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Prices and Productivity in Agriculture

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Abstract

Developing countries have been found to tax agriculture heavily, which might affect the productivity of resources allocated to agriculture, as well as their quantity. A variable-coefficient cross-country agricultural production function is estimated, with past price expectations among the determinants of the production coefficients. Productivity is found to be responsive to those expectations, with the implication that had these developing economies eliminated their price interventions, agricultural productivity would have increased on average by about a third.

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Prices and Productivity in Agriculture

During the fifties and sixties most western economies experienced rapid growth while international trade grew even more rapidly, stimulated perhaps by the large reductions in barriers to trade that took place on a multilateral basis during that period. On the other hand, during the seventies and eighties, most countries have experienced much lower rates of growth in output and in total factor productivity. Economic policies whose goals are unrelated to technical change may nevertheless have affected the rate and direction of these changes. Could this decline in productivity increases be due to the rapid growth in government programs, taxes, hidden barriers to trade and other regulatory activity that had the effect of increasing distortions within the world economy? How do these and other economic variables affect the nature of technical change? A better understanding of endogenous technical change should enable economists and policy makers to answer these questions.

In this paper we directly examine the effect of prices on the productivity of the agricultural sectors of a sample of eighteen developing countries over the period 1960 to 1984. We describe the theoretical basis for including price expectations in a production function and we empirically estimate such a function to establish the productivity effect, as opposed to the allocative effect, of price distortions in those countries. The price distortions we examine derive from both sector-specific policies and general trade and exchange rate policies.

The main empirical concern of this paper is aggregate productivity, as opposed to production. We measure productivity as the rate of change in total factor productivity, which is essentially the residual difference in output between two points in time or between two places, after calculating the estimated effects of measured differences in input quantities. This measure of productivity is of course not without ambiguity because one may arbitrarily reduce productivity differences measured in such a way by adjusting input quantities to account for "quality" changes. One logical response to this ambiguity is the position that all technological change must be embodied in some input, with the implication that if inputs and input quality are correctly measured, then the measured change in total factor productivity will be zero (for example Schultz, 1956). But our interest in this paper is to measure differences in output for a given amount of conventionally-measured inputs, so our approach is to account for changes in the quality of these inputs by introducing separate variables such as schooling of workers and irrigation investments in land.

Productivity change can be characterized not only by an index or rate of change in an index, but also by bias among inputs or among outputs. Bias in technologically-induced productivity change will affect factor and product shares, and thus the distribution of gains from the productivity change, but such issues are not the focus of this paper. We nonetheless measure Hicksian biases of the productivity differences we observe, measured as the difference in the ratio of marginal products. Because we examine only aggregate output in this paper, output bias is not relevant.

In examining factors related to productivity, it is important to distinguish the concept of technical change through innovation from the concept of efficiency, since they both affect productivity but are fundamentally different phenomena (Fare, et al.) The former generally refers to a change to improved techniques, while the latter refers to an increase in output that occurs while holding constant both the level of inputs and the technique of production. Prices have been identified as one of the determinants of both innovation and efficiency, though they have not been prominent in the explanation of either. We turn now to a brief review of the role of prices in previous productivity studies.

The economics literature on innovation is extensive (see Dosi for a recent review), but devotes little attention to the role of prices as a determinant. Innovation is generally considered to be an activity to which firms allocate resources according to its profitability. This profitability can be affected by supply-side factors such as the existence of new knowledge or the costs of research or by demand-side factors such as price changes or changes in appropriability (Schmookler). The clear implication of this conceptual approach is that increases in expected product price (or demand) would increase the benefits of innovation. Schmookler's examination of patent data clearly revealed a positive relationship between product demand and innovation. Contemporaneously with Schmookler, Lucas provided more straightforward support for this hypothesis. He found negative regression relationships between the rate of factor productivity in the U.S. manufacturing sector and the prices of labor and capital (each divided by output price). Binswanger developed a very explicit model of firm behavior which shows that the benefits of innovation will increase with expected prices if the optimal quantity is expected to increase because of the innovation. This implies a positive relationship between output price and innovation, but an ambiguous relationship between input price and innovation, depending on the nature and size of the anticipated input biases. Huffman and Evenson provide empirical evidence that supports the positive price-innovation relationship for the U.S. agricultural sector. Mundlak argues similarly that prices are one of the state variables which determine the choice of technique, and therefore also determine productivity, though his approach does not offer a hypothesis as to the sign of the relationship.

