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Agriculture Growth Sources

A Look at 77 Countries

Carlos Arnade

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Agriculture Growth Sources: A Look at 77 Countries. Carlos Arnade, Commercial Agriculture Division, Economic Research Service, U.S. Department of Agriculture. Staff Paper No. 9709.

Abstract

Multifactor productivity indices that are measured using data envelopment analysis are compared with indices measured using a Cobb-Douglas production function. Cobb-Douglas functions are then used to measure the relative impacts of input growth and productivity on agricultural output growth. Both input growth and productivity growth have accounted for agricultural growth in developed countries. However, in developing countries output growth can primarily be attributed to the growth in fertilizer and machinery. Productivity growth has fallen in many developing countries.

Keywords: Output growth, Input growth, Agricultural productivity.

Acknowledgments

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Introduction

In the early 1960's, it was commonly believed that new technology was required to significantly increase agricultural output in developing countries (Schultz 1964). In the subsequent three decades, developing country governments and international agencies encouraged the use of innovative agricultural technology. During this period, agricultural output more than doubled in many of these countries leading to what has been called the Green Revolution. Since yields significantly increased in many countries, it is generally believed that agricultural productivity has risen. However there is little documentation of changes in multifactor productivity, a measure of productivity relative to all the inputs, for many developing countries.

If multifactor productivity grows and is the major source of agricultural output growth, then returns to the factors not accounted for in the production function, such as management, benefit from the large growth in agricultural output. If, instead, multifactor productivity falls and inputs are a major source of output growth, then owners and vendors of visible factors of production are prime beneficiaries of output growth.

Krugman argues that, in East Asia, economywide output growth has been driven by growth in inputs rather than growth in productivity (1996).[1] He makes the point that input-led growth is not sustainable because it either represents one instance of change (that it occurs as a one-time spurt) or eventually slows down due to diminishing returns. In contrast, productivity- generated output growth is often ongoing and continuous. Krugman's claim that past East Asian growth rates will not continue has generated controversy (Krugman 1996).

A similar line of reasoning may apply to agriculture. Growth in output stemming from growth in fertilizer or machine use likely occurs in spurts and is unlikely to continue for an extended period of time (Traxler and Byerlee 1993). In contrast, agricultural productivity growth reflects the incremental sum of minor improvements in technology and efficiency and can grow continuously. Productivity growth has been continuous for U.S. agriculture. For example, Ball (1985) finds U.S. agricultural productivity has grown more than 1 percent annually since 1953, and more than 2 percent annually since 1973.

This paper uses FAO (United Nations Food and Agricultural Organization) data to account for the sources of agricultural growth in 76 countries for the years 1961 to 1987. Multifactor

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[1] Govindan, Gopinath, and Roe (1996) find that Indonesian growth rates also stem primarily from input growth.

productivity is measured in terms of four inputs: agricultural land, fertilizer, labor, and machinery. Output growth is ascribed to either productivity growth or growth stemming from increased use of one of the four inputs. The period considered provides a broad representation of what is considered the years of the Green Revolution.

The results presented here are best viewed in light of what is already established. Multifactor productivity growth is a major factor in the growth of GNP in the United States (Jorgenson, Gollop, and Fraumeni, 1987,1992). Productivity growth is a primary source of the growth of U.S. agriculture, dominating growth arising from increases in factor use (Jorgenson, Gollop, and Fraumeni 1992). Productivity also plays a significant role in worldwide growth. Nehru and Dhareshwar (1993) note that "one of the stylized factors that has emerged for TFP (total factor productivity) growth at the economywide level has been that roughly one-third to one-half of output growth can be attributed to TFP change."

The empirical section of this paper compares Malmquist productivity indices, which are estimated using data envelopment analysis, with productivity estimates obtained from a Cobb-Douglas production function.[2] Malmquist indices are considered one of the least restrictive indices in that no functional form is assumed for the production function. In contrast, the productivity indices derived from the Cobb-Douglas production function inherit all the restrictions embodied in that particular functional form. Despite these differences, we shall see that with FAO data there is not a wide divergence between productivity indices. Having attained this result, a Cobb-Douglas production function is used to decompose output growth.

Defining Productivity

Total factor productivity is the residual obtained after the influence of inputs on output has been accounted for. When input prices are constant, productivity growth reflects the observable rate of cost diminution. By reducing per unit costs, a rise in agricultural productivity can increase producer rents, significantly reduce the price of food, or both (Kendrik 1977). In either case, aggregate welfare rises when agricultural productivity increases.

Multifactor productivity measures efficiency, economies of scale, the effect of disembodied technical change on output, as well as other items not accounted for by inputs in the production function (e.g., Denny et al. 1981). Productivity reflects the contribution of residual factors of production or the residual growth in output not explained by growth in inputs. On this point there is widespread agreement. The method for measuring factors of production is an issue where there is less agreement and leads to various definitions of productivity. Three issues arise:

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[2] Description of the Malmquist index is provided in Färe et al. (1992). Arnade (1994) describes actual calculation of DEA numbers.

1. Is it essential to measure service flows from stock inputs?
2. Should inputs be adjusted for improvements in quality?
3. Should all measurable factors influencing output be accounted for?

Each issue is briefly addressed, and various definitions of productivity are described.

Inputs as Stocks

In one definition of productivity, stock inputs are measured as stocks. In another definition of productivity, the service flow from a stock input is calculated and used as a measure of the input. Typically, prices of service flows and the rental price of an asset are calculated from market price, interest rate, depreciation, and tax data. These rental prices are divided by the value of capital to obtain an implicit flow of services from an asset. One way to view the service flow from an asset is that it represents the amount of an asset that is consumed in a crop year. Thus it represents the amount of an asset used to produce a crop. Measuring stock inputs as service flows is ideal but requires data on interest rates, inflation, depreciation rates, and taxes (see Jorgenson and others 1987, Arnade 1993, Ball 1985).

In this paper, I use FAO data that measure three of the four inputs (agricultural land, labor, and machinery) as a stock. Without rental rates, inflation rates, taxes, and depreciation rates from each country, service flows cannot be measured. However defining productivity in terms of stock inputs is not unprecedented and has been done by Frisvold (1991), Frisvold and Ingram (1995), Govindan et al. (1996), Hayami and Ruttan (1971), and Fulginiti (1994).

Quality Adjusting Inputs

Quality adjustment in inputs is meant to capture embodied technical change. If inputs are adjusted for changes in quality, a measure of productivity reflects only disembodied technical changes and improvements in efficiency. For example production technology could be written as:

$$Y = \theta(t) * F(\mu_1(t) * x_1 ...... \mu_n(t) * x_n) \qquad (1)$$

where μ equals input-augmenting or embodied technical change, and Θ contains a measure of disembodied technical change. Input data are adjusted by quality measures to capture the changes in μ over time or across cross-sectional observations. Finding and utilizing appropriate data for quality adjustment of factors is a difficult process. (See Ball, 1995, and Jorgenson and others, 1987, for a description of a rigorous approach to input quality adjustment.)

When dealing with developing countries, data for quality adjustment are not consistently available. Hence, developing country productivity studies most often apply data in unadjusted form. Exceptions to this are studies by Arnade on Brazil (1993) and Thirtle et al. on Zimbabwe (1993). These studies had the advantage of focusing on one country. Where many developing countries are considered, the consistency of data required for quality adjustment rarely exists.

Since input quality clearly differs between countries and changes over time, there are two possible definitions of productivity. While either definition is relevant, one must not compare the two types of productivity indices:

1. Productivity differences arising from variation in input quality. Across time this accounts for embodied and disembodied technical change.
2. Productivity that is net of differences arising from variation in input quality. Across time this accounts for disembodied technical change.

