Agricultural Development

Issues, Evidence, and Consequences

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Investments in technology have yielded large gains for agriculture, and the benefits have been passed on to consumers in the form of lower prices. Thus history justifies public spending on agricultural research.

Summary findings

A comprehensive examination of data from many countries shows that in 1967–92, 81 percent of the world's population lived in countries where agricultural growth exceeded population growth. Moreover, that growth occurred as agricultural prices declined.

Productivity gains are a dominant characteristic of agriculture for the period. Average productivity increased for land and labor. Moreover, agricultural productivity gains were greater than average productivity gains for the economy in 80 percent of the countries studied.

Measuring the effects of technology choice on productivity is crucial to understanding the determinants of agricultural growth. After selectively reviewing applied production studies, Mundlak, Larson, and Crego conclude that the choice-of-technique method, which has its roots in Tinter's early production function studies, is best suited for examining the determinants of agricultural growth.

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AGRICULTURAL DEVELOPMENT; ISSUES, EVIDENCE, AND CONSEQUENCES

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CONTENTS

1. THE ISSUES	1
2. THE EVIDENCE	2
2.1 Supply and Demand	2
2.1.1 The Global Food Experience - an Overview	2
2.1.2 Demand and Agricultural Growth	4
2.1.3 Trade	7
2.2.1 Land	7
2.2.2 Labor	8
2.2.3 Summary	11
3. AGRICULTURE AND FARMERS	11
4. AGRICULTURE AND DEVELOPMENT	16
5. RESEARCH IMPLICATIONS	17
6. THE PRODUCTION STRUCTURE OF AGRICULTURE	20
REFERENCES	26
FIGURES	27

AGRICULTURAL DEVELOPMENT; ISSUES, EVIDENCE, AND CONSEQUENCES

1. THE ISSUES

Many roads lead to the interest in agricultural development, and it is only natural that we find differences among economists in their analyses and more so in perspectives, emphasis, and conclusions about the process and its outcome. To provide a perspective for our discussion, it is useful to list the central issues related to agricultural growth:

- Agriculture as a supplier of food,
- The welfare of farmers and more generally, the rural population,
- The role of agriculture in economic development,
- The impact of government intervention on the performance of the agricultural sector as a subject of political economy.
- Traditionally agriculture has been studied with the purpose of checking the validity of general economic propositions, and this also applies to the study of various aspects of growth.

Keeping this diversity of interests in mind, it is instructive to conduct the discussion against the background of the evidence. To do so, we present results from a comprehensive examination of a data base of a large number of countries for the period 1960-1990 or thereabout.¹ The presentation highlights important empirical propositions -

mostly known but often ignored - and provides a quantitative dimension of the cross-country variability of levels and rates of change over time. It is then followed by a short overview of the consequence for policy and analysis. Given space limitations, no attempt is made here to document all the assertions. This will be done elsewhere.

2. THE EVIDENCE

2.1 Supply and Demand

2.1.1 The Global Food Experience - an Overview

There is a keen interest in future market developments related to food supply. This interest is more intense than in other sectors because of the unique role of food and the nature of its demand. Much of the concern with food supply can be explained by the fear supply shortages and hunger at some point in the near or remote future. In the dialogue on this issue, reference is sometimes made to the experiences of countries that suffered food shortages for extended periods of time or to episodes of hunger in affluent economies. Although traumatic, such episodes do not generalize to give a correct global picture. It is here where the empirical perspective is essential.

A summary of the growth experience of countries is given in Figure 1 which presents a frequency distribution of total agricultural production growth rates for the period 1967-1992 for 130 countries.² The curve to the left is drawn with equal weight for each country. At any point on the graph, the reading on the vertical axis shows the

proportion of countries whose growth rate did not exceed the corresponding value on the horizontal axis. There is a wide spread in country performances, but most countries had positive growth, and the median rate is 1.92 percent per year. As some of the low growth countries are small in terms of their agricultural production, this curve does not provide a good view of the changes in global supply. A better view is obtained when the relative size of country is taken into account. This is done in the curve to the right, where the countries are weighted by their relative importance in world agricultural production. Countries with negative growth rates carry very little weight in terms of their contribution to overall food production. The median average growth rate of the weighted distribution is 2.25 percent. This means that 50 percent of the food production is produced in countries whose growth rates exceeded 2.25 percent, and the remaining is produced by countries with lower but usually positive. Put another way, growth rates have been somewhat higher in countries with large agricultural production.

