

The Price Response of Major Crops in Pakistan: An Application of the Simultaneous Equation Model

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This paper specifies a model to simultaneously estimate the price response, assuming an interdependence among crops. The model is applied to estimate own- and cross-price elasticities of five major crops in Pakistan, viz., wheat, cotton, rice, sugarcane, and maize based on the production and expected wholesale-price data for the period 1957-86. The study found little potential to enhance overall agricultural productivity by increasing the single crop price, since either the own-price elasticities were low or, otherwise, the negative cross-price effects on the production of other crops were high. However, a 10-percent systematic improvement in terms of trade for agriculture will increase overall agricultural productivity by about 6 percent in the long run.

1. INTRODUCTION

The response of farm production to expected commodity prices is a key relationship in agricultural policy development. Both the level and the composition of production are major concerns of economic policies. A sound policy designed to obtain the desired level and composition of production rests on a thorough understanding of (i) what policy determinants affect the farmers' decisions to produce a particular commodity, and (ii) the way the decision to produce one commodity affects the production levels of other commodities. This paper delineates a methodological framework to understand these factors, and applies it to estimate supply responses of five major crops, viz., wheat, cotton, rice, sugarcane, and maize, using the production and expected wholesale-price data for the period 1957-86.

In the context of the whole-farm enterprise mix, a decision to produce one crop affects other crops in three ways. First, since different crops may demand the same resources at the same time, the decision to produce more of one crop may reduce the production of other crops. Secondly, changes in the production of a particular crop may influence the production of other crops in the same direction if all the crops require the same resources but at different times of the year. Thirdly,

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two crops may be independent, if each is grown in a different geographical area or is grown in a different season and has different resource requirements. Hence the relationship between crops may be competitive, complementary, or even one in which crops are independent of each other. This paper studies the nature of these crop production relationships by simultaneously estimating the price response of five major crops in Pakistan.

Price elasticities of supply enter into a number of policy calculations, including support prices and buffer stock operations [Gotsch and Falcon (1975); Pinckney (1989)]. A study of the price response incorporating the interdependence of different crops can improve the knowledge and, therefore, the reliability of supply parameters used in these calculations. Once the direction and magnitude of interactions among crops and the factors influencing the supply are determined, planners will be generally helped in assessing the effect of a price policy on the output of different crops as well as the welfare of the farmers.

A cross-country review of empirical studies on the price response, using the single-crop estimation approach, is found in Askari and Cummings (1977) and Henneberry (1986). In Pakistan, too, there have been efforts to estimate the price responses of single crops. The results of these studies are given in Table 1.

Tweeten (1986) was the first to study a full system of own- and cross-price elasticities of the supply in Pakistan. He first estimated own-price elasticity and then used his estimates to calculate cross-price elasticities by applying the mathematical factor-share approach. Our study, on the other hand, applies a statistical approach to estimate the supply response parameters simultaneously for all crops.

In Section 2, a theoretical framework is developed for a simultaneous-supply-response model and a price-expectation model. The third section describes the results of the price-expectation model and the results of a simultaneous estimation of short- and long-run supply elasticities of five major crops in Pakistan. Section 4 summarizes the results of the study and discusses the implications of those results for the formulation of an appropriate agricultural policy.

2. THEORETICAL MODEL

The Supply Response Model

In general, in a system of (M) crops, the supply response of the i th crop can be assumed to be a function of own output price, prices of all the other relevant crops, and prices of the inputs and technology used for crop (i). The supply response estimated in this study is specified as

$$Y_{it}^* = A_i P_{it}^* (C_{ii}) \prod_{i \neq j=1}^{M-1} P_{jt}^* (C_{ij}) \prod_{i=1}^N P_{it}^* (C_{in}) e^{(D_i)T} e^{U_i} \dots \quad (1)$$

Table 1

Short-run Own- and Cross-price Elasticities Estimated/Calculated by Earlier Studies

Studies	Specification	Prices of					
		Wheat	Cotton	Rice	Sugarcane	Maize	Input
Falcon (1964)	Acreage						
	(i) Wheat (I)	0.1-0.2	-	-	-	-	-
	(ii) Wheat (B)	n.s	-	-	-	-	-
	(iii) Cotton Cotton Yield	-	0.40 n.s	-	-	-	-
Cummings (1975)	Output						
	(i) Wheat	0.1(ns)	-	-	-	-	-
	(ii) Cotton (iii) Rice	-	0.40 -	-	-	-	-
Ahmad <i>et al.</i> (1983)	Acreage						
	(i) Wheat	0.10	-	-	-	-	-
	(ii) Rice	-	-	0.16	-	-	-
	(iii) Sugarcane	-	-0.11	-	0.41	-	-
	(iv) Cotton	-	0.15	-	-0.26	-	-
	Output						
	(i) Wheat	0.28	-	-	-	-	-
	(ii) Rice (iii) Sugarcane (iv) Cotton	-	-	-	-	0.70	-0.57 -0.53

