Prices, Productivity, and Waste in LDC Agriculture

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GATT Paper 94-GATT 12
April 1994

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Journal Paper No. J-14813 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 2998. Partial support for this study was provided by the North Carolina Agricultural Research Service.

This material is based upon work supported by the Cooperative State Research Service, U.S. Department of Agriculture, under Agreement No. 92-38812-7261. Any opinions, findings, conclusions, or recommendations are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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ABSTRACT

Recent studies have revealed that LDCs have been taxing their agricultural sectors at rates of 40 to 50 percent. While it is widely acknowledged that this taxation might have significant allocative effects, this paper examines its productivity effects as well. This study specifies and estimates a cross-country aggregated agricultural production function. The results estimate that the elasticity of productivity with respect to output prices is about 0.13, indicating that the taxation levels have had very significant productivity impacts. Allais-Debreu measures of deadweight loss indicate that from 7 to 16 percent of output or of the agricultural resource base has been wasted due to the associated misallocation of agricultural inputs across these countries.

PRICES, PRODUCTIVITY, AND WASTE IN LDC AGRICULTURE

Introduction

Agriculture is heavily taxed in less developed countries, and combined direct and indirect tax rates of 40 to 50 percent are common. These levels of intervention surely have had significant impacts on both the allocation of resources to agriculture and on the productivity of those resources. This paper examines the direct effects of price policies on the productivity of agricultural resources and measures some of the deadweight losses accompanying these allocative distortions for a sample of 18 developing countries over the period 1960 to 1984. The price distortions examined are those created both by sector specific policies and by general trade and exchange rate policies. We estimate the productivity effect of price policies by directly estimating an aggregate production function conditional on past prices. We then estimate deadweight losses associated with the cross-country misallocation of tradable agricultural inputs. Measures of deadweight loss are based upon the concepts of waste introduced by Allais (1943,1977) and by Debreu (1951).

The next section of the paper identifies contradictory hypotheses regarding the relation between prices and productivity and develops a production function approach to distinguish between them. The production function follows from a model of endogenous technical change that leads to a variable coefficients technology with expected prices being among the factors affecting the value of the coefficients. The third section discusses the quantity oriented measures of waste introduced by Allais (1943, 1977) and Debreu (1951) and presents a production sector adaptation of these measures to be used in measuring the deadweight losses from misallocation of agricultural inputs among LDC agricultural sectors.[1] Section 4 presents estimates of productivity and efficiency measures and the last section offers conclusions.

The Productivity Effect of Price Distortions

Productivity is the amount of output forthcoming from a given set of inputs, or the ratio of an index of outputs to an index of inputs. Productivity might increase because of technical change (the production function shifts upward), an improvement in technical efficiency (output moves closer to the frontier defined by the production function), because of changes in the scale of production (in the absence of constant returns to scale), or because of improvements in allocative efficiency (which affect our measurement procedures, see Fare and Dogramaci.) In this paper, we consider productivity change only as it is manifested by technical change, more specifically by shifts in the aggregate agricultural production function.

Although most economic analysis tends to accept technical change as exogeneous, there is also a strain of the literature focusing on the possible causes of the rate and direction of technical change. This literature (see Dosi for a review) devotes little attention to the role of prices as a possible cause, which is a bit surprising given that our profession readily accepts the possibility of prices affecting almost every other realm of endeavor. Schmookler (1966) and Lucas (1967) believed that technical change is the result of innovative activity, and suggested that the amount of innovative activity depends upon its profitability. A possible implication of this conceptual approach is that increases in expected product price should increase incentives for innovation and therefore increase the rate of technical change. Both Schmookler and Lucas found empirical support for this hypothesis. Later corroboration was provided by Binswanger (1978) and by Huffman and Evenson (1989).

[1] Given the difficulties associated with the movement of resources across countries, the measurement of waste obtained in this paper represents a first step towards calculation of deadweight losses associated with the misallocation of resources across sectors.

While high output prices might increase productivity through faster technical change, it has been suggested that those same high prices might reduce productivity by reducing efficiency. For example, Hicks (1935, p.8) suggested that monopolists with the luxury of the "quiet life" might be technically inefficient. Following this line of thought, as competitive pressure forces prices lower, incentives for managers to improve technical efficiency (or for that matter to innovate) are greater because the firm's survival is threatened. The hypothesis related to price is thus exactly opposite that of Schmookler and Lucas, namely that a negative relation exists between output price and productivity, or a positive relation exists between input price and productivity. Various studies have offered empirical support for this hypothesis also, among them Leibenstein (1973), Nelson and Winter (1974), Bergsman (1974), Martin and Page (1983), and Kalaitzandonakes and Taylor (1990).

Given the competitive structure of agriculture, there seems little a priori likelihood that the "quiet life" hypothesis would prevail, except perhaps in relatively small, highly concentrated specialty commodities. Our expectation is that, in the aggregate, prices would be positively related to productivity, as suggested by the innovation literature.

Our next objective is to describe a model of production within which the technology embodied is to some degree the result of choice. By so doing, we will be able to test whether prices have a significant effect on the extent of productivity change. Our general approach is to posit an aggregate production function for which the coefficients are variable, but are determined at any one place and time by previous technology-changing choices, as well as by the current natural and institutional environments. We refer to these conditioning factors as technology-changing variables. The focus of this section is on the effect of prices as technology-changing variables. Other technology-changing variables of interest are those related to the quality of the natural and human resource endowments.