This paper reports productivity indices based on inputs that were not quality adjusted. The main reason for reporting this type of productivity index is that input prices, which are required in developing most input quality indices, are not consistently available across all countries. Even in countries where input price data are available, they are less reliable than quantity measures for three reasons:

1. Quantity data are measured in common units among countries whereas input prices must be converted into common units using exchange rates. Distorted and multiple exchange rates are common in developing countries.
2. High monthly inflation in many developing countries limits the credibility of input prices which are reported on an annual basis.
3. Countries often report one output and input quantity but report multiple input prices, some of which account for distortionary subsidies and some of which do not. It is not always clear which input price represents what the average producer pays.

These difficulties with international input price data precluded using input price data to adjust inputs for quality differences.

Choice of Inputs

One view is that all variables that influence output should be considered in the production function and productivity measurement. Productivity represents only what is unexplained due to unobservable data. This approach leads to the use of input variables determined by outside producers' choice set. For example Schuh and Norton (1991) included two education variables and a foreign aid variable along with more traditional inputs when estimating a production function. Frisvold and Ingram (1995) included an agricultural research and export growth variable in their production function. Hayami and Ruttan (1971) included school enrollment ratios and technical education along with their traditional agricultural input in their estimation of a Meta-Production Function across 38 countries.

The other view is that inputs that are not producer choice variables should not be included when measuring productivity. For example, fertilizer, land, and labor should be included as inputs but education and infrastructure should not be. Supporting this viewpoint is the point that public goods (public inputs) are not introduced into the production function from any formal aggregation technique. Yet it is beyond doubt that public inputs have a distinct influence on production and productivity, and comprise part of the technology of production.

In this paper I estimated production and productivity by utilizing inputs that are producer choice variables. Public inputs are later applied toward an explanation of productivity differences across countries. Productivity in this paper represents an aggregate output over aggregate choice inputs.

Productivity Measurement

Applied economists have developed numerous methods for measuring productivity (e.g., Antle and Capalbo 1988, Ball 1985, Jorgenson et al. 1987, Trueblood 1991, Färe 1992). The common factor among these techniques is that both inputs and outputs are measured, and productivity is then represented as the aggregate output divided by an aggregate input. Measurement of multifactor productivity has typically centered on developed nations where ample data are available (Ball 1985, Jorgenson et al. 1992, Kendrick 1977).

Only a limited number of studies provide estimates of multifactor agricultural productivity in developing nations (Arnade 1993, Nehru and Dhareshwar 1993, Thirtle et al. 1993). The unavailability of reliable input prices has made it difficult to calculate productivity in developing countries with indices that require the use of input price or cost shares although Arnade (1993) and Thirtle (1993) have estimated productivity for single countries by means of Tornqvist indices. Two techniques for measuring productivity that do not require input prices are estimation of production functions and data envelopment analysis.

This paper provides productivity indices that were measured two ways. Data envelopment analysis (DEA) was used to calculate a Malmquist index of productivity, and a productivity was calculated from a Cobb-Douglas production function.

The Malmquist index reflects the geometric mean of relative distance functions, each of which is calculated using DEA. In its simplest form, the Malmquist index is:

$$M_i(y^0,y^1,x^0,x^1) = \left[\frac{D^{0}(y^1,x^1)D^{1}(y^1,x^1)}{D^{0}(y^0,x^0)D^{1}(y^0,x^0)}\right]^{1/2} \tag{2}$$

where $D^0(.)$ refers to a distance function based on technology in period 0 and $D^1(.)$ refers to a distance function based on technology in period 1, y^1 and x^1 refer to a vector of outputs and inputs respectively from period 1, and y^0 and x^0 refer to a vector of outputs and inputs from period 0. The term $D^1(y^1,x^1)$ represents the efficiency of production in time period 1. If inputs are not being over-used or wasted, this number will be 1. $D^1(y^o,x^o)$ represents a mixed distance function that compares the input and output mix in period 1 with technology in period zero.

Färe et al. (1992) describe the Malmquist index and the distance functions that comprise this index. Additional descriptions of distance functions are provided by Deaton and Muellbauer (1980) and Malmquist (1953). The key point here is that distance functions are calculated by applying data envelopment analysis (DEA) to output and input data (see Färe et al. (1992), Färe and Whittaker (1993), Charnes et al. (1978) for a description of DEA) which does not impose any functional form on the production data. It would be difficult to design a more general approach to estimating productivity.

The traditional Cobb-Douglas production function was also used to calculate productivity. Defining the Cobb-Douglas production function to be:

$$Y = A * \prod X_i^{\theta_i} \tag{3}$$

Productivity is measured by solving equation 3 for the A term. In contrast to the Malmquist index, the Cobb-Douglas approach is remarkably restrictive. For example, the Cobb-Douglas production function can be viewed only as a first-order approximation to the technology, implies a unitary elasticity of substitution, implies homothetic technology, and implies Hicks-neutral technical change. Furthermore parameters on our Cobb-Douglas production function are imposed rather than estimated individually for each country. Parameter weights on inputs were slightly varied to produce two sets of productivity indices. One set of parameter weights that were imposed were similar to those used by Frisvold (1991) and then slightly varied to ensure homogeneity. Weights on the second set of parameters were evenly split between inputs.[3]

Having established that one of the chosen indices represents an extremely general index while the other is based on quite restrictive assumptions, the two are compared. These indices have in common the fact that they rely only on output and input data.[4] Table 1 lists Malmquist productivity numbers estimated using data envelopment analysis. Tables 2 and 3 list productivity estimates generated from a Cobb-Douglas production function. Two Cobb-Douglas estimates are provided for each country. In one, the parameters were: land -0.45, labor -0.20, machinery -0.20, fertilizer -0.15; in the other, the parameters were 0.25 on each of the four inputs.

With the exception of only a few countries, Cobb-Douglas estimates do not vary significantly from the Malmquist estimates. Where there is a difference, such as in Iraq, Egypt, Korea, and Venezuela, Cobb-Douglas estimates are not consistently either above or below Malmquist

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[3] Frisvold allowed livestock to be an input into production. In many developing countries, there is little meat processing, and livestock is sold as an output. Because of this I chose not to include livestock as an input into production.

[4] Price data, which are required by most index approaches or dual econometric approaches for measuring productivity, are often inaccurate or unavailable among developing countries. Reasons for this are stated earlier.

Data Envelopment and Technology Categories

Data envelopment analysis (DEA) is used to calculate distance functions, which make up the Malmquist productivity index. DEA creates a best practice frontier by taking a weighted average of cross-sectional data. Parameter weights are endogenously determined in a programming problem. A country's location relative to the frontier determines that country's efficiency. If a country lies on the frontier, it is efficient. If not, it is inefficient. Technical change is calculated by choosing a country's location in one time period relative to a frontier from another time period.

One feature of applying DEA is that all cross-sectional units, which possibly provide a frontier's boundary, must have the same technology. For this reason, countries were broken into four technology categories. Countries were classified into three of the four technology categories by ranking them by their tractor/labor ratio. Technology categories were identified where significant breaks occurred in this ratio. The three categories that were created this way can be called advanced-technology, middle-range technology, and low-technology countries. European countries, the United States, Australia, Canada, Argentina, and Uruguay fell into the first category. Middle-income developing countries and many Eastern European countries fell into the second category. Many low-income developing countries fell into the third category.

A separate category was created for Asian countries where Asian rice production is dominant. The reason for this is that wetland rice production technology is unique and uses significantly smaller size tractors. Animal inputs, which play a significant role in Asian rice production, were included as an additional input for countries in this category.

estimates.[5] It would be difficult, therefore, to argue that either approach imparts a directional bias to productivity estimates.