The literature on efficiency also suggests a role for prices. Hicks (1935, p.8) suggested that monopolists, with the luxury of the "quiet life", might be technically inefficient, and Leibenstein amplified this notion by asserting that within firms with market power, managerial motivation may be so lacking that technical inefficiency may be a significant source of potential productivity gains. The role of prices in this line of thought is that as competitive pressure forces prices lower, incentives for managers to improve technical efficiency (or to innovate, for that matter) are greater because the firm's survival is threatened . The hypothesis related to price is thus exactly the opposite to that suggested by innovation theory, namely a negative relationship between output prices and productivity or a positive relationship between input prices and productivity (Leibenstein, Nelson and Winter). Various studies have offered empirical support for this hypothesis. Bergsman, for example, examined the effects of import protection in six countries, and calculated that the cost of protection included productivity reductions equal to from two to six percent of GNP. Martin and Page estimated a frontier production function for logging and milling industries in Ghana, and found that public price subsidies reduced productivity. In agriculture Kalaitzandonakes and Taylor found that the average rate of productivity growth for a set of Florida vegetable crops that have no import competition was 1.6 percent per year, while the average rate for set of similar crops that compete with Mexican imports (which presumably then had prices that were lower relative to costs) was 5.1 percent.

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 such as those examined by Kalaitzandonakes and Taylor. Our expectation is that in the aggregate, prices would be positively related to productivity as suggested by the innovation literature. Indeed, a number of observers of the agricultural economy have asserted the existence of a positive relationship between prices and productivity, without offering explicit models or extensive data to support the assertions. Schultz (1979) for example argues passionately that it is clear from his observations that the higher are prices in agriculture, the faster is the rate of productivity increase. Schuh argued that the overvalued U.S. dollar in the sixties tended to depress agricultural prices in the United States and that this in turn reduced the rate at which new production technology was adopted. But despite the considerable attention to the question of prices and productivity in agriculture, as Capalbo and Antle state: "We know of virtually no research that has attempted to account for the effects of government intervention or regulation in agriculture on the measurement and explanation of agricultural productivity.." to which they add "...we would expect that government policies may have substantial effects on agricultural productivity."

The next section of this paper presents a model of endogenous technological change that leads to variable coefficient production function with expected prices being among the factors that determine the value of the coefficients. Following that is a section that describes data related to the price and productivity experience for the set of eighteen countries that we include in our empirical analysis. The final two sections present and interpret the econometric results and offer some conclusions.

I. A Model of Endogenous Technology

Our objective here is to develop a model of production within which the technology embodied is responsive to previous choices. Our general approach is to posit a production function for which the coefficients are variable and determined at any one place and time by those previous choices, and the current technological, natural and institutional environment. We start with the notion of a technique of production. Following Dixit (1976) a technique is a particular combination of inputs producing a particular output, i.e. a production process. The collection of all available techniques, as described by an isoquant map or a production function or indirectly by a cost function, we define to be the technology available at a point in time. When new techniques become available as a result of new knowledge, technology changes. The set of techniques which can be implemented in the short run, however, is a subset of the long-run technology to the extent that techniques require technique-specific capital that has low or zero opportunity cost. Thus under a variable coefficient production function such as we postulate, both past prices and current prices will affect the current choice of technique, and past prices will have a strong influence on productivity as reflected by current values of the production coefficients.