The idea of prices as arguments of an aggregate production function requires some justification. A number of previous studies (Swamy et al. [1990], Basmann et al. [1987], Mundlak

[1988]) have suggested that various kinds of state variables, including prices, are appropriate shifters of an aggregate production function, and Ruttan and his coworkers have advanced the notion of a metaproduction function which is shifted by similar variables (not including prices). Our rationalization is as follows: suppose it were true that prices at time t_0 serve as an incentive for discovery and adoption of improved techniques of production by time t_1. The use of these new techniques at t_1 could be measured with the vector of unique inputs (new seed varieties, new chemicals, etc.) required to implement the techniques, say x'_{t1}. This vector could then be expressed as a reduced-form function of prices at t_0, $x'_{t1}(p_{t0})$. A metaproduction function, $y = f(x,x')$, would reflect both technology sets if the list of input arguments were sufficiently detailed to reflect the increase in x' and the decrease in replaced inputs. Such a representation of an aggregate production function would seldom be possible due to the difficulty of identifying and measuring all relevant input items. One alternative is to attempt a hedonic index for aggregated input categories, such as chemical inputs, seed, or machinery services. But calculation of the hedonic index itself also requires data on the specific inputs x' and their prices. When such data are not available, another alternative is to consider an indirect production function in which one substitutes the prices that determine x' for x' itself, or $y_t = f(x_t, x'_t(p_{t-l})) = F (x_t, p_{t-l})$, where l represents lag length.

The function F is clearly a production function in that it describes the maximum levels of y that are available from sets of measured inputs x. The role of p_{t-l} is to condition productivity (the amount of output from given inputs) much as an index of technical change would do. Conceptually, this is a notion very different from a supply function, $y_t = S(Ep_t)$, where Ep_t represents expected prices. A supply function as normally defined reveals the response to prices that results from reallocation of inputs. But Ep_t may depend in part on p_{t-l} , and if so, then empirical estimates of

$S(p_{t-1})$ may be contaminated by the productivity response to prices, while $F(x_t,p_{t-1})$ would not be contaminated by allocative response to price because the allocative effect is accounted for by measurement of x_t.

In this paper, the following specification of the aggregate production function is considered:

$$y(x;\beta) = A\ \Pi_i\ x_i^{\beta i}\ , \qquad \text{where} \qquad \textbf{(1)}$$

$$\log A = \alpha_0 + \Sigma_k\ \alpha_k\ \tau_k + \mu_0\ , \qquad k=1,\ldots,m\ , \qquad \textbf{(1a)}$$

$$\beta_i = \gamma_{i0} + \Sigma_k\ \gamma_{ik}\ \tau_k + \mu_i\ , \qquad i=1,\ldots,n\ , \qquad \textbf{(1b)}$$

where y is the maximum output producible from a given vector of n inputs, x; τ_k's are the technology-changing variables; α's and γ's are fixed coefficients; μ_0 is a random variable distributed independently of the x_i's and the τ_k's; and the μ_i's are random variables independent of the τ_k with mean zero and a finite positive semidefinite covariance matrix. Thus, the β_i's here represent a variable elasticity of output with respect to each of the input variables x.[2] The technology-changing variables, τ, determine production elasticities and are considered by the decision makers to be parameters for the current production period. Expressing equation (1) in logs, we obtain the convenient econometric model

$$\log y = \alpha_0 + \Sigma_k\ \alpha_k\ \tau_k + \Sigma_i\ \gamma_{io} \log x_i \qquad \textbf{(2)}$$
$$+\ \Sigma_i\ \Sigma_k\ \gamma_{ik}\ \tau_k \log x_i\ +\ \Sigma_i\ \mu_i \log x_i\ +\ \mu_0\ .$$

This model allows us to evaluate directly the impact of past price policies (included in the vector of technology-changing variables) on the technology. We introduce the concept of elasticity of productivity with respect to the τ_i's, defined as

$$\psi_k \equiv \partial y/\partial\tau_k\ \tau_k/y, \qquad \textbf{(3)}$$

[2] This type of model has also been used by Zellner (1969), who showed that a macrocoefficient estimator will not possess aggregation bias if the coefficient vectors of individual microunits satisfy the assumptions of this model.

which indicates the percentage by which a total factor productivity index (percentage output change with inputs fixed) would change in response to a 1.0 percent change in τ_k. The elasticity of productivity of the technology-changing variables for this function is evaluated as

$$\psi_k = \tau_k (\Sigma_i \gamma_{ik} \log x_i + \alpha_k). \quad \textbf{(4)}$$

If the technology-changing variable τ_k is expressed as the log of some variable, say z_k, then the elasticity of productivity with respect to z_k is simply

$$\psi_k = \Sigma_i \gamma_{ik} \log x_i + \alpha_k. \quad \textbf{(4a)}$$

Thus, if changes in past price policies were matched by changes in past price expectations, we can conclude that ψ_k provides a measure of the effect of that price policy on current productivity.

The production elasticities specified in equation (1b) depend on the level of the technology changing variables, so they differ by observation.[3] The quality of available resources, the set of techniques available for production, and past price expectations will combine to determine the productivity of each input.

We use this approach to measure the effect of past price policies on agricultural productivity in a set of 18 developing countries.