With either measurement technique, multifactor productivity rises in most developed countries, rises in most Eastern European countries, and falls in many developing countries. The finding that multifactor productivity in the agricultural sector is falling for most developing countries may appear surprising but is consistent with the results obtained by Fulginiti, who measured a

[5] In Korea, there is a relatively large difference between the first Cobb-Douglas estimate and Malmquist estimates. There is a smaller difference in the second Cobb-Douglas estimate which puts more weight on fertilizer and machinery inputs. The rapid growth of these inputs appears to be the reason why multifactor productivity falls in Korea.

Malmquist index for 18 countries (1994).

The first column of table 4 reports output growth rates. It is clear that output has more than doubled in many countries where multifactor productivity falls. To determine if inputs were a major source of output growth, I used a Cobb-Douglas production function.

Malmquist productivity estimates are more general than Cobb-Douglas estimates. Yet in most countries, the restrictive Cobb-Douglas estimates produced index numbers similar to the general Malmquist index.[6]

The Cobb-Douglas function can provide a clear decomposition of the sources of output growth which DEA cannot. Given reasonable confidence in Cobb-Douglas productivity estimates, I chose to use the Cobb-Douglas to decompose output growth. If we write the Cobb-Douglas function as:

$$Y=A*X_f^{\theta 1}X_{ld}^{\theta 2}X_{lb}^{\theta 3}X_{mch}^{\theta 4} \tag{4}$$

where A is multifactor productivity, X_f is fertilizer, X_{ld} is land X_{lb} is labor, and X_{mch} is machinery, then take the log derivatives with respect to time we obtain:

$$\hat{Y}=\hat{A}+\theta_1*\hat{X}_f+\theta_2*\hat{X}_{ld}+\theta_3*\hat{X}_{lb}+\theta_4*\hat{X}_{mch} \tag{5}$$

Equation 5 decomposes output growth rates using Cobb-Douglas coefficients to weight average annual growth rates of inputs. Output and input growth rates were calculated by regressing the log of each variable on time.

Tables 4 and 5 record the impact of input growth on output. Column 1 reports output growth. Columns 2 through 5 report changes in output arising from growth of each input ($\Theta_i\hat{X}_i$ rather than $\hat{X}_i$). Growth rates represent the average annual growth over the entire period. What emerges from either table is that the large growth in agricultural output associated with the Green Revolution in developing countries arose primarily from growth in fertilizer and tractor inputs.

Tractors are often classified as a quasi-fixed input while fertilizer is a variable input. The markets for both inputs presumably operate quite differently. Without knowledge of these markets, it is not possible to determine if farm operators or input vendors benefited from the input-driven output growth. If input growth is due to an increase in input demand and the input supply curve is not perfectly elastic, then input vendors benefit. If output is due to an increase in

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[6] With the FAO data used in this report, the restrictions imposed by the Cobb-Douglas production function proved to be not too damaging. However, with other databases, these restrictions, or restrictions imposed by specifying any functional form, could result in productivity estimates far different from those generated by DEA.

input supply and the input demand curve is not perfectly elastic, then the users of inputs benefit. In any case, tables 1-5 show that participants in the aggregate tractor and fertilizer market must have benefited from the large output growth. Whether specific vendors (or buyers) of tractors or fertilizer benefited depends on market supply and demand conditions in those industries.

Productivity of the United States and its Major Competitors

It is interesting to examine the performance of the U.S. agricultural sector relative to that of its major competitors. Productivity numbers in tables 1-3 represent sectorwide rather than crop-specific performance. Yet since a large share of U.S. agricultural output represents the major export crops, a comparison of the agricultural sector of the United States with that of its major competitors can provide some insights.

The United States does not perform as well as European countries in terms of DEA-measured productivity growth. The United Kingdom performs the best of any European country. France, a major exporter of wheat and a major competitor of the United States experienced a cumulative 76-percent growth in productivity from the beginning of the period to the end of the period. In contrast, as measured by DEA, U.S. productivity increased 32 percent over the whole period.

Argentina's productivity growth, as measured by DEA, was erratic, rising almost as high as U.S. productivity growth in the mid-1970's only to fall from 1979 to 1987. Australia's growth was slightly faster than that of the United States. By the end of the period its cumulative growth was up 74 percent. Canada's growth was flat in the 1960's and 1970's but rose rapidly in the 1980's to record a 41-percent cumulative growth over the whole period.

The relative ranking of countries changes slightly when productivity is measured by the first Cobb-Douglas production function. The United Kingdom falls below the United States. Australian, Canadian, and U.S. productivity rose to almost that of France. The productivity growth rates of each of these four countries are not far apart. Argentina's remains volatile, rising in the mid-1970's and falling in the 1980's. The second Cobb-Douglas function, which attaches a higher weight to fertilizer and tractors, brings down developed-country productivity growth significantly. U.S. productivity falls when these inputs are highly weighted, while productivity in France, the United Kingdom, and Canada rise by much smaller amounts. Australia performs the best among U.S. competitors with this functional form. Note, however, that the DEA numbers are estimated under less restrictive assumptions than Cobb-Douglas numbers.

Table 4 demonstrates that all countries show significant output growth arising from increasing use of fertilizer. Argentina's output from fertilizer grows the most, followed by Canada. The United States also records a significant output growth arising from increased fertilizer use. The effect of outmigration of labor in agriculture has had a negative impact on agricultural output in the United States and in all competing countries. This phenomenon is largest in France, followed by the United States. Argentina, in contrast, loses little output from outmigration of agricultural labor because of low outmigration rates.

Conclusions

The technology used in the production of agricultural goods has changed significantly in developing countries during the past three decades leading to increases in agricultural yields and output. A generalized Malmquist productivity index was estimated for the agricultural sector in 77 countries using data envelopment analysis. The index was compared with indices obtained from a traditional Cobb-Douglas approach. With a few exceptions, Malmquist indices calculated from DEA do not differ greatly from Cobb-Douglas estimates. Results indicate that multifactor agricultural productivity has improved in developed countries and fallen in many developing countries.

Having shown that Cobb-Douglas estimates are useful, a Cobb-Douglas production function was used to break down the sources of growth in the output sector. In most developing countries agricultural output growth originates from the substantial increases in machinery and fertilizer use. This shows that the Green Revolution of the late 1960's and 1970's reflected growth in inputs rather than improvements in productivity or efficiency.

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1--DEA Productivity indices for selected countries, 1961-87[1]