Mundlak (1988) formalizes the choice of technique at the firm level for a single period optimization and a single output as follows:

$$(1) \qquad \max \quad = \Sigma_j \; p \; F_j(x_j) - \Sigma_j \; w_j \; x_j$$

subject to: $z - \Sigma_j z_j = 0$

where p is the output price, x_j is a variable input with price w_j, z_j is an allocatable fixed input, and there are J techniques available. The solution gives derived demands and shadow prices as a function of input and output prices, the initial endowment of fixed inputs and the available technology. If in addition we allow for corner solutions, whenever $x_j=0$ and $z_j=0$ are optimal the jth technique is not implemented. Therefore the solution to this problem determines both the techniques used and the level of their use. Mundlak's approach is inherently non-dynamic, since choices in the current period are in no way constrained by choices made in previous periods. This paper departs from Mundlak's approach by relaxing this assumption. We postulate that implementation of techniques often if not always involves investment in technique-specific capital which constrains future decisions. The set of techniques that is currently optimal then depends upon past choices, which were based on prices and price expectations that existed at various times in the past.

It is beyond the scope of this paper to derive a dynamic optimization model which explicitly solves for the current values of production function coefficients in terms of, say, distributed lags of past prices and past price expectations. However, the implications of the theory described above can be conveniently expressed in terms of a production function with fixed resources, which include technique-specific capital remaining from earlier choices of technique. If x^* is the optimal level of inputs, then optimal output is given by

$$F(x^*;p,w,z,T) = \Sigma_j \; y_j^*(p,w,z,T) \qquad (2)$$

where p and w are vectors of current and past price expectations, z is a vector of resources fixed within the period and T is the technology set. It should be noted that the relationship in (2) is defined conditional on prices, resource constraints including embodied capital, and the available technology. In this paper we postulate that the resource variables enter into the production function as determinants of the production coefficients. We thus refer to them as technology-changing variables.[1]

Equation (2) identifies three different types of constraints affecting the optimal level of output: a) the available technology, b) resource endowments, and c) prices. The available technology represents the introduction of new techniques which become available as a result of research or experience. They expand the technology set shifting the isoquant map. Resource endowments, which are constraints to the producer's optimization problem, include the physical environment, labor, land, and the capital stock including technique-specific capital and the various facets of human capital. Prices will affect the intensity of use of current implementable techniques, and will affect the adoption of new techniques.[2]

Let $y(x;\beta)$ be a real-valued function characterizing the maximum amount of y which can be produced from any given set of inputs $(x_1, \ldots, x_n)$ where β designates the vector of all its parameters. Also note that the production

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[1]Antle (1988) has derived an aggregate production function with similar characteristics from a model where the innovation process is assumed as inherently dynamic.

[2]These variables representing constraints in this model could also be endogenized. Prices would be so including demand in the analysis.

function is a single-valued mapping from input space into output space since the maximum attainable output for any stipulated set of inputs is unique. Let the function $y(x;\beta)$ have continuous second partial derivatives with respect to x. Let $MRS_{ni}(x,\beta)$ i=1, 2,...,n-1 designate the marginal rate of technical substitution of x_n for x_i at the point x. Let α_k, k=1, 2,...,m represent a technology-changing variables that determine the production function parameters according to

$$\beta_i = G_i\ (\ \alpha_1, \ldots, \alpha_m)\quad .$$

Assume that the production index y and all its first and second partial derivatives y_i and y_{ij} are differentiable at all points at least once with respect to each of the technology-changing variables $\alpha_1, \ldots, \alpha_m$. Now we define the elasticity of productivity with respect to α_k as

$$(3) \qquad \psi_k = \partial y/\partial\alpha_k\ \alpha_k/y,$$

which indicates the percentage by which the total factor productivity index will change in response to a one percent change in α_k (since the total factor productivity index is just y divided by a weighted index of x_i's, which are held constant here).

Given the assumptions above, each of the marginal rates of technical substitution is differentiable at every point X with respect to each technology-changing variable α_k, k=1, 2,...,m. Let $\epsilon_{i,\alpha k}$ designate the elasticity of the marginal rate of technical substitution $MRS_{n,i}$ with respect to the technology-changing variable α_k,

(4) $\epsilon_{n,i,\alpha k} = \alpha_k / MRS_{n,i} \quad \delta MRS_{n,i} / \delta \alpha_k$.

In the general case, the elasticities (3) and (4) with respect to the technology-changing parameters may be variable and depend upon all of the quantities of inputs $x_1, \ldots, x_n$ and all of the technology-changing variables.