Measures of Waste Due to Distortions

The issue of this section is the measurement of the net costs of policies affecting the performance of the agricultural sectors of developing countries. The allocative distortions implied by interventions give rise to deadweight losses due to misallocation of resources among sectors within a country and between agricultural sectors across countries. Measurement of the former requires either

[3] If the technology-changing variables were to include contemporaneous prices, this model would imply nonuniqueness in the relation between the marginal rate of substitution and the corresponding price ratios, in contrast to neoclassical theory. While that is not the case for the present application, the possibility resurrects an issue addressed by Joan Robinson, who argued for production models allowing reswitching, meaning that a technology may be more profitable than other technologies at more than one set of relative input prices (Harcourt, 1969).

information about supply and demand curves that relate the agricultural sector to the rest of the economy or information about the production technology in the two sectors and the amount of resources in the economy. Such information is difficult to acquire and was unavailable for this study. Measurement of the second type of loss, that is, loss from misallocation between countries, requires information about the agricultural production technology, which is available from the estimated production function, and about the amount of agricultural resources in each country, which is available in the data set. Although such a measurement of waste from cross-country misallocation may be of less interest than the first type, it is more feasible. Thus, we examine it in this study as a preliminary step toward a more complete measure of waste due to interventions in agricultural prices.

There have been two families of methods used to measure waste associated with distortions in the economy; the quantity oriented method, which originated with the work of Allais (1943,1977) and Debreu (1951); and the price oriented method, which originated with the work of Hicks (1942) and Boiteux (1951). We use the output space of Figure 1, in which distortions have led the economy to equilibrium point B (point B as an equilibrium could be supported by differentially distorted input prices across producers, for example), to illustrate the differences between these approaches.

The Hicks-Boiteux approach measures waste due to distortions as the amount of income that could be thrown away without reducing social welfare. It is equivalent to the difference between aggregate income at a Pareto optimal reference equilibrium and aggregate income at the distorted equilibrium, using reference equilibrium prices in both cases. Given a social welfare function W, the reference equilibrium in the output space of Figure 1 is point A, which generates welfare W_1, as compared with the distorted equilibrium point B, which generates the lesser welfare level, W_0. The Hicks-Boiteux waste due to the distortion is measured by distance Y_1-Y_2, which is equivalent to the maximum amount of income that could be extracted and thrown away while still maintaining the distorted level of welfare W_0. This total amount of waste can be decomposed into two components.

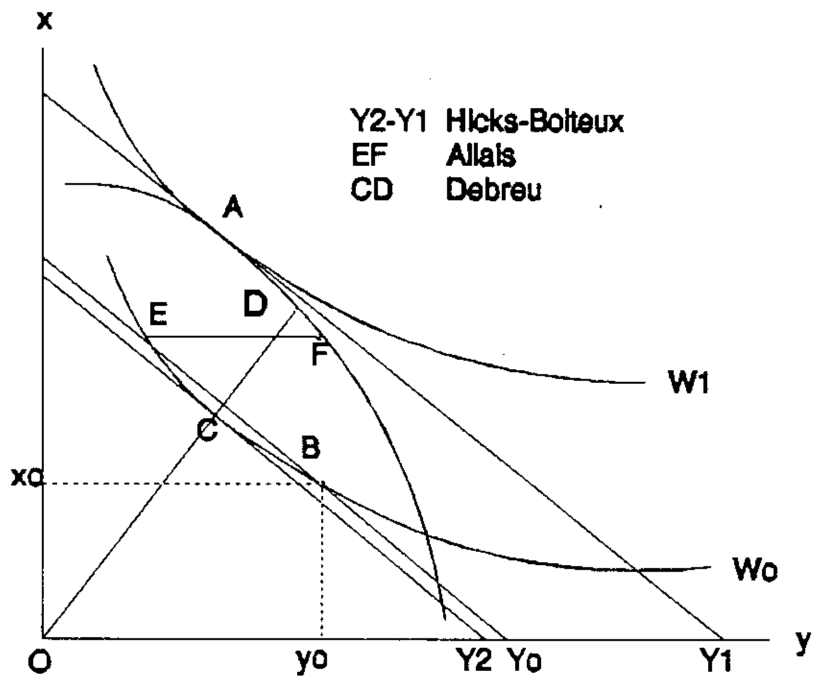

Figure 1. Hicksian, Allais and Debreu measures of waste at initial point B.

Waste in the producer sector is Y_1-Y_o, because optimal reallocation within the producing sector could have generated this amount of additional income, evaluated at reference prices. Waste in the consumer sector is Y_o-Y_2, because the initial level of welfare, W_0, could have been realized with this much less income.

We should note here that Peterson's 1979 measure of the social cost of cheap food policies in a similar set of countries is close to a Hicks-Boiteux measure. Peterson measured loss as the welfare triangle between demand and supply curves for a country with a food price held below equilibrium (world price) by some unspecified policy mechanism. This measure is conceptually the same as the Hicks-Boiteux measure in the case of identical consumers with equal welfare weights on all consumers, if the demand and supply curves were "general equilibrium" curves. However, if we relax these assumptions, the conceptually clear Hicks-Boiteux measure becomes complicated to the extent of empirical uselessness, while the simple welfare triangles lose interpretation entirely. The deadweight loss measures of Allais and Debreu are free of distributional assumptions and attendant problems.

Allais' measure of waste (1977, p. 114) is the "distributable surplus" pertaining to an existing allocation. He defines this as the maximum quantity of a reference good that can be made available ("liberated") by some reallocation that meets three requirements: (1) preference indexes for each consumer are no less than for the initial situation; (2) the amount of each resource used in production is no greater than for the initial situation; and (3) the production of each good is no less than in the initial situation. If commodity y in Figure 1 is the reference good, then the Allais distributable surplus measure is vector EF.