try	1964-66	67-69	70-72	73-75	76-78	79-81	82-84	1985-87
ed technology:								
ntina	0.85	1.13	0.72	1.22	1.50	1.13	1.16	0.93
alia	1.13	1.18	1.27	1.33	1.48	1.44	1.57	1.74
ria	0.99	0.95	0.89	1.06	1.04	1.11	1.26	1.36
um	0.93	0.95	1.01	1.06	1.09	1.17	1.24	1.33
da	0.97	1.00	1.00	0.96	1.11	1.13	1.27	1.41
nark	1.05	1.16	1.19	1.29	1.23	1.57	1.75	1.89
nd	0.90	0.87	0.89	0.90	0.96	1.00	0.98	1.01
e	1.04	1.16	1.23	1.33	1.31	1.56	1.68	1.76
Germany	1.04	1.25	1.35	1.42	1.48	1.68	1.88	1.98
nd	0.92	1.02	1.15	1.24	1.32	1.47	1.60	1.72
d	0.86	0.77	0.71	0.66	0.70	0.68	0.69	0.71
	0.97	0.96	0.88	0.91	0.87	1.01	1.06	1.10
Zealand	0.96	1.10	1.09	1.03	1.16	1.23	1.35	1.53
ay	0.97	0.98	1.00	1.01	1.02	1.02	1.05	1.10
en	0.99	1.16	1.80	1.28	1.32	1.38	1.46	1.52
erland	0.97	0.99	1.01	0.99	1.01	1.01	1.01	1.06
d Kingdom	1.09	1.16	1.31	1.41	1.51	1.92	2.50	2.64
d States	0.95	0.98	0.97	0.97	1.01	1.07	1.16	1.32
uay	0.81	0.69	0.59	0.66	0.67	0.61	0.82	0.74
echnology:								
	1.31	0.87	0.66	0.57	0.64	0.50	0.60	0.59
ria	0.78	0.81	0.91	0.86	1.15	0.96	1.06	1.05
	0.93	0.98	0.88	0.80	1.28	1.11	1.03	0.88
nbia	1.05	0.99	0.85	0.80	1.25	0.85	0.79	0.74
Rica	0.94	0.78	0.75	0.67	0.97	0.67	0.62	0.63
oslovakia	0.94	1.03	1.04	1.20	1.40	1.32	1.62	1.81
Germany	1.24	1.44	1.50	1.72	2.03	1.98	2.18	2.58
e	0.93	0.95	0.97	0.99	1.24	1.06	1.04	1.01
ary	0.99	0.91	0.95	1.05	1.38	1.23	1.46	1.56
	1.04	1.05	1.05	1.06	1.27	1.20	1.21	1.13
o	1.08	1.00	0.80	0.75	1.12	0.76	0.81	0.75
d	1.13	1.25	1.17	1.35	1.50	1.15	1.14	1.40
gal	0.84	0.72	0.68	0.70	0.67	0.61	0.63	0.66
nia	0.89	0.72	0.63	0.59	0.77	0.77	0.85	0.92
Africa	0.82	0.79	0.77	0.77	0.84	0.96	0.86	0.91
	1.08	1.11	1.23	1.36	1.69	1.72	1.94	2.25
y	1.03	0.70	0.52	0.43	0.52	0.41	0.46	0.54
	1.29	1.34	1.27	1.23	1.42	1.21	1.51	1.63
uela	0.68	0.63	0.53	0.43	0.48	0.43	0.47	0.34

Continued--

1 (cont.)--DEA Productivity indices for selected countries, 1961-87[1]

ntry	1964-66	67-69	70-72	73-75	76-78	79-81	82-84	1985-87
nology:								
a	0.72	0.59	0.47	0.46	0.57	0.45	0.35	0.35
ican Repub.	0.96	0.86	0.86	0.84	0.98	0.75	0.74	0.80
or	1.26	0.92	0.91	0.99	0.99	0.90	0.74	0.61
	1.23	1.38	1.55	1.58	1.95	1.71	1.83	2.10
vador	1.01	0.91	0.89	0.88	1.03	0.85	0.82	0.78
mala	1.05	0.93	0.94	0.92	1.09	0.85	0.80	0.79
ras	1.14	1.33	1.33	1.08	1.32	0.97	1.05	1.10
	0.31	0.54	0.49	0.49	0.58	0.42	0.41	0.40
	0.33	0.64	0.60	0.68	0.79	0.57	0.66	0.62
	1.22	0.51	0.46	0.76	1.61	1.54	1.57	1.92
h	0.75	0.67	0.63	0.60	0.67	0.58	0.53	0.55
	0.92	0.84	0.83	0.95	1.14	0.96	0.85	0.78
gua	0.64	0.55	0.52	0.46	0.47	0.30	0.29	0.26
a	1.01	0.87	0.57	0.48	0.59	0.56	0.52	0.56
an	0.77	0.80	0.59	0.54	0.63	0.56	0.56	0.62
uay	0.72	0.58	0.38	0.77	0.69	0.51	0.48	0.50
	1.16	1.25	1.58	1.40	1.61	1.97	1.34	0.76
	0.87	0.95	1.09	1.21	1.22	1.09	1.04	1.26
	0.94	0.92	0.89	0.83	0.89	0.67	0.64	0.67
a	0.89	0.76	0.51	0.48	0.55	0.40	0.38	0.43
bwe	1.06	1.07	1.13	1.31	1.44	1.22	1.04	1.44
technology:								
desh	0.85	0.70	0.49	0.46	0.40	0.37	0.36	0.37
h	0.98	0.82	0.91	0.89	0.87	0.85	0.79	0.78
dia	0.83	0.56	0.63	0.32	0.81	0.21	0.24	0.93
	0.90	0.85	0.76	0.76	0.68	0.65	0.68	0.74
	0.71	0.67	0.72	0.68	0.62	0.58	0.57	0.58
sia	1.04	0.97	0.93	0.86	0.83	0.81	0.82	0.80
	1.05	1.09	1.17	1.22	1.39	1.55	1.73	2.00
Korea	0.98	0.89	0.90	0.95	1.08	1.13	1.24	1.35
Korea	1.87	1.37	0.96	0.57	0.41	0.22	0.17	0.17
	0.99	0.45	0.51	0.51	0.44	0.37	0.56	0.39
ia	1.01	1.04	1.10	1.20	1.28	1.36	1.44	1.60
ar	0.97	0.49	0.45	0.42	0.38	0.36	0.33	0.36
	0.80	0.53	0.26	0.27	0.20	0.22	0.23	0.20
ines	1.00	0.93	0.93	0.96	1.01	0.94	0.92	0.92
ka	1.01	0.97	1.03	1.06	0.97	1.02	0.98	0.93
d	0.90	0.64	0.59	0.60	0.56	0.57	0.54	0.55
h	1.25	1.59	1.98	1.61	1.76	1.83	1.70	1.24
m	1.03	0.83	0.82	0.81	0.70	0.90	0.89	0.91

mbers represent the inverse of the Malmquist index described in the text so that productivity change should be > 1 for productivity to

e 2--Cobb-Douglas Productivity indices for selected countries[1]

try	1964-66	67-69	70-72	73-75	76-78	79-81	82-84	1985-87
ced technology:								
entina	0.94	0.97	0.90	1.00	1.40	1.10	1.11	1.08
tralia	1.18	1.22	1.35	1.41	1.56	1.52	1.61	1.76
tria	1.00	1.09	1.11	1.23	1.33	1.48	1.72	1.84
gium	0.99	1.12	1.30	1.44	1.51	1.72	1.88	2.08
ada	1.13	1.20	1.29	1.26	1.42	1.47	1.61	1.81
mark	1.03	1.05	1.05	1.12	1.21	1.41	1.63	1.75
and	0.99	0.99	1.05	1.06	1.22	1.28	1.40	1.38
ce	1.02	1.08	1.13	1.25	1.30	1.51	1.68	1.84
t Germany	1.03	1.21	1.28	1.33	1.38	1.52	1.72	1.88
and	0.99	1.13	1.30	1.42	1.55	1.77	2.00	2.20
nd	0.99	1.08	1.08	1.17	1.24	1.30	1.38	1.47
	1.05	1.13	1.14	1.23	1.22	1.36	1.45	1.51
Zealand	1.01	1.14	1.15	1.09	1.18	1.23	1.34	1.38
way	1.01	1.08	1.14	1.19	1.23	1.30	1.41	1.47
den	1.03	1.08	1.11	1.21	1.32	1.45	1.64	1.71
tzerland	0.98	1.10	1.13	1.20	1.28	1.34	1.44	1.51
ed Kingdom	1.09	1.17	1.29	1.33	1.35	1.44	1.56	1.63
ed States	1.04	1.12	1.21	1.27	1.39	1.52	1.59	1.77
guay	0.96	0.92	0.91	0.94	0.97	0.97	1.16	1.10
technology:								
il	1.06	0.92	0.87	0.85	0.81	0.84	0.89	0.86
aria	1.05	1.05	1.16	1.25	1.40	1.58	1.79	1.81
e	1.00	1.08	1.07	1.09	1.24	1.38	1.41	1.38
mbia	1.01	1.05	1.07	1.11	1.25	1.31	1.27	1.29
a Rica	1.03	1.13	1.27	1.33	1.47	1.50	1.49	1.61
hoslovakia	1.03	1.18	1.23	1.35	1.40	1.48	1.68	1.83
Germany	1.10	1.20	1.25	1.41	1.46	1.59	1.67	1.90
ce	0.99	0.99	1.08	1.18	1.17	1.25	1.28	1.28
gary	1.02	1.11	1.16	1.34	1.48	1.70	1.96	2.11
el	1.14	1.28	1.42	1.58	1.71	1.78	1.95	1.88
ico	1.11	1.10	1.10	1.13	1.21	1.26	1.27	1.26
nd	0.95	0.91	0.85	0.88	0.86	0.79	0.78	0.83
ugal	0.95	0.87	0.84	0.75	0.72	0.67	0.68	0.68
ania	0.96	0.97	0.99	1.08	1.31	1.40	1.54	1.85
h Africa	0.93	0.98	0.99	1.04	1.17	1.32	1.22	1.33
n	1.01	1.03	1.11	1.27	1.31	1.47	1.62	1.72
ey	0.93	0.80	0.76	0.68	0.66	0.65	0.66	0.69
R	1.07	1.18	1.22	1.27	1.30	1.25	1.33	1.43
zuela	1.04	1.12	1.14	1.13	1.14	1.30	1.40	1.28