The following class of production functions is considered:

(5a) $y(x;\beta) = B \prod (A_i \; x_i)^{\beta i}$

(5b) $\beta_i = G_i(p, w, z, T) \qquad i=1, 2, \ldots, n,$

(5c) $\log B = \beta_0 + \mu_0$

where y is the maximum output producible from a given vector of n inputs, x, with p and w now representing vectors of past price expectations that have determined technique-specific capital, z represents inputs held fixed in this period and T is the technology set. Log B combines a fixed intercept and random disturbance term, and it is assumed to be statistically independent of other variables on the right-hand side of equation (5a). The A_i are factor-augmenting coefficients and the x_i denote amounts of factor inputs as conventionally measured in units of variable efficiency, so that the $A_i x_i$ represent amounts of factor inputs in units of constant efficiency. We assume in this work that A_i=1 for every i. The β_i 's are stochastic variables, each representing a variable elasticity of output with respect to the ith input.[3]

The input vector x is the only argument of the production function (5a)-(5c), while p, w, z and T determine the production coefficients and are thus taken by the decision makers as parameters for the current production period. In this study the determination of the coefficients is represented as

$$(6) \qquad \beta_i = \gamma_{i0} + \Sigma_k \gamma_{ik} \alpha_k + \mu_i \qquad i=1, 2, \ldots, n$$

where α_k = (p, w, z, T), γ_{i0} and the γ_{ik} are fixed coefficients, and the μ_i's are random variables, independent of α_k, with mean vector zero and finite positive semi-definite covariance matrix.

Expressing equation (5a) in a log linear form and replacing β_i with equation (6):

$$(7) \log y(x;p,w,z,T) = \beta_0 + \Sigma_i \gamma_{i0} \log x_i + \Sigma_i \Sigma_k \gamma_{ik} \alpha_k \log x_i + \Sigma_i \mu_i \log x_i + \mu_0$$

Equation (7) provides a convenient model for evaluating the impact of price policies in the production function itself, as opposed to their impact on resource allocation for a given production function. If α_k is the logarithm of a measure of past expectations about some particular price or price index, then the elasticity of productivity, now determined as

[3]This type of model has also been used by Zellner (1969) who showed that a macro coefficient estimator will not possess aggregation bias if the coefficient vectors of individual micro units satisfy the assumptions of this model

(8) $\psi_k = \Sigma_i \ \gamma_{ik} \ \log x_i$

measures the elasticity of productivity with respect to that measure of past price expectations. If changes in past price policies were matched by changes in past price expectations, then ψ_k also provides a measure of the effect that changes in past policies would have had on current productivity.

Equation (6) is used to determine the contribution of inputs to production. These output elasticities depend on the level of the variables that condition the individual's choice, so they differ by observations.[4] Changes in available resources, in the set of techniques available for production, and price expectations will alter the contribution of each input to production.

The elasticities of equation (4) determine if the technology-changing parameters have a neutral or bias effect on input use. Several notions of neutrality could be defined. The most useful in the present context is that of Hicks' neutrality, in which the marginal rate of technical substitution between two inputs is independent of the technology-changing parameters. Thus, from equation (7) Hicks' neutrality implies

(9) $\delta MRS_{ni}/\delta\alpha_k = x_i/x_n \ (\gamma_{ik}/\beta_n - \gamma_{nk}/\beta_n^2 \ \beta_i) = 0$

[4]In contrast to neoclassical theory, this model implies nonuniqueness in the relationship between the marginal rate of substitution and the corresponding price ratios. It recreates an issue addressed by Joan Robinson who argued for production models that allowed reswitching, meaning that a technology may be more profitable than other technologies at more than one set of relative input prices (Harcourt, 1969).

where (n,i) represent any pair of inputs and k refers to technology-changing parameters. In terms of the elasticities expressed in equation (4),

$$(10) \quad \epsilon_{n,i,\alpha k} = \alpha_k \, (\gamma_{ik}/\beta_i - \gamma_{nk}/\beta_n) = 0.$$

If $\epsilon_{n,i,\alpha k} = 0$ then the level of α_k does not affect the mix between inputs n and i, while $\epsilon_{n,i,\alpha k} > 0$ implies a bias against input x_i, and $\epsilon_{n,i,\alpha k} < 0$ implies a bias against input x_n.