Debreu measures waste (1951, p. 42) by reference to the *coefficient of resource utilization,* which he defines as the smallest fraction of the actually available physical resources permitting the achievement of an initial satisfaction level for each consumer. The Debreu measure of loss is the fraction of physical resources that can be discarded, which is 1.0 minus the coefficient of resource utilization. In Figure 1, Debreu loss can be measured by vector CD.

As is evident from Figure 1, all three measures of waste require reference to the welfare indifference curve W_0. This can be avoided by modifying the Allais and Debreu approaches to measure only production sector loss, i.e., the amount that can be discarded while preserving the initial production (and consumption) bundle B. These measures of waste in the production sector are shown in Figure 2 as vectors BH (Allais production sector waste) and BG (Debreu production sector waste). It is clear from reference to Figures 1 and 2 that production sector waste is less than total waste (BH is less than EF, and BG is less than CD).

In this study, we wish to consider measures of waste in the combined agricultural production sectors of several countries. Assume that tradable agricultural inputs (fertilizer, for example) are not employed outside agriculture, and that the amounts of nontradable inputs (land and labor, for example) are not responsive to the price or use of tradables. We can, in this case, utilize the aggregate agricultural production function to derive a transformation surface among countries, holding nontradable inputs fixed and reallocating tradable inputs to trace out the transformation surface. When marginal productivities of tradable inputs are not equal across countries, deadweight loss is incurred in the combined agricultural sectors. Now consider x and y of Figures 1 and 2 to be agricultural output from each of two countries, with the production possibilities curve representing levels that could be produced by allocation of tradable inputs between the two agricultural sectors. The initial equilibrium is at point B because producers in the two countries face differential input/output price ratios due to differential price distortions. The Allais measure we examine is σ, or the amount of aggregate agricultural output that could be discarded as a fraction of initial output (where "output" is measured as $x + y$ in Figures 1 and 2, and when agricultural output is considered homogeneous across countries.) The geometric interpretation of our Allais measure σ in Figure 1 is

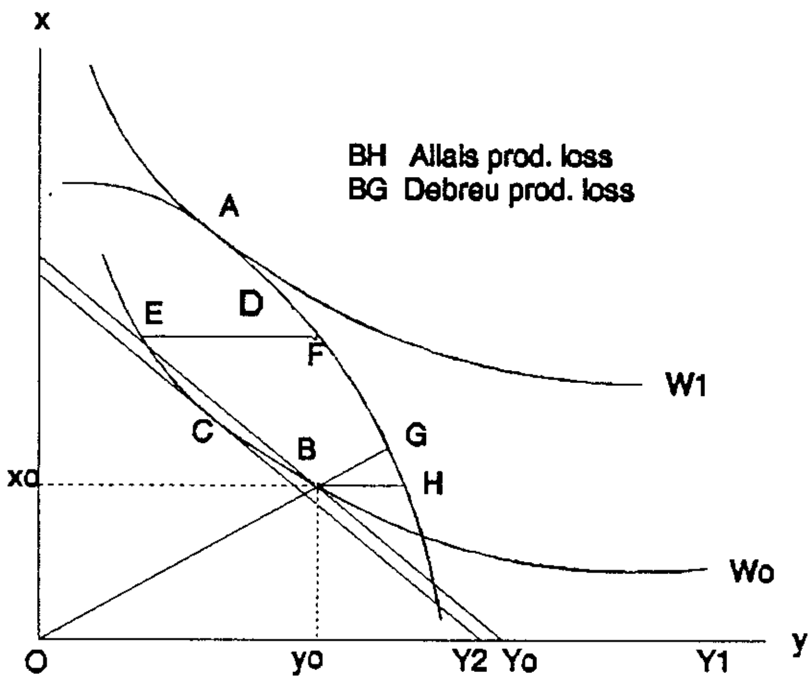

Figure 2. Allais and Debreu measures of producer sector waste at initial point B.

the ratio of Y_0Y_1 to OY_0, if the slopes of the budget lines were set equal to -1.0. (Note that this is a larger measure of waste than is BH.)

The Debreu measure we specify is λ, the fraction of resources that could be discarded (1.0 minus the coefficient of resource utilization). In Figure 2, this is represented by the ratio of BG to OB. Given the production function to be estimated in the next section, as well as the associated information about aggregate agricultural input levels, these two measures of waste can be calculated as the solutions to the following nonlinear programming problems:

the Allais measure of distributable surplus, σ,

$$\max_{x_{ji}} \ \sigma$$

$$\begin{aligned} \textit{subj to} : y - \sigma y^0 &\geq y^0 \\ z_{jl} &= z_{jl}^0, \quad \forall j,l, \\ \Sigma_j x_{ji} &\leq \Sigma_j x_{ji}^0, \quad \forall i; \end{aligned} \tag{5}$$

the Debreu measure of loss, λ,

$$\max_{x_{ji}} \ \lambda$$

$$\begin{aligned} \textit{subj to} : \quad y &\geq y^0, \\ z_{jl} - \lambda z_{jl}^0 &= z_{jl}^0, \quad \forall j,l, \ \textit{and} \\ \Sigma_j x_{ji} - \lambda \Sigma_j x_{ji}^0 &\leq \Sigma_j x_{ji}^0, \quad \forall i, \end{aligned} \tag{6}$$

$$\textit{where} \quad y = \Sigma_j y_j,$$

$$y_j = \exp[\alpha_0 + \Sigma_k \alpha_k T_{jk} + \Sigma_i(\gamma_{i0} + \Sigma_k \gamma_{ik} T_{jk})x_{ji} + \Sigma_l(\gamma_{l0} + \Sigma_k \gamma_{lk} T_{jk})z_{jl}] \text{ , i.e., equation(2) ,}$$

$$T_{jk} = \textit{average over time of } \tau_k \textit{ in country } j \text{ ,}$$

$$z_{jl} = \textit{level of } x_{ji} \textit{ for non-tradable input } l \textit{ in country } j,$$

$$x_{ji} = \textit{level of } x_{ji} \textit{ for tradable input } i \textit{ in country } j,$$

$$y^0 = \Sigma_j y_j^0$$

$$y_j^0,\ z_{jl}^0,\ x_{jl}^0 = \textit{averages over time of 18-country output and input levels for each country.}$$