Continued--

2 (cont.)--Cobb-Douglas Productivity indices for selected countries

ıntry	1964-66	67-69	70-72	73-75	76-78	79-81	82-84	1985-87
hnology:								
a	1.04	1.03	1.08	1.22	1.30	1.26	1.20	1.29
nican Repub.	0.93	0.86	0.87	0.96	0.95	1.05	1.05	0.99
dor	1.17	0.94	1.01	0.87	0.82	0.81	0.75	0.80
t	1.02	1.03	1.06	1.04	1.03	0.99	0.97	1.03
vador	1.00	0.92	0.94	1.03	1.06	1.15	1.07	0.96
mala	1.00	0.98	1.06	1.13	1.13	1.16	1.14	0.97
uras	0.94	0.92	0.84	0.75	0.86	0.80	0.83	0.90
	0.78	0.68	0.62	0.60	0.58	0.53	0.53	0.51
	1.02	1.03	1.03	0.89	0.95	0.83	0.84	0.86
	1.01	0.43	0.40	0.65	0.86	0.76	0.78	0.80
n	1.07	0.73	0.56	0.53	0.62	0.75	0.91	1.10
	0.95	0.97	0.95	1.01	1.08	1.02	0.93	0.91
gua	1.01	0.99	0.97	0.97	0.91	0.72	0.63	0.53
a	1.00	0.96	0.83	0.71	0.67	0.66	0.64	0.67
an	0.58	0.54	0.53	0.48	0.41	0.40	0.39	0.40
uay	1.00	0.96	0.86	1.00	1.13	0.94	0.98	0.99
	1.11	1.07	1.10	1.05	1.03	0.99	1.08	1.05
	0.69	0.86	0.86	0.84	0.95	0.92	0.94	0.98
	0.97	1.03	1.08	1.10	1.08	1.04	1.10	1.14
a	1.05	1.01	0.90	0.93	1.07	0.81	0.77	0.83
bwe	1.01	1.04	1.14	1.14	1.26	1.11	1.02	1.21
e technology:								
desh	0.79	0.73	0.60	0.59	0.54	0.52	0.51	0.50
h	1.10	1.16	1.21	1.26	1.32	1.40	1.51	1.71
odia	0.85	0.74	0.78	0.53	0.75	0.36	0.47	0.74
	1.03	1.01	0.96	0.96	0.89	0.87	0.96	1.03
	0.72	0.65	0.62	0.60	0.59	0.56	0.56	0.55
sia	1.07	1.02	1.03	1.02	1.05	1.09	1.11	1.12
	0.98	1.04	1.12	1.16	1.24	1.38	1.73	1.64
Korea	1.00	0.97	1.01	1.11	1.18	1.21	1.29	1.43
Korea	1.16	1.04	1.05	0.99	1.22	1.18	1.19	1.17
	1.12	1.00	1.02	1.00	0.92	1.05	1.41	1.53
ia	1.04	1.11	1.19	1.35	1.38	1.49	1.58	1.74
ar	0.95	0.79	0.75	0.73	0.73	0.79	0.83	0.86
	0.88	0.69	0.58	0.53	0.48	0.44	0.41	0.40
ines	1.02	0.94	0.95	0.99	1.13	1.14	1.15	1.17
ka	0.95	0.95	0.95	0.95	0.91	0.92	0.89	0.88
d	0.89	0.72	0.72	0.72	0.70	0.68	0.65	0.63
h	1.06	1.15	1.23	1.11	1.18	1.18	1.13	1.15
m	1.08	0.89	0.85	0.85	0.79	0.92	0.96	0.98

oductivity numbers calculated from a Cobb-Douglas production function with parameter values equal to .45 on the land inputs, .2 on the t, .2 for fertilizer, and .15 for machines. Asian indices included livestock inputs with parameter values of .1 for machines and .05 for

3--2nd Cobb-Douglas Productivity indices for selected countries[1]

ry	1964-66	67-69	70-72	73-75	76-78	79-81	82-84	1985-87
ed technology:								
ntina	0.91	0.87	0.78	0.88	0.98	0.91	0.90	0.84
ralia	1.12	1.13	1.25	1.32	1.45	1.38	1.46	1.57
ria	0.96	0.98	0.96	1.05	1.10	1.17	1.33	1.41
um	0.95	1.02	1.14	1.24	1.27	1.40	1.49	1.60
da	1.06	1.09	1.13	1.05	1.13	1.12	1.18	1.29
ark	0.99	0.97	0.93	0.97	1.02	1.16	1.30	1.45
nd	0.93	0.89	0.90	0.87	0.99	1.00	1.06	1.02
e	0.97	0.97	0.97	1.05	1.05	1.18	1.27	1.36
Germany	0.98	1.10	1.11	1.14	1.17	1.25	1.39	1.48
nd	0.95	1.05	1.17	1.26	1.36	1.52	1.68	1.80
d	0.96	0.97	0.92	0.99	1.00	1.02	1.06	1.10
	1.00	1.01	0.97	1.02	0.96	1.01	1.05	1.05
Zealand	0.97	1.10	1.09	1.03	1.11	1.17	1.26	1.29
ay	0.97	0.99	1.00	1.02	1.02	1.04	1.10	1.11
en	0.98	0.99	0.97	1.04	1.11	1.20	1.33	1.38
erland	0.94	1.04	1.05	1.10	1.11	1.16	1.21	1.24
d Kingdom	1.06	1.10	1.19	1.23	1.23	1.29	1.35	1.40
d States	0.91	0.84	0.81	0.84	0.85	0.83	1.04	0.96
uay	0.81	0.69	0.59	0.66	0.67	0.61	0.82	0.74
echnology:								
	1.07	0.85	0.74	0.68	0.60	0.59	0.63	0.58
ria	0.93	0.84	0.90	0.94	0.99	1.05	1.15	1.17
	0.96	1.01	0.99	1.01	1.15	1.26	1.26	1.15
nbia	0.97	1.01	1.00	1.01	1.13	1.17	1.11	1.11
Rica	1.01	1.07	1.18	1.19	1.30	1.30	1.27	1.29
oslovakia	0.97	1.06	1.05	1.13	1.15	1.21	1.34	1.44
Germany	1.04	1.10	1.11	1.22	1.26	1.36	1.42	1.57
e	0.93	0.89	0.93	0.98	0.93	0.95	0.94	0.92
ary	0.99	0.91	0.95	1.05	1.38	1.23	1.46	1.56
	0.96	0.96	0.94	1.04	1.12	1.26	1.41	1.50
o	1.06	1.01	1.00	0.98	1.03	1.05	1.03	1.01
d	0.89	0.80	0.70	0.69	0.66	0.59	0.57	0.59
gal	0.92	0.89	0.87	0.79	0.65	0.67	0.70	0.72
nia	0.86	0.80	0.78	0.80	0.91	0.93	0.99	1.17
Africa	0.91	0.95	0.95	0.95	1.02	1.10	1.03	1.16
	0.96	0.91	0.92	1.02	1.01	1.10	1.18	1.19
y	0.93	0.67	0.61	0.52	0.47	0.45	0.45	0.46
	0.97	1.01	0.98	0.98	0.98	0.92	0.94	0.97
uela	0.99	1.04	1.00	0.92	0.87	0.97	1.04	0.84