Has supply lagged demand? If this were the case, agricultural prices would have risen, but this has not happened. This is seen in Figure 2, which presents the distribution of the rates of change of agricultural prices over the same time period.³ Domestic farm prices are deflated by domestic consumer price indices. The median of the unweighted distribution is -.45 percent per year and when we weigh the countries by their importance in world production, the median changes to -.61 percent per year. Note that the vertical line at zero growth rate cuts the graph of the weighted distribution at .71, indicating that 71 percent of world production in the period 1967-1992 was produced in countries where

real prices fell.

Because the prices in Figure 2 are of aggregate output, their rates of change tend to be biased upward. As income increases, there is a shift in consumption and production to higher value products, and this change in composition causes the aggregate price to increase. Thus, the fact that we observe a decline in prices even despite an upward bias, suggests that supply grew faster than demand. This result is consistent with the finding reported in Binswanger et al (1987) that over the period 1900-1984, world prices of important agricultural commodities, such as the major cereals, deflated by US wholesale prices, declined at average annual rates of .5 to .7 percent. This overview indicates that recent experience, which generalizes well to the entire post-war period, is of faster growth of supply compared to demand.

2.1.2 Demand and Agricultural Growth

What are the sources of the spread in growth rates? This is of course the main question in the study of growth in general and of agricultural growth in particular. The search for answers naturally focuses on the supply side. However, before examining factors related to supply, it is instructive to examine the role of demand.

On the whole, agricultural products are tradable, and therefore there is no need for each country to increase its production to meet domestic demand changes. Some countries can benefit from comparative advantage and reduce their production in an environment of growth and of reduction of trade restrictions. Such behavior may explain

some of the observed spread in growth rates. For instance, Singapore's agricultural production more than doubled between 1967 and 1979, but declined thereafter to such an extent that 1992 production was below that of 1967. Other countries do not fully utilize their potential in agricultural production in order to protect farm income and are engaged in policies that involve a reduction of their domestic production and restrictions on imports. Together these restrictions indicate that there have been excess supplies. Further, import barriers further restrict the expansion of production in exporting countries as potentially importing countries attempt to use their own markets for the development of their farm sector.

An indirect view of the role of demand can be obtained by comparing the distribution of growth rates of *per capita* output, presented in Figure 3, with *total* output, in Figure 1. The median rate of change of per capita production of the equal weight distribution is minus .03 percent although in about 51 percent of the countries output exceeded population growth. Taking into account the production weights, the median growth rate is .7 percent, and output growth exceeded population growth in countries that accounted for 81 percent of world production. Such a pronounced difference between the two distributions underlines the importance of distinguishing between country problems and global problems, and the pitfall of generalizing from country performance to world performance.

We also note that the graphs in Figure 3 are more steep than the corresponding graphs in Figure 1.⁴ This implies a higher concentration of countries around the median

growth rate, that is, the variance of *total* growth rates is larger than that of *per capita* rates. This concentration in the center indicates that many countries met a large part of growth in demand through home production. In fact, on the whole, production growth exceeded population growth somewhat because of the increase in demand due to the rise in income as well as the decline in prices. Clearly, this development is consistent with demand derived from production growth.

A more direct view of the role of demand is obtained by comparing the rate of growth of agricultural per capita output with that of per capita total output, taken as a measure of income. Ignoring trade for a moment, we note that for the closed economy under constant prices this ratio is roughly the income elasticity for food. We say roughly, because agriculture is not identical with food and it includes industrial crops whose demand is not the same as that of food. However, in most countries, food dominates agricultural production.