Empirical Estimation of the Production Function

We have selected for this study a set of 18 countries for which recent World Bank studies have made available new data on the level of agricultural price distortions (for more detail, see Elisiana, et al, 1993). Table 1 lists these countries, the years for which we examined each, and the average level of agricultural protection during the period. The protection rates include the price effects of both direct commodity price interventions and indirect agricultural price effects of real exchange rate distortions and protection afforded to nonagricultural commodities. The simple average total discrimination against the sector amounts to 36 percent.

Agricultural output will be reduced by interventions of this size (except in Korea, which provided net protection to the sector), because of re-allocation of resources away from agriculture. But our concern is whether the productivity of resources allocated to the sector is also affected. To estimate the productivity effect of price distortions, we first fit the production function in equation (2) using pooled data for these countries, and then used the parameter estimates along with estimated price distortions to calculate estimated agricultural productivity effects of past price policies. The

Table 1. Agricultural protection and growth rates, 18 countries

Country	Years	NPR[a] (Percent)	Production growth[b] (Percent)
Argentina	1961-84	-40	2.1
Brazil	1969-83	-13	3.8
Chile	1961-83	-25	1.8
Colombia	1961-83	-33	2.8
Dominican R.	1966-85	-40	2.8
Egypt	1964-84	-53	2.7
Ghana	1958-76	-24	1.1
Ivory Coast	1961-82	-53	5.2
Korea	1961-84	16	4.2
Malaysia	1961-83	-18	3.3
Morocco	1963-84	-34	4.0
Pakistan	1961-84	-47	3.8
Philippines	1961-82	-32	3.8
Portugal	1961-83	-18	-0.1
Sri Lanka	1961-85	-49	2.1
Thailand	1961-84	-41	4.7
Turkey	1961-83	-36	2.8
Zambia	1966-84	-53	2.2

[a] NPR, the nominal protection rate, is defined as (domestic price/border price)-1, with domestic price adjusted for exchange rate misalignment and price distortions for industry.
[b] Average annual growth rate, calculated from FAO production indexes.

elasticity of productivity (equation [4]) multiplied by the percentage of price distortion will indicate the shift that would have occurred in the production function if past prices had been at border prices, as opposed to the protected levels determined by past policies.

A number of previous studies have estimated cross-country agricultural production functions for countries similar to our set[4], and we utilize measures of outputs and traditional inputs that are similar to those studies. Traditional inputs in the production function include land, labor, livestock, machinery, and fertilizer. (Of these, the set considered to be tradable is either fertilizer alone or machinery and fertilizer.) Nontraditional inputs, or the "technology-changing variables" considered, include past output and input prices, past agricultural research, land quality, and schooling. The variables are measured as follows.

Output (y): Value of agricultural production in millions of 1980 "international" dollars[5].

Land (x_1): Thousands of hectares of arable and permanent cropland and permanent pastures.

Livestock (x_2): Number of cow equivalent livestock units as reported by Hayami and Ruttan (1985).

Machinery (x_3): Agricultural tractors and garden tractors (FAO) in thousands of horsepower units, aggregated according to Hayami and Ruttan's procedures.

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[4] The series started with a study by Bhattacharjee (1955), followed by a series of studies by Hayami and Ruttan and their associates (Hayami (1969), Hayami and Ruttan (1970), Nguyen (1979), Yamada and Ruttan (1980), Kawagoe, Hayami, and Ruttan (1985)). Evenson and Kislev (1975), Mundlak and Hellingshausen (1982), Antle (1983), and Lau and Yotopolous (1989) examined countries and/or variables which differed from the Hayami and Ruttan series of studies.

[5] "International" dollars are obtained by the United Nations Food and Agriculture Organization (FAO), using the Geary-Khamis (see Elisiana et al., 1993) price index with the purpose of aggregating agricultural products for international comparison. The international average prices of agricultural commodities are determined simultaneously with the exchange rates of the national currencies in such a manner that the calculated exchange rates equalize the purchasing power of national currencies with respect to the defined groups of commodities.

Fertilizer (x_4): The sum of nitrogen, potash, and phosphate content of various fertilizers consumed, measured in thousands of metric tons in nutrient units.

Labor (x_5): Thousands of participants in the economically active population in agriculture.

We distinguish among three types of technology-changing variables: those related to past prices, which we take to represent past price expectations; those measuring past public research efforts; and those related to the quality of the country's endowments. As proxies for the technology-changing variables we use:

Output price (τ_1): Five-year moving averages of Tornqvist indexes of prices received for major agricultural products, as reported by the World Bank. Price indexes were constructed as follows. Deflated domestic currency price series for the relevant commodities were used to construct Tornqvist indexes for each country. Then, for 1980, a cross-country price index was constructed as a Tornqvist index value for each country relative to a base consisting of the 18-country average price and quantity for each commodity (prices converted to dollars at the 1980 official exchange rates). Subsequently, the domestic price index series for each country was divided by the 1980 cross-country index value for that country.