Continued--

(cont.)--2nd Cobb-Douglas Productivity indices for selected countries

	1964-66	67-69	70-72	73-75	76-78	79-81	82-84	1985-87
ology:								
	1.03	0.99	0.99	1.08	1.20	1.13	1.04	1.09
can Repub.	0.93	0.82	0.76	0.73	0.83	0.82	0.92	0.84
r	1.18	0.84	0.96	0.77	0.68	0.66	0.61	0.64
	1.00	1.00	1.01	0.98	0.95	0.88	0.85	0.90
ador	0.97	0.89	0.87	0.93	0.94	1.05	0.98	0.86
nala	0.97	0.91	0.99	1.02	0.97	1.01	1.01	0.84
as	0.91	0.81	0.71	0.65	0.74	0.70	0.73	0.79
	0.71	0.57	0.50	0.48	0.44	0.39	0.38	0.36
	0.96	0.89	0.84	0.65	0.69	0.56	0.54	0.55
	0.96	0.89	0.84	0.65	0.69	0.56	0.54	0.59
	0.96	0.67	0.51	0.44	0.47	0.52	0.60	0.72
	0.92	0.91	0.88	0.95	1.03	0.99	0.88	0.84
ua	0.87	0.81	0.78	0.77	0.67	0.54	0.47	0.38
	1.00	0.94	0.75	0.64	0.54	0.48	0.44	0.47
n	0.48	0.41	0.39	0.34	0.27	0.25	0.24	0.24
ay	0.93	0.88	0.71	0.94	1.06	0.75	0.78	0.77
	1.16	1.10	1.12	1.05	1.01	0.99	1.12	1.05
	0.64	0.79	0.77	0.72	0.90	0.82	0.86	0.90
	0.96	1.01	1.05	1.06	1.03	1.00	1.06	1.10
	1.04	0.97	0.78	0.80	0.91	0.68	0.66	0.71
we	0.97	0.99	1.06	1.05	1.21	1.04	0.97	1.16
technology:								
esh	0.70	0.60	0.46	0.44	0.39	0.37	0.35	0.35
	1.11	1.19	1.24	1.30	1.37	1.47	1.60	1.83
dia	0.80	0.67	0.72	0.52	0.75	0.33	0.43	0.72
	0.92	0.86	0.77	0.75	0.66	0.61	0.66	0.71
	0.64	0.54	0.49	0.45	0.42	0.38	0.43	0.36
ia	1.05	0.95	0.93	0.89	0.91	0.92	0.92	0.89
	0.80	0.74	0.76	0.71	0.70	0.74	0.88	0.81
orea	0.95	0.89	0.89	0.96	0.99	0.97	1.00	1.09
orea	1.11	0.92	0.86	0.71	0.79	0.70	0.64	0.57
	1.03	0.82	0.81	0.79	0.72	0.77	1.04	1.12
a	0.99	1.00	1.03	1.16	1.13	1.20	1.25	1.31
r	0.93	0.70	0.62	0.59	0.58	0.61	0.63	0.65
	0.80	0.57	0.44	0.37	0.33	0.29	0.27	0.26
es	0.95	0.82	0.81	0.83	0.93	0.94	0.97	1.00
a	0.91	0.88	0.86	0.87	0.83	0.81	0.78	0.76
d	0.79	0.57	0.55	0.50	0.46	0.41	0.37	0.36
	1.06	1.14	1.21	1.04	1.10	1.08	0.97	0.93
n	1.08	0.85	0.78	0.74	0.62	0.68	0.69	0.69

ductivity numbers calculated from a Cobb Douglas production function with parameter values equal to .25 on the four inputs. Asian indices estock inputs with parameter values of .2 for machines and .05 for livestock.

4-Contribution to average growth rate-1rst Cobb Douglas[1]

y	Output	Labor	Land	Tractors	Fertilizer	Productivity
ed technology:						
ntina	1.87	-0.13	0.16	0.39	1.00	0.45
ralia	2.16	-0.15	-0.05	0.12	0.23	2.02
ria	1.17	-0.94	-0.26	0.62	0.09	1.66
ium	1.39	-0.98	-0.38	0.62	-0.07	2.22
da	2.25	-0.63	0.48	0.21	1.02	1.17
nark	1.11	-0.81	0.09	0.14	0.23	1.46
nd	0.92	-0.79	-0.03	0.72	0.36	0.66
ce	1.66	-0.83	-0.15	0.49	0.47	1.65
t Germany	1.17	-2.15	-0.07	0.29	0.15	2.95
and	3.38	-0.46	-0.06	0.78	0.17	2.96
nd	2.37	-0.48	0.02	1.03	0.72	1.08
	1.36	-0.86	-0.28	1.15	0.59	0.77
Zealand	1.64	-0.03	0.80	-0.04	0.15	0.76
way	1.11	-0.72	-0.02	0.77	0.32	0.76
den	0.86	-0.77	-0.15	0.12	0.16	1.51
zerland	1.37	-0.50	-0.17	0.51	0.26	1.28
ed Kingdom	1.60	-0.34	-0.11	0.11	0.36	1.58
ed States	1.85	-0.41	-0.03	-0.05	0.45	1.89
uay	0.70	-0.21	-0.03	0.22	0.34	0.37
technology:						
a	3.33	-0.05	1.13	1.89	1.82	-1.46
ria	1.77	-1.05	0.25	0.41	0.85	1.31
	1.71	-0.26	0.52	0.03	0.38	1.04
mbia	2.96	0.11	0.26	0.44	0.86	1.29
a Rica	3.91	0.04	1.38	0.34	0.81	1.34
hoslovakia	2.05	-0.53	-0.08	0.16	0.61	1.89
Germany	1.88	-0.50	-0.05	0.27	0.23	1.93
ce	2.86	-0.40	0.16	1.64	0.78	0.68
gary	2.75	-0.70	-0.15	-0.07	1.10	2.57
l	3.75	-0.36	0.45	0.98	0.63	2.05
ico	3.43	1.16	0.07	0.80	1.31	1.11
nd	0.98	-0.39	-0.15	2.07	0.77	-1.31
ugal	0.43	-0.49	-0.17	1.72	0.39	-1.02
ania	3.82	-0.63	0.39	0.85	1.48	1.73
h Africa	2.14	-0.19	-0.10	0.31	0.78	1.34
n	2.97	-0.72	-0.06	1.60	0.54	1.61
ey	2.89	0.14	0.02	2.33	1.93	-1.53
R	1.91	-0.52	0.05	0.61	1.20	0.58
zuela	3.92	-0.14	0.21	1.15	1.79	0.92

