-Douglas production function and regressed output per capita (per male worker) on

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16 The F-statistics calculated for testing the equality of the labor and education coefficients are: 0.22 for Regression 2 vs. Regression 4; 0.31 for Regression 3 vs. Regression 5; 0.65 for Regression 7 vs. Regression 9; 0.77 for Regression 8 vs. Regression 10.

conventional inputs per capita and on non-conventional inputs. In order to make the data comparable among years we restricted the countries included in the sample to 36 (Mauritius and Surinam were dropped from the sample for lack of labor data).

This appears to be caused by high intercorrelation between land area per worker and livestock per worker. Differences in the two sets of estimates do not seem to imply different conclusions. The production parameters seem largely stable over time. The null hypothesis of the equality of the production coefficients among 1955, 1960, and 1965 is accepted according to the results of analysis of variance (the F-statistic calculated from Regressions 12, 13, 14, and 17 is only 0.95).

III. Accounting for Productivity Differences

The results obtained from estimation of the agricultural production function in the previous sections may be used to account for intercountry differences in labor productivity (output per male worker) in agriculture in 1960).

Since our production function is now assumed to be linear homogeneous (with respect to conventional inputs) in the Cobb-Douglas form, the percentage difference in output per worker can be expressed as the sum of percentage differences in conventional inputs and non-conventional inputs per worker each weighted by the relevant production elasticities. Only the school enrollment ratio was used as the education variable in this accounting, but the results would have been essentially the same if the literacy ratio had been used.

Two alternative sets of results are presented. The first set involves group comparisons between LDC's and DC's. The second set involves individual comparisons of selected LDC's and DC's with the United States.

Group Comparisons

The sources of differences in labor productivity between the eleven LDC's and different groups of DC's are presented in Table 3. Each column compares for each group the percentage difference in agricultural output per worker between LDC's and DC's with the percentage differences in input variables weighted by the specified production elasticities. Inside of the parentheses is shown the index with the output-per-worker difference set equal to 100. The countries classified as LDC's, for the purposes of this comparison, all had per capita incomeof less than 350 U.S. dollars and more than 35 per cent of their labor force engaged in agriculture. The countries classified as DC's had per capita income higher than 700 U.S. dollars and less than 30 per cent of the labor force engaged in agriculture. Countries falling between these criteria are not included in the comparisons presented in Table 3.

The difference in average agricultural output per worker between the eleven LDC's and the thirteen DC's of group 1 was 88.8 per cent; the difference between the eleven DC's and the nine older DC's of group 2 was 83.5 per cent; and the difference between the eleven LDC's and the four DC's of recent settlement--group 3--was 93.6 per cent. The six variables included in the production function accounted for 95, 85, and 96 per cent of the difference in agricultural output per worker between the LDC's and the three DC's groups.

TABLE 3$: ACCOUNTING FOR DIFFERENCE IN LABOR PRODUCTIVITY IN AGRICULTURE BETWEEN DEVELOPED COUNTRIES (DC) AND LESS DEVELOPED COUNTRIES (LDC) AS PERCENT OF THE LABOUR PRODUCTIVITY OF DC

	Group 1 (13 DC's)		Group 2 (9 DC's)		Group 3 (4 DC's)	
Difference in output per male worker - per cent	88.8	(100)*	83.5	(100)	93.6	(100)
Percent of difference explained: Total	84.2	(95)	71.1	(85)	90.0	(96)
Resource accumulation:	29.2	(33)	17.5	(21)	32.6	(35)
Land	9.2	(10)	1.8	(2)	9.7	(10)
Livestock	20.0	(23)	15.7	(19)	22.9	(25)
Technical inputs:	24.3	(27)	24.3	(29)	24.5	(26)
Fertilizer	14.5	(16)	14.5	(17)	14.6	(16)
Machinery	9.8	(11)	9.8	(12)	9.9	(10)
Human Capital:	30.7	(35)	29.4	(35)	32.9	(35)
General Education	18.2	(21)	17.6	(21)	19.5	(21)
Technical Education	12.5	(14)	11.7	(14)	13.4	(14)

* Inside of parentheses are percentages with output per worker set equal to 100.

LDC : Brazil, Ceylon, Colombia, India, Mexico, Peru, Philippines, Syria, Taiwan, Turkey, UAR.

DC : Austrialia, Belgium, Canada, Denmark, France, Germany, Netherlands, New Zealand, Norway, Sweden, Switzerland, U.K., U.S.A.