We now turn to the task of using this approach to measure the effect of past price policies on agricultural productivity in a set of eighteen developing countries.

II. Agricultural Protection and Growth in Eighteen LDC's.

We have selected for this study a set of eighteen countries for which recent World Bank studies have made considerable data available. Table 1 lists these countries, the years for which we examined each, the average level of agricultural protection during the period, and the average rate of growth of agricultural production during the period. Only Korea provided net protection of agricultural prices during this period. Our concern here is with productivity growth, rather than production growth, however. Our approach is first to estimate the production function in equation (7) using pooled data for these countries, and then to use the parameter estimates along with estimated price distortions to calculate estimated agricultural productivity effects of past price policies. The elasticity of productivity (equation (8)), multiplied by the percentage 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. The basic assumption is that all countries have access to the same technology, and that they thus share a common meta production function. This recognizes that different countries use different production techniques and that the coexistence of some countries using advanced techniques with others using traditional techniques could be explained by economic variables.

A distinction is made in the previous section between inputs and technology-changing variables. The former consist of traditionally-measured physical inputs, while the latter consist of measures of qualities of these inputs, prices, and research effort. In order to achieve comparability with other studies we use the same input categories as those in the series of studies introduced by Hayami and Ruttan, and later extended by Evenson and Kislev, Nguyen and Antle. They are:

Output (y): Value of agricultural production in millions of 1980 US dollars.

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

Livestock (x_2): Weighted average of various types of animals reported by FAO, using the weights in Hayami and Ruttan.

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

Fertilizers (x_4): The sum of nitrogen, potash, and phosphate content of various fertilizers consumed, measured in thousands of metric tons as reported by the International Fertilizer Institute.

Labor (x_5): Measured in thousand of participants in the economically active population in agriculture as reported by FAO.

We distinguish three types of technology changing variables, those related to past price expectations, those related to the introduction of new techniques, and those related to the quality of the country's physical environment. As proxies for them we have used:

Output price (α_1): Five-year moving averages of Divisia indexes of prices received for major agricultural products, as reported by the World Bank and adjusted to reflect relative differences across countries.

Wages (α_2): Five-year moving averages of monthly wages in US dollars paid to agricultural workers, as reported by the International Labor Organization and the World Bank.

Fertilizer Prices (α_3): Five-year moving averages of an index of prices paid for fertilizer (nitrogen, potash, and phosphate) which was constructed to reflect cross-country and time variations (Sources: FAO Yearbook and World Bank).

Agricultural Research (α_4): A measure of research stock, obtained by imposing a nine-year inverted-V lag structure on annual research expenditures in thousands of 1980 US dollars, as reported by Pardey and Roseboom, Judd, et.al., and the World Bank.

Land Quality Index (α_5): This is an index of land quality reported in Peterson (1987).

Life Expectancy (α_6): As reported by the World Bank, introduced as a "human capital" variable to measure health investments.

Irrigation (α_7): The percentage of irrigated land in total arable and permanent cropland. It is included as a proxy for investments in the sector.

School Enrollment Ratio(α_8): Gross enrollment ratio for primary schools obtained from World Bank Tables.

To keep the data set as large as possible, we used regression interpolations to generate estimates of missing observations.

III. The Estimated Cross-Country Production Function

All countries and years are pooled together in a single equation of the form specified in equation (7) giving a total of 410 observations, and the parameters are estimated using OLS. Although the error structure in equation (7) is uncorrelated with the variables representing inputs, its variance is not. The Breusch-Pagan (Breusch and Pagan, 1979) test for heteroskedastic errors gave a value of 7.09 which compared to a χ^2_5 value of 11.07 indicates that the null hypothesis of homoscedasticity is not rejected. Table 2 presents the parameter estimates of the model in equation (7). The table contains a total of 46 parameters, twenty of which are significant at the 1% level, five at the 5% level, and four at the 10% level. R^2 for the equation is 0.99 and collinearity diagnostics developed by Belsley, Kuh and Welsch (1980) indicate an absence of multicollinearity.