Wages (τ_2): Five-year moving averages of monthly wages in US dollars paid to agricultural workers. The deflated wages for each country were divided by a 1980 cross-country index consisting of the 18-country wages weighted by employment.

Fertilizer Prices (τ_3): Five-year moving averages of an index of prices paid for fertilizer (nitrogen, potash, and phosphate). The index was constructed in the same manner as was the output price index described previously.

Agricultural Research (τ_4): Stock of agricultural research, measured with a five-year inverted-V lag structure to accumulate annual research expenditures in thousands of 1980 US dollars. Alternatives considered include research expenditures accumulated with no lag and with a nine-year lag, and a five-year inverted-V lag structure for research personnel to accumulate the number of scientific person years.

Land Quality Index (τ_5): Peterson's (1987) international land quality index. An alternative measure considered is the soil-type weighted potential production of dry matter (WPDM) in tons per hectare for each country. These variables are constant through time for each country.

Human Capital (τ_6): The gross enrollment ratio for primary schools. An alternative measure of the quality of human capital considered is life expectancy.

To keep the data set as large as possible, we used regression interpolations to generate estimates of approximately 270 missing observations (out of a total of 4,510.) A list of the specific sources, a detailed explanation of the data manipulation, and a listing of the variables used in this analysis can be found in Elisiana et al. (1993).

All countries and years are pooled in a single equation of the form specified in equation (2). This pool yields 410 observations. Although the structural error terms specified in equation (2) are presumed uncorrelated with the variables, the econometric error term and its variance are. Thus, we first estimated the equation with OLS and then used the Breusch-Pagan (1979) test for heteroskedastic errors to determine if these correlations (or others, for that matter) are significant. The null hypothesis of homoskedasticity could not be rejected at the five percent significance level. We thus conclude that the μ_i random components of the β_i coefficients are not significant. Table 2 presents the 22 parameter estimates, 12 of which are significant at the one percent level, 2 at the five percent level, and 2 at the ten percent level. The R^2 is 0.94. Diagnostics developed by Belsley, Kuh, and Welsch (1980) indicate that only the variances of the coefficients of livestock and livestock-research interaction might be affected by multicollinearity. But for these coefficient estimates only 81 percent and 84 percent of the variances were contributed by a single eigenvector, and since these coefficients

Table 2. Least squares estimates of the production function (equation 2), 18 countries[a]

	Inputs					
	Land	Livestock	Machinery	Fertilizer	Labor	Intercept (α_o, α_k)
Linear terms (γ_{io})	0.040 (0.083)	0.146 (0.114)	0.173 (0.061)	0.093 (0.051)	0.838 (0.093)	-1.964 (0.652)
Expected Output Pr. (γ_{i1})	0.527 (0.044)	-0.554 (0.054)	0.064 (0.030)	-0.019 (0.024)	0.231 (0.048)	-2.266 (0.336)
Expected Wages (γ_{i2})					-0.011 (0.003)	
Expected Fert. Price (γ_{i3})			(0.006)	0.006		
Research (γ_{i4})	0.011 (0.016)	0.041 (0.022)	0.005 (0.013)	0.022 (0.009)	-0.140 (0.017)	0.523 (0.119)
Land Quality (γ_{i5})	0.054 (0.007)					
Schooling (γ_{i6})					0.040 (0.009)	

[a] Based on 410 observations from 1961 to 1985; standard errors in parentheses; overall $R^2 = 0.94$

are both consistent with others' results and unimportant for our purposes, we conclude an absence of multicollinearity problems in our estimates.

The coefficients in Table 2 and in equation (4) can be used to evaluate elasticities of productivity with respect to technology-changing variables at the mean value of input variables. The results (Table 3) show significant effects for four of the six technology-changing variables. The productivity elasticities of greatest interest here are those for past price expectations. They indicate that a 10 percent change (due to different policy choices, for example) in past output price expectations would produce a 1.3 percent shift of the production function, whereas increases of the same magnitude in expected wages and fertilizer prices would shift it down by 0.9 percent and up by 0.3 percent, respectively. The positive effect of output price expectations is consistent with the Schmookler-Lucas hypothesis and is inconsistent with the efficiency literature.

Quality of soil and schooling have positive and significant effects on productivity. Since the land quality variable is a constant for each country, its coefficient may also reflect other unobserved country fixed effects. The coefficient of agricultural research, proxied as a five-year inverted-V lag structure of agricultural research expenditures, is negative but not significantly different from zero. Whereas the insignificance of this research variable is in marked contrast to significant positive effects estimated by Evenson and Kislev (1975) and by Antle (1983) (who used number of scientific publications as the research variable), lagged price expectations in this model also serve as a proxy for research, and we obtain significant positive effects for that variable. In other words, these findings indicate a significant impact of price induced research, but not so for research measured in terms of government expenditures.