Figure 4 presents the distribution of such a ratio for growth in real *value* for 91 countries during 1960-1992.⁵ The median values are .82 and .86 for the weighted and unweighted distributions, respectively. Since prices were not constant, and rather declined, this result serves as an upper bound for the income elasticity.

We emphasize the role of demand because most discussions of economic growth deal with a single good economy where there are no prices, except for the discount rate. However, the single-good economy is an aggregate of many sectors, and therefore the discussion of growth at the sectoral level adds a dimension missing from aggregate

models. Indeed, when it comes to agriculture, it is demand which has an enormous impact on the dynamics of the sector.

2.1.3 Trade

Agriculture produces a tradable product, but the foregoing review indicates a tendency toward self sufficiency. This is reflected in the fact that trade accounts for only 10-12 percent of total world production. This tendency toward self-sufficiency is in part due to policies as indicated above, but is also due to objective market conditions. The margin between import and export prices may be wide, distribution costs within the country, both for the exporter and the importer, can be high, especially in countries with inadequate infrastructure.

2.2 Inputs and Productivity Changes

Turning to the supply side, the joint event of output growth and declining prices indicates that productivity growth more than offsets the effect of the declining prices on profitability. To evaluate the sources of growth we examine changes in land and labor, the two inputs that together account for the large proportion of output.

2.2.1 Land

It is often thought that agricultural land is a fixed quantity. This view is true for countries' total physical areas whereas cultivated land, hereon "land," is an economic

quantity and as seen in Figure 5, was subject to changes. In 65 percent of the countries the cultivated area increased during 1967-1992, with a median average annual growth rate of .4 percent. For the world as a whole, the average annual growth rate was .58 percent which amounts to about 15.7 percent growth for the period as a whole. Land growth was faster in tree crops, 1.48, than in annual crops, .52, percent per year. Thus, in spite of the lower prices for agriculture, it was still profitable to expand the area of agricultural land.

The growth rate of land is much smaller than that of output and this reflects an increase in land productivity. Figure 6 presents the distribution of growth rates in average land productivity for 87 countries. In 11 countries (13 percent of the countries) the average productivity declined, but these countries carry small production weights (less than 2 percent of production) and the weighted distribution shows a concentration in the positive growth rates. Thus, the bulk of world production was obtained with an increase in land productivity. The median growth rates are 1.8 and 1.92 percent for the unweighted and weighted distributions respectively.

2.2.2 Labor

Changes in the agricultural labor force have taken a somewhat different pattern. In 40 percent of the countries, *total* agricultural labor declined. Figure 7 presents the distribution of changes in the labor force for 148 countries during 1950 to 1990. The median growth rate was .56 percent while similar to that of harvested land, there is a

substantial spread across countries.

Several technological factors affected labor demand. In part, the labor requirement, particularly harvest labor, is increasing with the level of output and as such increases with yields. Similarly, when the composition of output changes from cereals to fruits and vegetables, labor requirements increase as well. Also, an increase in livestock production frequently increases labor requirements for agricultural labor. Finally, the increase in cultivated land adds to the labor demand. On the other hand, mechanization of agriculture reduces the labor requirements. All of this regards demand for labor input but the data report a different variable: the labor force in agriculture. This measure includes workers not fully employed in agriculture and many of them eventually leave agriculture, but the timing and the degree of such migration depends on the off-farm work and income opportunities.

With all these qualifications, the net effect of mechanization on agricultural labor input is detected in the labor-to-land ratio which are presented in Figure 8. In about half of the countries this ratio declined, and the rate of decline was stronger than the rate of increase in the other half of countries. This uneven effect is attributed to the dependence of the degree of mechanization on the economic environment, which determines the profitability of mechanization. It is the poorer countries, with lower wage-rental ratios, that rely more heavily on labor than on machines. In those countries, the off-farm migration was not sufficient for the data to show a decline in the actual labor input in agriculture.