Group 1 includes all DC's;
Group 2 excludes Australia, Canada, New Zealand, and the United States ffrom DC's;
Group 3 includes only the four DC's excluded from Group 2.
Accounting formula:

$$\left(\frac{Y_d - Y_l}{Y_d}\right) = 0.10\left(\frac{a_d - a_l}{a_d}\right) + 0.25\left(\frac{s_d - s_l}{s_d}\right) + 0.15\left(\frac{f_d - f_l}{f_d}\right) + 0.10\left(\frac{m_d - m_l}{m_d}\right) + 0.40\left(\frac{E_d - E_l}{E_d}\right) + 0.15\left(\frac{U_d - U_l}{U_d}\right)$$

where y, a, s, f, m, are respectively, output, land, livestock, fertilizer, machinery per male worker; E and U are, respectively, the general education (school enrollment ratio) and the technical education variable; lower case letter d denotes DC and l denotes LDC.

$ Tables 1 and 2 are not reproduced here.

In the comparison between the eleven LDC's and the thirteen DC's - group 1 - each generalized category, internal resource accumulation (land and livestock), technical inputs from the industrial sector (fertilizer and machinery), and human capital (general and technical education in agriculture), account for approximately one-third of the explained difference in labor productivity.

The main difference between group 1 and the other two groups is the amount of the difference explained by land. Difference in land accounts for only 2 percent of the difference in labor productivity between the LDC's and the older DC's, while it accounts for 19 per cent between the LDC's and the new DC's. This implies that it should be feasible for the LDC's, even with the present land-labor ratios to achieve levels of productivity per worker roughly equivalent to the labor productivity levels achieved by workers in the older DC's - that is, roughly four times as high as present LDC levels and well over half the level achieved by the DC's of recent settlement. The critical elements in achieving such increases in labor productivity are the supply of modern industrial inputs in which the new technology is embodied and the investment in general education and in research and extension which raises the capacity to develop and adopt a more productivity technology.

Comparison of group 2 and 3 results does indicate that resource endowments, particularly land, do represent a serious barrier to efforts of both that LDC's and the older DC's to achieve levels of output per worker comparable to the levels currently enjoyed in the more recently settled DC's. This is the first time, to our knowledge, that the economic advantage of the favourable resource endowments in these countries has been demonstrated quantitatively.

Individual Comparisons

The individual country comparisons presented in Table 4 were developed in order to provide somewhat deeper insight into the sources of differences in labor productivity between different "ideal type" DC's and LDC's and the United States. Each now compares the percentage difference in agricultural output per worker between each country and the United States with the linear combinations of percentage differences in input variables weighted by the specified production elasticities. Inside of the parentheses is the index with the output-per-worker differences set equal to 100. In general, the results are consistent with the group comparisons.

In the four underdeveloped countries - India, Philippines, United Arab Republic, and Colombia - internal resource accumulation accounts for approximately one-third and technical inputs roughly one-fourth of the differences. Human capital accounts for more than one-third of the difference between the United States and India, the United Arab Republic, and Colombia. In the Philippines, which has achieved a relatively high level of schooling and produces a relatively large number of agricultural college graduates, human capital explains less than one-fourth of the productivity difference. The contrast between India and the Philippines in this respect is quite striking.

In the comparisons between the countries of Europe and the United States, differences in internal resource accumulation represent the most significant source of difference in labor productivity. The constraint of land on agricultural productivity is relatively modest for the United Kingdom which experienced the drastic agricultural transformation after the repeal of the Corn Law; it is strongest for

TABLE 4 : ACCOUNTING FOR LABOR PRODUCTIVITY DIFFERENCES FROM THE UNITED STATES AS PERCENT OF U.S. LABOR PRODUCTIVITY, 11 SELECTED COUNTRIES

	Difference in output per worker from U.S. as percent of U.S.	Total	Percentage of difference explained by: Resource accumulation (land and livestock	Technical inputs (fertilizer and machinery)	Human capital (general and technical education)
LDC					
India	97.8	102.1	32.7	25.0	44.4
	(100) [a]	(104)	(33)	(26)	(45)
Philippines	96.2	82.1	33.4	24.9	23.8
	(100)	(85)	(34)	(26)	(25)
UAR	95.6	97.0	33.8	24.6	38.6
	(100)	(101)	(35)	(26)	(40)
Colombia	89.7	89.4	25.8	24.7	38.9
	(100)	(100)	(29)	(28)	(43)
EUROPE					
Denmark	52.3	51.0	20.4	13.2	17.4
	(100)	(97)	(39)	(25)	(33)
Netherlands	56.6	51.7	25.0	15.0	11.7
	(100)	(91)	(44)	(26)	(21)
United Kingdom	55.8	50.2	18.2	13.4	18.6
	(100)	(90)	(33)	(24)	(33)
France	63.9	64.3	26.2	16.5	21.6
	(100	(101)	(41)	(26)	(34)
JAPAN	89.2	66.0	34.1	22.4	9.5
	(100)	(74)	(38)	(25)	(11)
PASTORAL FARMING					
Argentina	60.0	45.9	-4.8	24.3	26.4
	(100)	(76)	(-8)	(40)	(44)
New Zealand	-42.4	-49.1	-55.2	2.7	3.4
	(100)	(116)	(130)	(-6)	(-8)

a Inside parentheses are percentages with output per worker differences set equal to 100.