Elasticities of productivity with respect to technology changing variables can be evaluated at the mean value of input variables, using the coefficients in table 2 and equation (8). The results (Table 3) show relatively small effects of the technology-changing variables. The elasticities of greater interest here are the ones that represent the effects of past price expectations on productivity. They indicate that a ten percent change in past output price expectations (due to different policy choices, for example) would produce a five percent shift of the production function, while increases in expected wages and fertilizer prices of the same magnitude would shift it down by three percent and one percent respectively. Agricultural research, quality of the soil, irrigation, life expectancy, and schooling all have positive effects on productivity.

Production elasticities evaluated at the average value of the technology changing variables are presented in row one of Table 4. The sum of these coefficients is 0.952, very close to constant returns to scale. Estimation of these elasticities in a fixed coefficients model was also performed to contrast them with those derived form the variable coefficients model (row 2 of Table 4). It is useful to note that our fixed coefficients results are very similar in magnitude to those of Evenson and Kislev in their study of 36 countries for 1955-1968. The elasticities from our variable coefficients model are higher for land, and lower for livestock, as compared to the studies of Hayami and Ruttan, Evenson and Kislev, Nguyen, Mundlak and Hellinghausen, and Antle.

The effect of output price expectations on relative level of input use (bias) is revealed by the elasticity of the marginal rate of technical substitution with respect to that variable (equation (10) above). The estimates of these elasticities evaluated at the average value of the variables indicate that past price policies (which affected output prices negatively) biased the input mix against labor and machinery and in favor of livestock relative to all remaining inputs. They increased the share of land relative to all other inputs except livestock and decreased machinery relative to fertilizer (Table 5).

IV. Estimated Productivity Effects of Agricultural Policies.

In this section we examine the implications of the model for evaluating the impact of various government policies on agricultural productivity. The previous theory suggests that the productivity of LDC's agriculture will be affected by policies that result on implicit or explicit taxation of the sector. Evidence for a set of developing countries was presented in Table 1. The nominal protection rate reported there is the multiple by which an index of domestic agricultural prices has been raised by government policies above a comparable index of international prices. These are Divisia indexes constructed across commodities that represent between 60 and 80 percent of the total value of agricultural output for each of the eighteen countries in the series. The period analyzed covers the years 1960-84. The protection rates include the price effects of both direct commodity price interventions and the 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.

In general, the effect of a policy can be described as a percentage price wedge, that is, the difference between the expected demand price and the expected supply price in the period when decisions about the techniques to use are made, expressed as a percentage of the equilibrium price. We assume in this study that prices are exogenous to the agricultural sector, so that the price wedges created by various policies can be characterized as exogenous price changes.

To evaluate the effects of policy wedges on the agricultural productivity of each country we multiply the elasticities of productivity by the price wedges reported in Table 6. The elasticities of productivity, equation (8), are evaluated at the mean of inputs for each country. Table 6 reports two price wedges. Column 3 presents the average effect of direct government interventions, i.e. those aimed directly at the agricultural outputs. The average price wedge due to all interventions for each country is in column 4.

Elimination of commodity specific interventions would have increased productivity in every country except those which have been subsidizing the sector. In Brazil, Ghana, Korea and Turkey agricultural commodities seem to have been subsidized, and the elimination of the subsidies would have meant a reduction of expected prices received by farmers with the corresponding downward shift of the production function in these countries. Indirect interventions have acted to tax agriculture in every country except Portugal, so that even in Brazil, Ghana and Turkey the total 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 productivity increases would have ranged from 0.2 percent in Chile to 118 percent in Egypt.