Continued--

4 (cont.)--Contribution to average growth rate-1rst Cobb Douglas

y	Output	Labor	Land	Tractors	Fertilizer	Productivity
hnology:						
a	3.60	0.23	0.04	0.99	0.99	1.35
ican Repub.	2.48	0.22	0.40	0.35	1.15	0.37
lor	1.50	0.13	0.92	1.14	1.17	-1.85
t	2.28	0.21	-0.14	1.14	0.82	0.28
vador	1.79	0.09	0.30	0.59	0.51	0.29
mala	3.10	0.38	0.57	0.38	1.24	0.53
uras	2.45	1.01	-0.30	1.62	0.84	-0.63
	4.04	0.20	0.001	2.01	2.49	-0.66
	3.96	0.04	0.06	1.35	2.38	-0.13
n	0.98	0.70	0.12	1.16	1.24	-0.84
a	2.81	0.67	0.13	0.32	1.09	0.60
agua	1.73	0.32	0.43	2.31	1.18	-2.51
a	1.54	-0.07	0.12	1.95	1.85	-2.31
tan	3.45	0.41	0.38	3.37	2.12	-2.82
uay	4.38	0.45	0.65	1.68	1.31	0.29
	1.38	0.26	0.06	0.58	0.26	0.22
n	3.05	0.39	0.05	0.92	0.53	1.15
	2.03	0.18	0.07	0.91	0.17	0.71
a	2.40	0.44	0.02	0.99	1.45	-0.49
bwe	2.67	0.46	0.18	0.29	0.68	1.05

e technology:							Animals
desh	1.50	0.26	0.05	2.46	0.96	-2.33	0.10
n	2.80	0.28	0.28	0.0	0.0	2.10	0.14
odia	-1.81	0.14	0.18	0.22	0.20	-2.46	-0.09
	4.10	0.35	-0.03	2.40	0.05	1.27	0.06
	2.50	0.28	0.05	2.34	1.31	-1.44	-0.04
sia	3.80	0.14	0.18	2.60	0.37	0.46	0.05
	1.90	-0.91	-0.23	0.07	1.76	1.21	0.00
Korea	4.57	0.14	0.45	1.60	0.70	1.68	0.00
Korea	4.40	0.02	0.03	0.76	2.90	0.69	0.00
	3.65	0.18	0.03	0.26	1.24	1.83	0.11
sia	5.60	0.18	0.36	1.82	0.76	2.56	-0.08
ar	0.20	0.01	0.01	0.14	0.04	-0.12	0.12
	1.84	0.36	0.45	3.29	1.29	-3.85	0.29
pines	3.44	0.32	0.36	1.26	0.50	1.05	-0.06
nka	1.79	0.35	0.30	0.63	0.65	-0.18	0.04
nd	4.21	0.39	1.08	2.47	1.94	-1.71	0.04
n	3.00	0.42	0.00	0.72	1.02	0.89	-0.05
m	2.70	0.15	0.23	1.25	1.41	-0.36	0.02

mbers represent growth rates in percentage terms. For example Argentina's output growth averaged 1.87% annually from 1961 to 1987.

5--Contribution to average output growth rate-2nd Cobb-Douglas 1961-87[1]

try	Output	Labor	Land	Tractors	Fertilizer	Productivity
ced technology:						
entina	1.87	-0.17	0.09	0.50	1.67	-0.22
stralia	2.17	-0.19	-0.03	0.15	0.39	1.85
stria	1.17	-1.17	-0.15	0.78	0.15	1.56
gium	1.40	-1.24	-0.21	0.78	-0.12	2.19
nada	2.25	-0.79	0.27	0.27	1.70	0.81
nmark	1.11	-1.01	0.05	0.18	0.38	1.52
land	0.92	-0.99	-0.02	0.91	0.60	0.43
nce	1.66	-1.04	-0.09	0.61	0.79	1.38
st Germany	1.17	-0.98	-0.08	0.36	0.24	1.63
lland	3.38	-0.57	-0.03	0.97	0.28	2.74
land	2.37	-0.60	0.01	1.29	1.19	0.47
y	1.35	-1.08	-0.16	1.44	0.99	0.18
w Zealand	1.64	-0.04	0.45	-0.05	0.25	1.04
rway	1.11	-0.91	-0.01	0.97	0.54	0.52
eden	0.86	-0.97	-0.08	0.15	0.26	1.50
itzerland	1.37	-0.63	-0.09	0.64	0.44	1.02
ted Kingdom	1.59	-0.43	-0.06	0.14	0.59	1.36
ted States	1.85	-0.51	-0.02	-0.06	0.75	1.69
guay	0.69	-0.26	-0.02	0.27	0.57	0.13
technology:						
zil	3.35	-0.07	0.63	2.37	3.04	-2.64
garia	1.76	-1.36	0.14	0.51	1.41	1.01
e	1.70	-0.33	0.29	0.04	0.64	1.07
mbia	2.95	0.13	0.14	0.55	1.43	0.69
ta Rica	3.91	0.06	0.77	0.42	1.35	1.32
choslovakia	2.05	-0.66	-0.05	0.20	1.01	1.54
t Germany	1.88	-0.62	-0.03	0.34	0.39	1.81
ece	2.86	-0.50	0.09	2.05	1.31	-0.09
gary	2.75	-0.88	-0.08	-0.08	1.83	1.96
el	3.76	-0.45	0.25	1.23	1.06	1.67
xico	3.43	0.20	0.04	1.00	2.17	0.03
nd	0.98	-0.49	-0.08	2.59	1.27	-2.31
ugal	0.43	-0.62	-0.01	2.15	0.66	-1.67
nania	3.81	-0.79	0.21	1.06	2.47	0.85
th Africa	2.14	-0.24	-0.05	0.39	1.29	0.74
in	2.97	-0.89	-0.03	1.99	0.91	1.00
key	2.89	0.17	0.01	2.91	3.21	-3.41
SR	1.91	-0.65	0.03	0.76	2.01	-0.22
ezuela	3.92	-0.17	0.11	1.43	2.97	-0.44

Continued--

5 (cont.)--Contribution to average output growth rate-2nd Cobb-Douglas 1961-87

y	Output	Labor	Land	Tractors	Fertilizer	Productivity	Animals
nology:							
a	3.60	0.29	0.02	1.24	1.64	0.41	
ican Repub.	2.48	0.27	0.22	0.44	1.91	-0.35	
dor	1.50	0.16	0.51	1.42	1.95	-2.54	
	2.28	0.27	-0.08	1.39	1.36	-0.66	
vador	1.79	0.12	0.17	0.73	0.86	-0.09	
mala	3.10	0.47	0.32	0.48	2.07	-0.23	
uras	2.45	0.56	-0.48	2.02	1.40	-1.05	
	4.04	0.25	0.001	2.51	4.16	-2.87	
	3.96	0.02	0.08	1.69	3.97	-1.80	
n	0.98	-0.87	0.07	1.45	2.08	-1.74	
a	2.81	0.83	0.07	0.40	1.82	-0.31	
agua	1.73	0.40	0.24	2.90	1.97	-3.76	
ia	1.54	-0.08	0.07	2.44	3.08	-3.96	
tan	3.45	0.52	0.21	4.22	3.52	-5.05	
uay	4.38	0.57	0.36	2.10	2.18	-0.83	
	1.38	0.32	0.03	0.73	0.42	-0.14	
n	3.05	0.50	0.03	1.15	0.88	0.49	
	2.03	0.23	0.04	1.14	0.28	0.35	
a	2.40	0.56	0.01	1.23	2.41	-1.81	
bwe	2.67	0.58	0.10	0.37	1.14	0.49	
technology:							Animals
desh	1.50	0.33	0.05	3.08	1.92	-3.89	0.01
n	2.80	0.35	0.28	0.0	0.0	2.03	0.14
odia	-1.81	0.18	0.18	0.28	0.40	-2.76	-0.09
	4.10	0.44	-0.03	3.00	0.09	0.54	0.06
	2.50	0.35	0.05	2.92	2.62	-3.44	0.04
sia	3.80	0.18	0.18	3.25	0.74	-0.60	0.05
	1.90	-1.14	-0.23	0.92	3.52	-0.90	0.00
Korea	4.57	0.18	0.45	2.00	1.40	0.54	0.00
Korea	4.40	0.02	0.03	0.95	5.80	-2.40	0.00
	3.65	0.23	0.03	0.33	2.48	0.47	0.11
sia	5.60	0.23	0.36	2.28	1.52	1.29	-0.08
ar	0.20	0.01	0.01	0.18	0.08	-0.20	0.12
	1.84	0.45	0.45	4.12	2.59	-6.06	0.29
ines	3.44	0.40	0.36	1.57	0.99	0.18	-0.06
ka	1.79	0.44	0.30	0.79	1.30	-1.00	0.04
nd	4.21	0.48	1.08	3.09	3.88	-4.36	0.04
n	3.00	0.53	0.0	0.90	2.04	-0.42	-0.05
m	2.70	0.19	0.23	1.56	2.82	-2.12	0.02