Continued-

Table 1 – (Continued)

Studies	Specification	Prices of					
		Wheat	Cotton	Rice	Sugarcane	Maize	Input
Tweeten (1986)	Output						
	(i) Wheat	0.15	-0.020	-0.004	-0.007	—	-0.119
	(ii) Cotton	0	0.300	-0.010	-0.015	—	-0.275
	(iii) Rice	0	-0.028	0.200	-0.009	—	-0.163
	(iv) Sugarcane	0	-0.043	-0.009	0.300	—	-0.248
Chaudhry and Bashir (1986) ^a	Acreage						
	(i) Wheat	ns	—	—	—	—	—
	(ii) Cotton	—	0.055	—	—	—	—
	(iii) Rice	—	—	0.342	—	—	—
	(iv) Sugarcane	—	—	—	0.242	—	—
	(v) Maize	—	—	—	—	0.148	—
Pinckney (1989)	Acreage						
	(i) Wheat	0.09	—	—	—	—	-0.06
	Yield						
	(i) Wheat	0.34	-0.04	—	—	—	—
Average Own-price Elasticity	ticity	0.17	0.28	0.21	0.41	0.15	-0.28 ^b

(I) = Irrigated, (B) = Barani

^aMean of the significant coefficients for different regions of the Punjab.^bAverage of input elasticities in different crops.

- $i \neq j = 1, 2, 3 \dots M = \text{crops};$
- $t = 1, 2, 3 \dots S = \text{observations}; \text{ and}$
- $n = 1, 2, 3 \dots N = \text{inputs}.$

where Y_{it}^* is the desired production of crop (i) in period (t); P_{it}^* , P_{jt}^* , P_{nt}^* are the expected own-output price, the j th output price, and n th input price, respectively, in period (t); T_i is a trend variable used as a proxy for technology;¹ A_i is an intercept of the i th crop equation; C_{ii}^* , C_{ij}^* , C_{in}^* are long-run supply elasticities of own-price, cross-price, and fertilizer-price, respectively; D_i is long-run growth rate in productivity; e is the natural exponent; and U_i is the random error.

It is hypothesized that C_{ii}^* will be positive and C_{in}^* negative. C_{ij}^* may be positive if the i th and j th crops are complementary, but negative if they are substitutes, and zero if they are independent.

The desired values of production in Equation (1) can be replaced with the actual values (Y_{it}) if the Nerlovian adjustment process is assumed as follows [Nerlove (1958)]:

$$Y_{it}/Y_{it-1} = (Y_{it}^*/Y_{it-1})^{B_i} \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

where (Y_{it-1}) is actual output in the preceding year and B_i is the adjustment coefficient for crop (i). Substituting the values of Y_{it}^* from Equation (2) into Equation (1) and using the log-linear form will give

$$\begin{aligned} \ln Y_{it} = & \ln A_i^* + C_{ii}^* \ln P_{it}^* + \sum_{i \neq j=1}^{M-1} C_{ij}^* \ln P_{jt}^* + \sum_{i=1}^N C_{in}^* \ln P_{nt}^* + \\ & (1-B_i) \ln Y_{it-1} + D_i^* T_i + U_i \quad \dots \quad \dots \quad \dots \quad (3) \end{aligned}$$

where C_{ii}^* , C_{ij}^* , C_{in}^* are respective short-run parameters. The long-run elasticities (C_{ii}^* , C_{ij}^* , C_{in}^* , D_i) can be calculated by dividing the short-run elasticities by one minus the coefficient of lag production, B_i .

Assuming that the supply response of each crop is homogeneous of degree zero (i.e., changing the prices of all the crops and inputs in the same proportion does not affect the output), one price can be used to normalize other prices. In this study the fertilizer price, the only input price included in the study, has been used

¹Ideally, each component of technology, like water availability or plant variety, should be treated separately. However, to keep the model manageable and to avoid multicollinearity, the trend variable is used to capture the effect of all such variables.

to normalize the crop prices in each Equation. Thus Equation (3) becomes

$$\begin{aligned} \ln Y_{it} = & \ln A_i^* + C_{it}^* \ln(P_{it}^*/P_{nt}^*) + \sum_{i \neq j=1}^{M-1} C_{ij}^* \ln(P_{jt}^*/P_{nt}^*) + \\ & (1-B_i) \ln Y_{it-1} + D_i^* T + U_i \quad \dots \quad \dots \quad \dots \quad (4) \end{aligned}$$

The price ratios will hereafter be termed as normalized prices. In Equation (4), the coefficients of normalized prices of the i th and j th crops are the respective own- and cross-price elasticities. The supply elasticity of the i th crop with respect to fertilizer price is the negative of the sum of all the normalized-price coefficients of the i th crop.² The standard error of the coefficient of the fertilizer-price elasticity can be calculated by using the addition rule of variance for independent variables [Madala (1977)].