V. Summary and Conclusions

In this study we shown evidence that price policies have had a significant negative impact on agricultural productivity in a sample of eighteen developing countries. The policies in question include both direct agricultural price interventions and policies that have affected agricultural prices indirectly, such as trade and macroeconomic policies that distort agricultural prices. Recent studies by the World Bank indicate that if all such policies had been eliminated over the study period, agricultural prices would have fallen by 14 percent in Korea, but would have risen in all other countries, by as much as 115 percent in the cases of Ivory Coast and Zambia. The average price rise across countries would have been 56 percent. The concern of this study is the productivity effect of these price changes, measured as the percentage change in output for given levels of traditionally-measured inputs (land, livestock, machinery, fertilizer and labor). The results of the analysis indicate that the price changes would have increased this measure of productivity by 28 percent.

The theoretical basis for prices having an affect on productivity arises from the effect that price expectations can have on the choice of technique by producers, and on the incentives for discovering and adopting new knowledge. While there is considerable theoretical and empirical support in the literature for the idea that prices can affect innovation and/or efficiency (and thus presumably productivity), there is no consensus as to whether this effect is positive or negative. Our empirical results indicate a positive productivity effect of output prices, and a negative effect of input prices, supporting results previously obtained by Schmookler, Lucas, Binswanger and others as opposed to the implications of studies by Leibenstein, Nelson and Winter, Martin and Page and some others.

In order to establish the relationship between price expectations and productivity, we have estimated a cross-country production function for the eighteen countries for 1960-1985. We used a variable coefficient specification in which the production elasticities of such traditionally measured inputs as land, labor and tractors are themselves functions of expected prices (measured as five-year moving averages of realized prices) and other technology-shifting variables. While a number of similar cross-country agricultural production functions have been previously estimated, our study is unique in using a variable-coefficient specification with technology-shifting variables as determinants of the variable coefficients, and in including input and output price expectations as variables in the function. Our estimates of production elasticities at the mean of the data are: 0.41 for land, 0.11 for livestock, 0.13 for tractors, 0.06 for fertilizer and 0.24 for labor. Compared with the previous studies, these estimates are higher for land and lower for livestock, and within the previous ranges for other inputs.

The analytical approach permits the calculation of elasticities of productivity with respect to each of the technology-changing variables. Evaluated at the mean of data values for all countries, these elasticities are: 0.50 for past output price expectations, -0.35 for past wage expectations, -0.15 for past fertilizer price expectations, 0.18 for the stock of agricultural research, 0.07 for land quality, 0.72 for percent of land irrigated, 0.15 for life expectancy, and 0.03 for schooling. Such estimates as these are obviously of great interest in evaluating public policies related to these variables.

The results of this study are important in demonstrating that taxation of the agricultural sector in developing economies can have significant effects on the productivity of resources employed in agriculture, as well as effects on the amount of such resources allocated to agriculture. They underscore Schultz's contentions of decades ago that growth in agricultural output cannot be explained satisfactorily by an analysis which is based solely on conventional inputs, and that policies that depress agricultural prices have a negative affect on agricultural productivity.

Table 1. Agricultural Protection and Growth, 18 countries

Countries	Years	NPR[a] (%)	Production growth[b] (%)
Argentina	61-85	-40	2.1
Brazil	66-83	-11	3.8
Chile	61-83	-25	1.8
Colombia	61-83	-33	2.8
Dominican R.	66-85	-40	2.8
Egypt	61-84	-53	2.7
Ghana	61-84	-17	1.1
Ivory Coast	61-82	-53	5.2
Korea	61-84	16	4.2
Malaysia	61-83	-18	3.3
Morocco	61-84	-31	4.0
Pakistan	61-84	-47	3.8
Philippines	61-82	-32	3.8
Portugal	61-83	-18	-0.1
Sri Lanka	61-85	-49	2.1
Thailand	61-84	-41	4.7
Turkey	61-83	-36	2.8
Zambia	66-84	-53	2.2

(a) NPR= nominal protection rate= (domestic price/border price)-1, adjusted for exchange rate misalignment and protection to industry.
(b) calculated from FAO production indexes.