France which preserved peasant farms by protective tariffs. Increase in the use of technical inputs and improvements in the quality of human capital can bring labor productivity of the several European countries closer to the U.S. level. Nevertheless it seems apparent that major advances in labor productivity in European agriculture (especially in countries like France) toward the U.S. level are dependent on the absorption of a higher percentage of the agricultural labor force into the nonagricultural sector. The Japanese case is similar to the European, except that Japan, characterized by a stronger constraint of land, has moved further toward the exhaustion of productivity differentials associated with investment in education and research. In our judgement the model underestimates the significance of the land constraint in the Japanese case and, to a lesser degree, in the European case. Without a significant increase in land area per worker it would be impossible for Japanese agriculture to increase technical inputs (especially machinery) to the U.S. level.

The two pastoral farming cases are of particular interest. In spite of low levels of technical inputs, labor productivity in Argentina is roughly comparable to that in Europe. This is due almost entirely to a favourable man-land ratio comparable to that in the United States. Argentina has, as a result of under-investment in technology and human capital, failed to fully exploit its favourable man-land ratio. New Zealand, in contrast, has achieved a level of labor productivity well above the U.S. level (the highest in the world) by complementing its favourable resource endowments with high levels of technical inputs and investment in education and research.

The results obtained in both group and individual comparisons are somewhat different than those obtained by Krueger. Using a different methodology, Krueger found that human capital explained more than half the difference in income levels between the United States and a group of less developed countries. This is in contrast to our studies in which human capital explains approximately one-third of the difference in labor productivity. Krueger's results apply to the entire economy and ours to only the agricultural sector. It seems reasonable to expect that resource endowments would be of relatively greater significance in the agricultural sector than in the total economy. We see, therefore, no inconsistency between our results and those obtained by Krueger. In general the consistency between the results presented in Tables 3 and 4, combined with our general knowledge of the economies being studied, strengthens our confidence in the methodology employed in this study.

IV. Implications for Agricultural Development Strategy.

The implications of this analysis for agricultural development strategy in the less developed countries have both encouraging and discouraging aspects. It is clear that output per worker in the several LDC's can be increased by several multiples, while land area per worker remains constant or even declines slightly. To achieve increases of this magnitude will require substantial investment (a) in rural education and (b) in the physical, biological, and social sciences. The latter is required for the technical and institutional infrastructure needed for the invention, development, and extension of a more efficient agricultural technology. It will also require the allocation of substantial resources to the production of the technical inputs supplied by the industrial sector, by which new technology is carried into agriculture. By and large, these changes achieve the higher levels of output per worker through increase in output per unit area.

A more discouraging aspect of this analysis is that in order to achieve levels of labor productivity comparable to the levels achieved in the DC's of recent origin it will be necessary to complement those technical changes designed to increase output per unit area with technologies that reduce the labor input per unit area. Significant reduction in labor input per unit area is likely to occur, however, only in those economies in which urban-industrial development is sufficiently advanced to absorb not only the growth in the rural labor force but also to permit a continuous reduction in employment in rural areas.[17] It should be noted that this has occurred in Japan only since World War II. In most LDC's it seems likely that the agricultural labor force will continue to expand more rapidly than the nonagricultural demand for labor from rural areas.

The implications for agricultural development strategy for most less developed countries seem relatively clear. An attempt must be made to close the gap in the level of modern industrial inputs and in education and research. Agricultural surpluses generated by closing the gap, over and above the amount necessary to maintain the growth of agricultural productivity, must be used to finance industrial

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17 See the article by Folke Dovring.

development.[18]

Maintenance of the rate of growth of agricultural productivity can be expected to impose a substantial drain on the savings that can be generated from the agricultural surpluses. Initially a substantial component of industrial capacity must be designed to provide technical inputs for the agricultural sector. Substantial investment will be needed to create the institutional infrastructure to improve general education in rural areas and to produce the technical and scientific manpower needed to bring about technical changes in agriculture. Investment in land development, such as irrigation and drainage, will also be necessary in a number of countries in order to obtain a full return from the new biological and chemical technology.

If successful, the effort would, over time, result in a rate of growth in the nonagricultural labor force sufficient to permit a reduction in the agricultural labor force and a rise in labor productivity toward the levels of the DC's of recent settlement. Clearly the process outlined here is inconsistent with the low cost route to agricultural development that seemed to be opened up by the dual economy models which have dominated much of the theoretical discussion of agricultural development during the last decade.

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18 Shigeru Ishikawa has suggested that achievement of national agricultural output and productivity objectives may, in some developing countries, require a net flow of savings from the nonagricultural to the agricultural sector. The possibility has been such a shock to some students of development economics that they recommend a "development without agriculture" policy (e.g., M.J. Flanders).

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