Production elasticities evaluated at the average values of the variables are presented in row one of Table 4. All are significantly different from zero. The sum of the coefficients is 1.06, a value

Table 3. Productivity elasticities (evaluated at the mean of variables, standard errors in parentheses)

Productivity with respect to	
Expected output price	0.13 (0.028)
Expected wages	-0.09 (0.023)
Expected fert. price	0.03 (0.028)
Research	-0.02 (0.020)
Land quality	0.51 (0.065)
Schooling	0.30 (0.071)

Table 4. Production elasticities for traditional inputs (standard errors in parentheses)

Regression model	Traditional input					Sum
	Land	Livestock	Machinery	Fertilizer	Labor	
Variable coeff.[a]	0.25 (0.147)	0.17 (0.036)	0.21 (0.033)	0.18 (0.067)	0.25 (0.039)	1.06
Fixed coeff.	-0.10 (0.027)	0.40 (0.036)	0.17 (0.022)	0.03 (0.021)	0.33 (0.028)	0.83

[a]Evaluated at the mean value of variables.

close to constant returns to scale. Previous estimates of labor elasticity concentrated in the range of 0.30-0.42 (see Bhattacharjee [1955], Evenson and Kislev [1975], Hayami and Ruttan [1970], Kawagoe, Hayami and Ruttan [1985], Lau and Yotopolous [1989], and Mundlak and Hellinghausen [1982]). Thus, our estimate of 0.25 is low relative to others, suggesting that the cost share of labor should be only about one-fourth, but our data set is not adequate to observe this share empirically. Previous estimates of land elasticity have been anything but consistent. The Lau and Yotopolous (1989) estimate was about 0.9 when country effects were included, Bhattacharjee's (1955) estimate was 0.36, the first Hayami (1969) estimates and Mundlak and Hellingshausen's (1982) were about 0.2, and the remaining estimates were smaller, many near zero. Our estimate of 0.25 is large compared to the estimates of most previous studies. Our estimate of livestock elasticity is slightly below the average of others, our estimate of machinery elasticity is higher than most others, and our estimate of fertilizer elasticity is close to the mean of previous estimates.

The second row of Table 4 shows the estimates of a fixed coefficients model, i.e. equation (2) restricted by $\alpha_k = \gamma_{ik} = 0$ for all i and k, as a contrast to estimates from the variable coefficients model. The fixed coefficient results are similar to those of Evenson and Kislev in a similarly restricted aggregate output model, and to those of Kawagoe, Hayami, and Ruttan (1985) for their subset of LDC countries. Lau and Yotopolous hypothesized that a lack of country specific effects is the explanation for low land elasticity estimates from such a model. Upon introduction of such effects into the Kawagoe, Hayami, Ruttan (KHR) model and data, estimates of land elasticity rose to nearly 0.9. Because our variable coefficients model also includes country specific effects via land-quality and other technology-changing variables, and it too yields higher estimates of land elasticity, our results support the Lau-Yotopolous hypothesis that the omission of country specific effects biases the estimates of land elasticity downward.

Implications for Productivity Losses and Waste Due to Interventions

To evaluate the effects of policy wedges on the level of agricultural productivity in each country, we multiply the productivity elasticities (column 1 of Table 5) by the estimated policy-induced price wedges (columns 2 and 3 of Table 5.) The productivity elasticities are calculated by using equation (4) evaluated at the mean of inputs for each country. Two price wedges are considered. Column 3 presents the average effect of direct government interventions, i.e. those aimed directly at the agricultural outputs. The total intervention wedge in column 4 adds to this the price effect of both exchange rate policies and other interventions.

Elimination of direct (commodity specific) interventions would have increased productivity in every country except those subsidizing the sector. Brazil, Ghana, Korea, and Turkey, have had direct subsidies, and elimination of those subsidies would have reduced price expectations, which in turn would have led to a lower rate of productivity increase in these countries. Indirect interventions have taxed agriculture in every country except Portugal, with the result that even in Brazil, Ghana, and Turkey, the net effect of all interventions is to tax agriculture. Thus, all countries except Korea would have experienced an increase in productivity if all interventions had been eliminated. The estimated productivity effects of price interventions range from 1.4 percent in Chile to 129 percent in Zambia.

We now turn to measures of deadweight losses due to the allocative distortions of the price interventions. Given the production function as estimated in Table 2, a production function specific to each country can be evaluated by inserting average values of the technology-changing variables for that country. This yields a Cobb-Douglas production function in the five traditionally-measured inputs for each country, as specified in the nonlinear programming problems described by equations (5) and (6). The Allais and Debreu measures of waste due to cross-country misallocation of tradable resources will depend upon which resources are considered tradable. It seems clear that fertilizer is

Table 5. Estimated productivity changes from elimination of output price policies

Country	Elasticity of productivity with respect to output price[a]	Price changes due to elimination of		Productivity changes due to elimination of	
		Direct interv. (percent)	Total interv. (percent)	Direct interv. (percent)	Total interv. (percent)
Argentina	0.257	31.3	66.1	8.1	17.0
Brazil	0.515	-6.6	15.2	-3.4	7.8
Chile	0.105	3.2	32.7	0.3	3.5
Colombia	0.028	11.9	48.5	0.3	1.4
Dominican Republic	0.435	32.2	67.5	14.0	29.4
Egypt	0.577	75.7	114.3	43.7	66.0
Ghana	0.505	-7.8	32.1	-3.9	16.2
Ivory Coast	0.787	56.1	111.8	44.2	88.0
Korea	0.078	-34.8	-13.9	-2.7	-1.1
Malaysia	0.300	11.8	21.6	3.5	6.5
Morocco	0.345	26.1	52.2	9.0	18.0
Pakistan	0.133	32.9	88.8	4.4	11.8
Philippines	0.088	14.4	46.9	1.3	4.1
Portugal	0.250	28.0	22.8	7.0	5.7
Sri Lanka	0.379	33.2	97.4	12.6	36.9
Thailand	0.223	45.9	71.1	10.2	15.9
Turkey	0.338	-1.7	56.4	-0.6	19.0
Zambia	1.122	29.0	115.1	32.5	129.1

[a] Evaluated from equation (4), according to estimated coefficients and mean values of inputs for each country.

in the category of tradables, even in the short run. In the longer run, machinery might also be considered tradable. We therefore solve problems (5) and (6) under both sets of assumptions, using the MINOS algorithm within the GAMS software package.