Table 2. Least Squares Estimates of Equation (7), 18 countries[a]

	Inputs					
	Land	Livestock	Machinery	Fertilizer	Labor	Intercept
Linear terms	-0.564	-0.313	0.795	-0.647	1.485	0.458
	(0.194)	(0.300)	(0.144)	(0.161)	(0.180)	(0.217)
Interaction terms with						
Output Price exp.	-0.011	-0.051	0.025	0.003	0.053	
	(0.036)	(0.037)	(0.018)	(0.014)	(0.017)	
Expected wages	0.032	-0.006	-0.008	-0.010	0.023	
	(0.014)	(0.018)	(0.011)	(0.009)	(0.012)	
Expected fert.	-0.092	0.012	0.037	0.015	0.055	
	(0.023)	(0.029)	(0.015)	(0.016)	(0.016)	
Research	0.045	-0.064	0.014	-0.028	0.025	
	(0.015)	(0.023)	(0.013)	(0.012)	(0.016)	
Land Quality	0.006	-0.001	-0.002	0.002	-0.005	
	(0.0004)	(0.0007)	(0.0003)	(0.0003)	(0.001)	
Life Expectancy	0.013	0.014	-0.017	0.007	-0.019	
	(0.004)	(0.007)	(0.004)	(0.004)	(0.005)	
Irrigation	0.283	-0.661	-0.132	0.309	0.371	
	(0.124)	(0.193)	(0.093)	(0.095)	(0.115)	
Schooling	-0.002	0.0003	0.003	-0.002	-0.0001	
	(0.0009)	(0.001)	(0.0007)	(0.009)	(0.001)	

[a] Based on 410 observations during the years 1961 to 1985, standard errors in parentheses, overall R^2=0.99

Table 3. Productivity Elasticities (evaluated at the mean)

Productivity with respect to:	
Output Price Expectations	0.502
Expected Wages	-0.355
Expected Fert. Prices	-0.147
Research	0.180
Land Quality	0.072
Life Expectancy	0.152
Irrigation	0.720
Schooling	0.026

Table 4. Production Elasticities (standard errors in parentheses)

Regression Model	Land	Livestock	Machinery	Fertilizer	Labor
Variable Coeff.	0.411	0.112	0.133	0.061	0.236
	(0.147)	(0.036)	(0.033)	(0.067)	(0.039)
Fixed Coeff.	-0.099	0.396	0.175	0.035	0.333
	(0.027)	(0.036)	(0.022)	(0.021)	(0.028)

Table 5. Biasing Effects of Output Price Expectations

m\i	Livestock	Machinery	Fertilizer	Labor
Land	0.132	-0.067	-0.026	-0.077
Livestock		-0.200	-0.158	-0.209
Machinery			0.041	-0.010
Fertilizer				-0.051

Table 6. Estimated Productivity Changes from Elimination of Policies

Country	Elasticity of Productivity with Respect to Output Price[a]	Price changes due to elimination of: Direct Interv. (%)	Price changes due to elimination of: Total Interv. (%)	Productivity changes due to elimination of: Direct Interv. (%)	Productivity changes due to elimination of: Total Interv. (%)
Argentina	0.787	30.1	65.4	23.69	51.45
Brazil	0.306	-5.4	12.5	-1.66	3.82
Chile	0.007	3.2	32.7	0.02	0.22
Colombia	0.368	12.4	49.6	4.55	18.26
Dominican R.	0.124	32.2	67.5	3.99	8.35
Egypt	1.057	71.7	112.5	75.80	118.95
Ghana	0.630	-10.5	12.6	-6.62	7.97
Ivory Coast	0.925	57.7	114.6	53.34	106.02
Korea	1.328	-34.6	-14.11	-45.92	-18.75
Malaysia	0.981	11.8	21.7	11.62	21.30
Morocco	0.150	26.8	46.8	4.02	7.01
Pakistan	0.420	32.9	88.8	13.81	37.32
Philippines	0.726	14.2	46.6	10.35	33.83
Portugal	0.766	29.5	24.5	22.61	18.80
Sri Lanka	0.954	34.1	99.2	32.50	94.67
Thailand	0.902	46.2	71.1	41.68	64.08
Turkey	0.905	-1.8	56.4	-1.62	50.84
Zambia	0.091	29.0	115.1	2.65	10.51

[a] Evaluated from equation (8), using estimated coefficients and mean value of inputs for each country.

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