When output per unit of land increases while the labor per unit of land is constant, there is an increase in productivity. The distribution of the growth rates of average labor productivity in 87 countries is drawn in Figure 9. The growth rates of average labor productivity are somewhat higher than that of average land productivity. The median rates are 2.0 and 2.6 percent for the unweighted and weighted distributions, respectively. A comparison of the weighted distributions of average labor and land productivity for 87 countries is presented in Figure 10.⁶

Changes of these partial-productivity measures reflect changes in the agricultural labor force, cultivated land, other inputs and technology. The major input that is missing from the discussion so far is capital. Data on this variable is limited but preliminary estimates indicate that it grew faster than output. However, its factor share in total output can be quite high and hence it can have a strong direct effect on productivity. In any case, it is important to emphasize that perceived productivity changes are outcomes of decisions on inputs and implemented technology. These decisions are endogenous and have to be studied in conjunction with, and as a part of, the productivity analysis. We return to this subject below.

How does the productivity performance in agriculture compare with that in non-agriculture? Figure 11 presents the distribution of the differences in the growth rates of average labor productivity in nonagriculture and agriculture. The median values are -1.58 and -1.1 for the unweighted and weighted distributions, respectively, which implies a higher growth rate in average labor productivity in agriculture. However, what is

striking is that labor productivity grew faster in agriculture than in the rest of the economy in nearly 80% of the countries.

2.2.3 Summary

What comes out clearly from this description is the existence of a large spread in input and output changes across countries. The important question here is what accounts for such a spread and more specifically, to what extent does the economic environment contribute to this spread. The term 'economic environment' is used here to represent the set of all the variables that affect the production decisions made by firms. These include prices, interest rates, price uncertainty, availability of inputs, the competitiveness of the input markets, availability and quality of infrastructure, the access to new information, the legal and organizational infrastructure needed to conduct business activity, the stability of the economic variables, tax structure and alike. Not all of these variables change to a degree that affects production in a given country in any given period, and the strategy of research is to concentrate on isolating the effects of the important variables that did change. The list of pertinent variables may vary from country to country and the purpose of a country analysis is to identify them and thereby supplement the results obtained in a cross-country analysis.

3. AGRICULTURE AND FARMERS

In evaluating the impact of technical change on agriculture it is important to

differentiate between agriculture as an economic activity (or a sector) and farmers. The welfare of the sector is measured by the returns to land, which is the factor specific to agriculture. The main welfare issue related to farmers is their income level and, to a lesser extent, its stability. Farm operators benefit from increases in land rent, residual income, and labor income. In this discussion, we ignore income from other forms of capital without affecting the main conclusions of the discussion.

As economic theory and the empirical literature tell us, the returns to land are reflected in land prices. Thus, if the agricultural sector benefits from the technical change, land prices would be expected to increase, and it is therefore of interest to observe the changes in land prices over time. Unfortunately, there is no readily available comprehensive data set with time series of land prices for various countries. In view of the importance of this variable, together with Rita Butzer, we are assembling data by an intensive library search. At this point we review some of the data assembled thus far.

A cross-country comparison of land prices is a difficult task because of quality differences, notwithstanding the difficulty of quantifying the importance of the economic environment that affects such prices. Nevertheless, the time path of land prices in the various countries is telling. There are two ways, pertinent to our discussion, to look at land prices. The first is to deflate land prices by the price of the agricultural product, and the second is to deflate them by the price of the consumption good as measured by the "CPI." The first, referred to as the output measure, provides the price of land reflecting its productivity, whereas the second, referred to as the consumption measure, indicates

the value of land in terms of the purchasing power it has over an aggregate consumption good, whose price is measured by the “CPI.”

Figure 12 shows the pattern of real agricultural land prices for the United States, Canada, South Africa and Japan countries for which extended time series are currently available. In Figure 12, land prices are reported as indices with 1986 = 1. The upper panel shows the output measure of land prices whereas the lower panel shows its consumption measure. By both measures, land prices declined in the pre-war period. They were gradually increasing in the immediate postwar period. This rise gained impetus during the inflationary period of the 1970s and came to an end in the early 1980s, when the economies started to deflate.