Optimum values of the objective functions for these problems are reported in Table 6. The Allais measure of waste indicates a short-run deadweight loss of 7.5 percent of output and a long-run loss of 16.7 percent of output. These fractions of total output could be "liberated" for reallocation if machinery and/or fertilizer were reallocated optimally. The Debreu measures are similar at 7.4 and 14.4 percent for the two lengths of run, but in this case these are the fractions of the resource base that could be extracted without reducing total production. These numbers compare with Peterson's social cost of cheap food policies (for 27 LDC's in 1963 and 1969), which he estimated at 3.76 percent of total national income of the countries. Our estimates are expressed as a fraction of agricultural production or agricultural resource base rather than of national income, ours are for a different set of countries for a different set of years, and ours are based on totally different methods and concepts, yet the numbers seem to be of a similar magnitude. The two studies mutually support the conclusion that the allocative effects of agricultural price policies in these countries are nontrivial. Our results further support the conclusion that cheap food policies have a substantial effect on the productivity of the resources allocated to agriculture, as well as their quantity.

Clearly, these estimates of productivity effects and deadweight allocative losses are subject to a number of limitations and errors. For the most part, the data are from sources widely used by other researchers, but they are in some cases probably little better than guesstimates produced by international organizations on the basis of limited information. Apart from these errors in measurement, our coefficient estimates entail substantial sampling error as well as unknown specification error. Notwithstanding these disclaimers, the t-tests offer encouragement that we are

Table 6. Measures of production sector waste due to inefficient intercountry allocation of tradable agricultural inputs

Set of tradable inputs	Allais' loss measure (σ)	Debreu's loss measure (λ)
Fertilizer	0.0756	0.0736
Machinery and fertilizer	0.1670	0.1441

measuring some significant relationships here, as does the consistency of our results with those of others, to the extent they are comparable. Unfortunately, we have no statistical tests of the significance of our measures of deadweight loss due to price policies, since those programming results cannot be represented as functions of the statistically estimated parameters. We do note, however, that our results certainly do not seem inconsistent with those of Peterson.

Summary and Conclusions

This study has examined both the productivity effects and the allocative effects of price interventions in LDC agriculture. The results of the study suggest that policies with negative price effects have had significant negative affects on agricultural productivity, with an estimated elasticity of productivity of about 0.13 with respect to output prices. This supports the hypothesis of a positive relationship between prices and technological change as advanced by Schmookler, Lucas and others, as opposed to a hypothesis advanced by Leibenstein. We estimate that elimination of agricultural price interventions in the 18 countries over the study period would have increased output prices by a simple average of 56 percent, and that the resulting increases in productivity would have averaged about 25 percent.

We evaluate the cost of the allocative effects of these price distortions using variations of the general equilibrium deadweight loss measures advanced by Allais and Debreu. Our results indicate that in the short run (with only fertilizer tradable) the deadweight loss is equivalent to 7.5 percent of either output or resources. In the longer run (with both fertilizer and machinery tradable) the estimates rise to 16.7 and 14.4 percent, respectively. Our variations from the original Allais and Debreu general equilibrium measures are substantial. We examine only production sector losses, and those under the assumption that inputs are not traded between agricultural and nonagricultural sectors, but rather only between agricultural sectors. These restrictions are imposed by the limitations of our data, and they result in deadweight losses that are conceptually smaller than the general equilibrium measures of loss.

Central to these results was the estimation of a cross-country agricultural production function, specified such that the coefficients of traditionally measured inputs are functions of past prices and other technology-changing variables. The rationale for such a specification is that past prices are hypothesized to affect past innovative effort, and therefore current productivity. Our estimated relationship between output and a lagged five-year moving average of prices can, however, be challenged as reflecting a supply response relationship rather than a productivity response relationship. Two considerations support our interpretation. First, a five-year moving average of past prices looks too far into the past to be a very credible proxy for expected harvest prices. Second, the estimated productivity response of output to prices is in *addition* to the allocative effect of prices, since the latter effect is accounted for by measured inputs in the production function. The fact that our estimates of production elasticities for the traditionally-measured inputs both sum to one and are consistent with a number of previous production function studies lends support to this assertion. However, the possibility of ambiguity in separating the allocative and productivity effects of prices suggests that additional theoretical development of the relationship between prices and productivity might have a high payoff in distinguishing between these effects. Given the size and therefore the importance of the productivity effect we have estimated, this seems an important task.

Our estimates of the deadweight losses due to the allocative effect of price interventions have a number of limitations. They are incomplete in that we do not consider general equilibrium effects of exchange between the agricultural sector, consumers, and other productive sectors. Conceptually, our measure of intercountry loss is correct only if the levels of other agricultural inputs are unaffected by the changes in the use of tradables, and if transportation costs are nil. Furthermore, the intercountry misallocation we have measured may occur for reasons other than price interventions.

Nonetheless, our loss estimates of 7 to 15 percent of agricultural output or resources are not inconsistent with Peterson's earlier estimate of about 4 percent of total national income. These studies support one another in suggesting that the welfare triangles associated with agricultural price interventions in the developing countries may not be small.

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