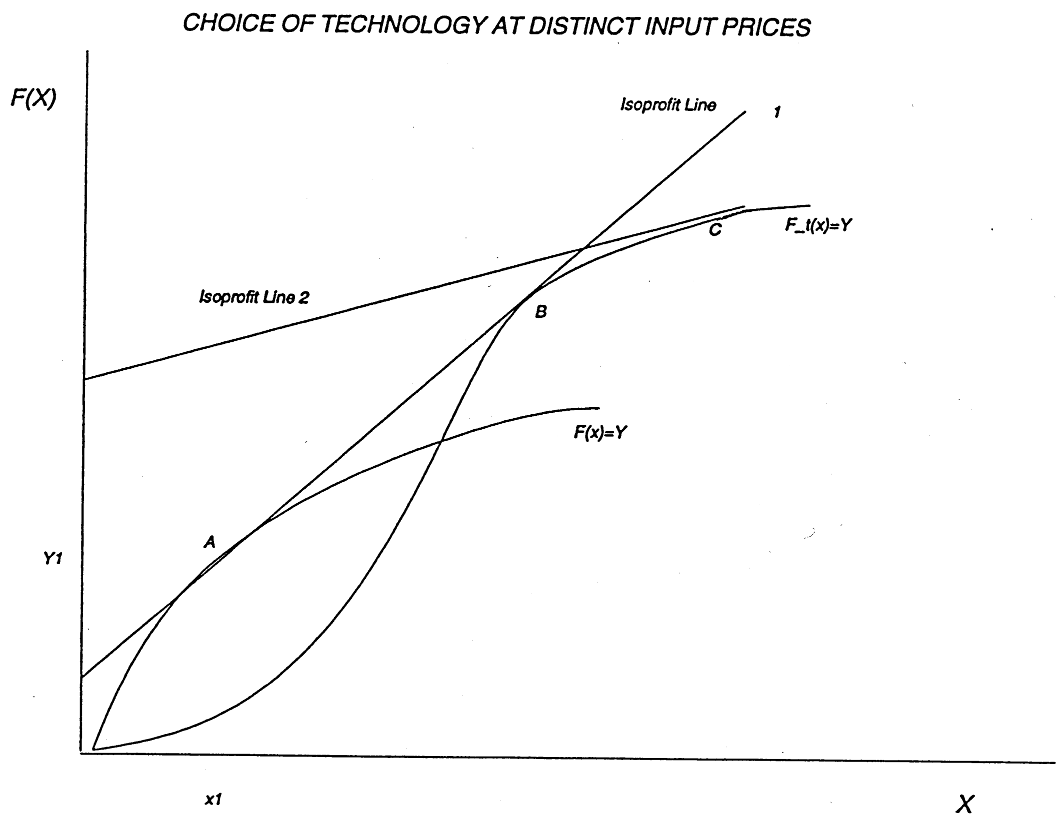
Appendix

Technical change is typically represented as shifting isoquants inward. Fewer inputs are required to produce the same level of output. Technical change indices calculated using DEA showed that in many developing countries more inputs were required to produce the same output. Since technical change is a large component of productivity, and since productivity is declining in developing countries, this phenomenon requires explanation. This explanation will illuminate many input-subsidy programs in developing nations.

Seed varieties for grains that were developed in the 1970's (and which were adopted by many developing countries) can produce more output than traditional varieties. These varieties, however demand more intensive use of inputs, particularly fertilizer. Traditional technology, due to diminishing returns, requires intensive use of inputs at high output levels but does not require much fertilizer input to produce a low level of output. These fertilizer-using seed varieties of grains can be portrayed as shifting isoquants outward at low levels of production and shifting isoquants inward at high levels of production. Without changes in input prices, low-output producers may have little incentive to raise their costs to adopt the new technology.

In figure 1, isoprofit line 1 is drawn to illustrate this situation where producers are indifferent between two technologies. There are two technologies with production functions F(x) and $F_{-t}(x)$ respectively produced with one input. As drawn, the new technology $F_{-t}(x)$ is only more productive at a higher level of input use. Isoprofit lines are drawn by taking the definition of profits: $\pi=pF(x)-wx$ and solving for the production function: $F(x)=(\pi/p)+(w/p)x$. The intercept of the isoprofit line is the level of profits over the output price (π/p), while the slope is the ratio of the input price to the output price (w/p). Optimal producers locate where the slope of the profit line equals the slope of the production function. At this point, the marginal value product of production equals the input price.

With the isoprofit line 1 representing profits π and output price p, and input price w, producers are indifferent between technologies. They can use the old technology, move to point A on the production function labeled F(x), produce Y1, and use X1. Or producers can adopt the new technology and produce at B on the production function labeled $F_{-t}(x)$. At either point A or B the marginal value product of input x equals the input price. This is represented by the tangency of the isoprofit line (with slope w/p) to both production functions. However at B both more output is produced and more inputs are used. Such a situation, could have faced developing nations.



CHOICE OF TECHNOLOGY AT DISTINCT INPUT PRICES
F(X)
Isoprofit Line
1
F_t(x)=Y
C
Isoprofit Line 2
B
F(x)=Y
A
Y1
x1
X

Figure 1

Suppose governments and consumers are not indifferent between points A and B. Producing at point B creates more output and employs more inputs, which governments want. Governments could push producers into adopting the new technology by pushing down the input price. This flattens the slope of the isoprofit line.

Isoprofit lines with a slope equal to that of the second line drawn in figure 1 are tangent to the production functions only at output levels where the new technology is superior. As drawn, isoprofit 2 line represents lower input prices and higher profits for producers. With the new input prices producers move to point C, where the production function labeled $F_{-t}(x)$ is tangent to the new isoprofit line.

This graph illustrates the motivation many developing governments had for using input subsidies. With subsidies, producers have an incentive to adopt new technology, which produces more output and leads to higher profits. Without subsidies, producers may not favor the new technology. Producers either stay with the new technology after subsidies are removed or choose to again switch technologies and reduce output.

Though many developing countries removed input subsidies in the 1980's, producers stayed with the new technology. Once high- yielding input-intensive crops were adopted, producers tended to use them. The reason for this may be that (a) there are adjustment costs to switching technologies, (b) as before adoption, producers are indifferent between technologies, or (c) inputs required by the new technology are cheaper after new technology is adopted.[7]

Note in figure 1 productivity need not rise when new technology is adopted. Productivity is represented by the slope of a ray from the origin to the point of production. Figure 1 could be drawn so that productivity is higher or lower with the new technology. Programs that increase output and employ more inputs may be deemed a success but they do not necessarily increase productivity.

[7] Inputs such as fertilizer may be cheaper because scale economies arise in production and marketing of inputs after the new technology is adopted.