Comparing land prices at the beginning and end of each series, we see that by the output measure prices are considerably higher, but according to the consumption measure there is little change. In the US, the consumption-land-price index was .84 in 1992, compared to .73 in 1910. For Canada the values for 1990 and 1914 are .87 and .76, respectively. The series for South Africa begins in 1940 at a level of .88, whereas the 1993 value is .65. Data for other countries show the same trend. On the whole, prices in the 1990s are historically relatively low, and it is remarkable that land prices today are not much different from those at the beginning of the century. Moreover, land prices reflect subsidies to agriculture. If account were made for subsidies (which are relatively new), then land prices would exhibit even less growth over their historic levels.

Another striking observation is the high correlation between the price movements

for the four countries plotted in Figure 12, as well as for most countries. The correlation is stronger for the output measure than for the consumption measure. This correlation indicates that much of the impact of the dramatic changes in agricultural technology was transmitted to the various countries (or at least to those observed here). However, the benefits were not captured by agriculture and eventually were distributed to the consumers. This was done through a decline in agricultural prices relative to prices of the other consumption goods.

The changes in the welfare of people in agriculture is a different, and far more complex, story. The income of farmers is the return to their labor and factors in their possession. Aside from the returns to land discussed above, which applies mainly to land owners, labor income is the main income source for farm operators and primarily the only source for landless labor.⁷ Data on returns to labor are deficient. Therefore, we will examine changes in the structural composition of the labor force and infer the impact of the changes in technology on labor.

Even though in most countries there was an increase in the agricultural labor force, this increase lagged behind the increase in the total labor force due to off-farm migration. This is seen by comparing the growth rates of agricultural labor with that of the population. Under the assumption of equal fertility rates in agriculture and nonagriculture, the growth rate of agricultural labor less that of the population gives the rate of labor migration from agriculture to nonagriculture, expressed as a percentage of the agricultural labor force.⁸ The distribution of this difference in growth rates for 148

countries is plotted in Figure 13, which shows that such migration took place in practically all countries. The median average annual migration rate for the period 1950 to 1990 is 1.97 percent. That is, at the median the agricultural labor force declined at an annual average rate of about 2 percent.

In interpreting this result, it should be noted that off-farm migration is determined not only by changes in agricultural profitability but also by changes in labor demand in nonagriculture as well as sectoral differences in the level of standard-of-living. A detailed study of off-farm migration based on the cross-country data for the period 1950-1990 appears in Larson and Mundlak (1995). Naturally, when labor income in agriculture is low, people will migrate to other sectors. Thus, off-farm migration is probably the most important single process that contributes to the alleviation of rural poverty. This result should be kept in mind in judging not only economic processes but also institutional and legal reforms. There is nothing more effective in improving people's welfare than allowing them to choose freely between opportunities and thus escape areas of hardship. The traditional exploitation of agricultural labor may have taken place because migration opportunities for such labor were restricted by institutional arrangement, by lack of infrastructure, or by lack of opportunities outside of agriculture. For migration to take place, opportunities in nonagriculture are required. This is where economic growth comes in as a factor in the alleviation of agricultural-based poverty.

4. AGRICULTURE AND DEVELOPMENT

The technological change in agriculture had two important effects on the economy as a whole. First, it improved the overall food supply while prices declined and thus improved consumer welfare. Second, it made it possible to produce more output with relatively less labor and thus facilitated the development of nonagriculture. As a result of the migration, the share of agriculture in the total labor force has declined. This is seen in Figure 14 in which the share is plotted for 148 countries for the years 1950 and 1990. The share varies considerably among countries. It is high in less-developed economies and declines with the level of development. Even so, it has declined in all countries. The median share was 70 percent in 1950, but only 33 percent in 1990. The proportion of countries with a share below 10 percent increased from 1.3 percent in 1950 to 15 percent in 1990. Few indicators are better able to tell the story of the role of agriculture in economic development. The freeing of labor that is a necessary condition for development. Therefore, understanding of the process of off-farm migration, and the determinants of its rate, contributes to our understanding of the process of development.

The net outcome of the processes reviewed above is a decline in the relative importance of agriculture in total output. The change in the distribution of this share in the 40 year period between 1950 and 1990, as seen from Figure 15, is indeed noteworthy; the median for this group of 67 countries declined from 30 to 8 percent over this period.⁹

In summary, technological change in agriculture serves the rest of the economy by increasing supplies at lower prices and contributing labor to the development of

nonagriculture. At the same time, in the longer run, none of the benefits are captured in agriculture. Who would stand to benefit from further increases in agricultural productivity in the future? There is no reason to think that the future will be any different from the past.

This welfare conclusion has an important policy implication for the finance of agricultural research. Historically, much agricultural research was publicly financed because the fruits of the research can not be internalized by the researcher. The foregoing discussion indicates that it is indeed in the interest of the public at large to promote research that will produce technological change in agriculture. Therefore, the burden of this research should be carried by the public at large and not by agriculture, which does not seem to capture and maintain the benefit from it. Furthermore, because the fruits of the research are eventually spread to all countries, a strong case can be made for financing research internationally. But countries can take lead in advancing technology and benefit from it until the new technology spreads to other countries. Also, for countries to take advantage of global developments, they must have an ongoing active research program. Thus, there is a strong case for country finance of its own research as well.

5. RESEARCH IMPLICATIONS

An important conclusion to be drawn from the foregoing review is that the underlying process of agricultural growth is universal but its pace varies over time and

across countries. The basic question is how to account for this variability. There is no simple answer to this question because there is no single factor that can provide the answer. This is also true when it comes to the evaluation of the consequences of policies. Much research on agricultural policy concentrates on the implications of sector-specific policies, which are pertinent but by themselves insufficient to unfold the whole story.

The process of development is a process of continuous adjustments made by households and firms. These adjustments and their consequences are spread over time and as such are dynamic in their nature. They are carried out in response to changes in the economic environment subject to the prevailing constraints. Thus the key to understanding of the economic performance of agriculture, as well as other sectors, is in the study of the impact of the economic environment on such decisions. The task is to formulate a framework that will channel the net effect of the various variables forming the economic environment into measures conducive to empirical analysis.

The approach is based on the simple premise that an increase in output is obtained by a change in resources, in the efficiency of their use or in the implemented technology. For most countries, the limiting factor to growth is not the available technology as determined by the frontier of knowledge, because they are far from the frontier. The pressing research issue is to identify the constraints that prevent the country from taking full advantage of the available technology, and the determinants that control the pace of convergence to the frontier. As these constraints are affected by the economic environment, a successful mapping of the economic environment to variables

considered by producers in making their production decisions can form the framework for the analysis.

There are several important blocks in this formulation. First is the mapping of the economic environment to sectoral incentives. Second is the impact that sectoral incentives have on factor demand and factor supply. Third is the dependence of the implemented technology on incentives and on resource and other constraints. In this, an explicit account should be taken of the fact that the decisions have consequences in more than one period. The dependence of factor demand on incentives is obvious. A good illustration of the dependence of factor supply on incentives is that of labor where the off-farm migration is affected by the intersectoral income differentials. A good illustration of the dependence on constraints is that of the choice of techniques. Different techniques have different resource requirements, where on the whole, the more advanced techniques are more capital, human and physical, intensive. Hence, capital scarcity determines the pace of implementation of new techniques. As decisions on the implemented technology are made jointly with the decisions on input demand, that demand also depends on the same constraints that affect the implemented technology. The research and policy implications of this point can not be overemphasized.

Underlying the process of implementation of new techniques is the flow of new

techniques, or changes in the available technology. Such a flow is correlated with investment in research and development but, more profoundly, it depends on the advancement in basic knowledge which, by its very nature, follows a random walk. The voluminous literature that aims to explain this flow, for which agriculture is a good example, provides plenty of anecdotal evidence but no structural model, and therefore little predictive power.

The empirical knowledge of the various blocks makes it possible to simulate the economy and to evaluate the consequences of various policies. This is the approach taken in Mundlak, Cavallo and Domenech for Argentina and Coeymans and Mundlak for Chile. These studies construct simulation models along the lines indicated above which are fitted to the historical data. Thereafter, the model is simulated to evaluate the consequences of alternative policies of interest within a historical context in order to understand the dynamic, quantitative effect of various policies and to infer from them desirable courses of action for future development.

6. THE PRODUCTION STRUCTURE OF AGRICULTURE

Technology and competitive conditions plays a role in the determination of supply. Almost any of the foregoing discussion involve attributes of technology. Technical change is the key factor for growth and affects income distribution. Factor shares determine the relationships between factor prices and product prices and the competitive position of a sector. Returns-to-scale affect the size distribution of firms.

Elasticities of substitution affects the functional distribution of income due to capital accumulation. Not independent of all of the above is the question of supply response and factor demand. Hence, the empirical analysis of technology, and its changes, is of cardinal importance.

The literature on production functions and related topics deals with various aspects of the subject but comes short of providing an integrated framework which is readily applicable in the evaluation of the dynamics of agriculture. To provide an insight into this literature we summarize some key findings on the central issues pertinent to the construction of such a framework based on a recent literature review (Mundlak 1997). There are two fairly distinct periods in the study of agricultural production functions, before and after duality. The changing of the guards was in the early 1970s. Duality is a powerful theory to analyze supply issues using primal or dual functions. However, its empirical use is more limited. As a result, the appearance of duality changed not only the method of estimation but also the questions asked to the extent that there is little continuity in the subjects of interest. This is illustrated below.

The empirical work on agricultural production functions originated in a methodological paper by Tintner (1944) and an application by Tintner and Brownlee (1944). This work was influenced by the work of Paul Douglas and it thus took fifteen years to adopt the work of Douglas in agricultural economics application. The primal estimation of the Cobb-Douglas function was the centerpiece in the pre-duality work. The approach does not impose competitive conditions on the estimation but instead

submits them to empirical testing. Such testing often shows a difference between observed factor shares and the estimated production elasticities. This result is not an absolute rejection of the prevalence of the competitive conditions but rather a conditional result, based on the model and the statistical procedure used. Still, it is indicative of the existence of deviations from such conditions.

Empirical results maintain that the elasticity of labor never exceeds 0.5, and in most cases it varies in the range of 0.25 to 0.45. This value is less than the elasticity of labor in nonagriculture. If all non-labor income is considered to be capital income, then the result supports the position that agriculture is cost-capital-intensive and therefore less susceptible to increases in the wage rate than nonagriculture. Also, the factor share of labor in agriculture has declined with time, indicating that technical change was labor-saving.

The elasticity of land varies between zero, in some cases, and about one third. We interpret this elasticity to be a measure of the competitive position of agriculture. From the perspective of farm income it is meaningful to look at the sum of labor and land elasticities, and this sum often fluctuates around 0.5.

One motivation for estimating production functions is to provide weights for the computation of technical change. However, this approach has not provided any substantive advantage compared to the use of factor shares, even though they may not be the same as the production elasticities. The reason is specification errors and interpretation of statistical studies are often greater than the discrepancies between the

factor shares and the true production elasticities. An example is the error involved in finding increasing returns to scale and its subsequent incorporation in the computation of total factor productivity. This leads to the elimination of residuals in comparisons of growth over time or productivity differences across countries. Such a procedure was motivated by the belief that all growth can be accounted for and therefore there should be no residual (Griliches, 1963). However, this belief has no foundation and it is inconsistent with theory.

An important feature common to many studies is a lack of robustness in the estimates and their dependence on the selected variables and sample coverage. This result is consistent with the interpretation that the implemented technology is sensitive to variations in the economic environment.

What distinguishes the dual approach from the primal is the appearance of prices in the empirical equation. Hence, in evaluating the performance of this approach we address the following questions:

- What has been the contribution of prices to the empirical equation?
- What additional information is obtained from the dual equations and how can they be interpreted?
- Are the underlying assumptions of duality met?
- What are the statistical benefits of this approach?

The dual estimates are obtained by regressing factor shares on prices, a time trend and sometimes output. When the change in use of inputs is decomposed to price,

technology (more correctly, time) and output effects, trend and output account for most of the changes whereas the role of prices is the least important. Thus the apparent direct contribution of prices to the explanation of inputs or output variations is rather limited. There is an indirect contribution that works through the impact on the quasi-fixed inputs, not captured in the usual dual estimates, but this is not discussed here.

On the whole, the own-price elasticities reported in the literature are less than one. There is no uniformity in the signs of the cross-elasticities but in general, most inputs appear to be substitutes. The price elasticities of factor demand and product supply are usually obtained under the assumption that factor supplies are perfectly elastic. In practice, this is not the case. Consequently, the magnitude of the estimated elasticities are affected and the results need not represent demand-driven substitution. This is particularly relevant to elasticities related to labor, land and capital.

Interestingly, on the whole, the studies based on duality do not show increasing returns to scale. Moreover, technical change, obtained by including a time trend in regressions of factor shares, is largely labor-saving, capital using, and fertilizer using. The results on land are somewhat ambiguous. However, this is reflective of the data. Therefore, the effect of including prices was not sufficient to change conclusions that could be drawn from the raw data. This does not give a strong mark to the analysis in that the results are obvious without it.

Duality between technology and prices holds under well defined conditions that can be tested empirically. In most studies, these underlying conditions are not fully met,

particularly concavity of the cost function and convexity of the profit function.

Therefore, the estimated technology is inconsistent with the basic premises of the model.

In a way, this is the most disappointing result because duality is a very powerful theory.

An important question then is why the theoretical results are inconsistent with the empirical analysis. There is more than one reason, but probably the most important one is the improper treatment of technology.

One of the expected virtues of duality has been its apparent solution of the simultaneous equation bias realized in some primal estimators. However, a closer examination of this issue indicates that in general dual estimators are inferior to primal estimators (Mundlak, 1996).

In summary, a close examination of the literature suggests that various anomalies and apparent inconsistencies in empirical results can be interpreted within the framework of the choice of techniques which views the implemented technology to be sensitive to the economic environment. This provides an appropriate framework for empirical analysis and provides the needed insight for the evaluation of changes in policies.

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FIGURES

Figure 3 Per Capita Agricultural Production
1967-1992 130 Countries

Figure 5 Harvested Land

1967 - 1992 131 Countries

Figure 6 Land Productivity

1960 - 1992 87 Countries

Figure 9 Average Labor Productivity

1960 - 1992 87 Countries

Figure 10 Labor and Land Productivity

1960 - 1992 87 Countries

Figure 11 Differential Growth of Labor Productivity

Non-Ag Minus Ag 1960 -1992 88 Countries

The Price of Land in Agriculture

Figure 12

Relative to Consumer Prices

Figure 15 Share of Agriculture in GDP

1950, 1990 67 Countries

Notes

1. This research has been conducted at the World Bank. The data were assembled from the known international sources such as FAO, ILO, the World Bank, IMF as well as from country publications. The results are presented in terms of empirical distributions. The number of countries and the period covered in the figures vary according to data availability.
2. Unless indicated otherwise, all growth rates are computed from a semi-logarithmic regression of the variable in question on time.
3. The number of countries varies across figures because of incomplete data sets.
4. In making such a statement, we note that the vertical axis in the two figures is the same and that the units of the horizontal axis are also the same
5. Based on national accounts data, converted to dollars and deflated by the US GDP deflator.
6. The variance of the average land productivity is lower than that of the average labor productivity. This is due to bigger variance in the rates of change of the labor force than of land. The pattern of changes in land and labor productivity is discussed by Hayami and Ruttan (1985).
7. Part of the rent (residual income) may also be shared by tenants, depending on the nature of the contract.
8. The assumption of equal fertility rates is made here for purpose of illustration. The migration rates could be estimated under the assumption of different fertility rates.
9. The median in 1990 for a larger set of 110 countries is 9 percent. Figure 15 contains fewer countries on which we have data also for 1950.

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