So far, the i th crop was treated as independent of the j th crop. However, there are reasons to believe that each crop has contemporaneous relationships with other crop. For instance, decision mistakes about the production of one crop affect the production of other crops, in the whole-farm context. Consider the case in which farmers commit the mistake of producing more wheat than the relationship in Equation (4) dictates. This may leave very little resources for competing crops, but more resources for complementary crops. Thus, a deviation from the specified relationship in the case of one crop in one year leads to deviations in the case of other crops also. Then, there are some missing variables common to all the equations; weather is one of them. This omission may lead to contemporaneous relationship of the error term, too, across the equations. For example, heavy rains in July-August adversely affect flower setting in cotton, whereas they are good for rice cultivation. Therefore, the error term in each crop equation is assumed to be contemporaneously correlated but independent over time. Zellner (1962) called such a set of equations a "seemingly unrelated regression" (SUR) model and suggested joint estimation of the parameters by GLS, using the following relationship [Pindyck and

²Expanding Equation (4) will give

$$\begin{aligned} \ln Y_{it} = & \ln A_i^* + C_{it}^* \ln(P_{it}^*) - \sum_{i \neq j=1}^{M-1} C_{ij}^* \ln(P_{jt}^*) + \sum_{i \neq j=1}^{M-1} C_{ij}^* \ln(P_{nt}^*) - C_{it}^* \ln(P_{nt}^*) + \\ & (1-B_i) \ln Y_{it-1} + D_i^* T + U_i \end{aligned}$$

The fertilizer-price elasticity, which is the coefficient of P_{nt}^* , is the negative of the sum of all the normalized (own- and cross-) price coefficients. The own- and cross-price elasticities, which are the coefficients of P_{it}^* , P_{jt}^* , are the same as those of normalized price coefficients, that is, the coefficients of (P_{it}^*/P_{nt}^*) and (P_{jt}^*/P_{nt}^*) , respectively.

Rubinfeld (1976)],

$$C = [X'(Z)^{-1}X]^{-1} [X'(Z)^{-1}Y] \quad \dots \quad \dots \quad \dots \quad (5)$$

where C is a vector of coefficients of order $(\sum_{i=1}^M k_i \times 1)$ (k_i is number of independent variables in equation (i)); X is a matrix of independent variables of order $(SM \times \sum_{i=1}^M k_i)$; Y is a vector of dependent variables of order $(SM \times 1)$; and Z is the inverse of the variance-covariance matrix of order $(SM \times SM)$. Z is estimated from the residuals of OLS estimates of each equation.

Two important points have to be noted when estimating the set of equations represented by Equation (4): (a) the possibility that serial correlation may exist in time-series data; and (b) each equation has a lagged dependent variable on the right-hand side which may lead to biased estimates in small samples, though they are consistent in large samples. The combination of autocorrelation and the presence of a lagged dependent variable does not even lead to consistent estimates [Johnston (1972)]. However, the presence of a number of explanatory variables other than the lagged dependent variable and the use of a comparatively large data set (spread over 30 years in this study) help to minimize the asymptotic bias of the estimates [Narayana and Shah (1984)].

The Crop Price Expectation Model

The set of equations represented in Equation (4) expressed the production relationship in terms of expected prices, which can be estimated by taking the weighted average of the previous years' prices, or by incorporating the effect of the past prices on current year's production through the use of the Nerlovian Adaptive Expectation model. This study uses the Autoregressive Integrated Moving Average (ARIMA) model to estimate the expected price of a crop, because, unlike other models, this model has the flexibility to forecast the value of a variable by identifying separately the stationary and random components of each of its past values. The ARIMA model uses three tools in estimating the predicted prices: (i) the degree of differencing (d); (ii) the autoregressive (AR) process of order (p); and (iii) the moving average (MA) process of order (q).³ After allowing for the secular trend or the drifting effect by taking appropriate differences of the series, different AR and MA schemes are tried, using the following formulation [Hall and Lilien (1986)].

$$P_t^d = a + v_1 w_{t-1} + v_2 w_{t-2} + \dots + v_q w_{t-q} + r_1 P_{t-1}^d + r_2 P_{t-2}^d + \dots + r_p P_{t-p}^d \quad (6)$$

³A good theoretical treatment of the ARIMA model and its applications is given in [Pindyck and Rubinfeld (1978), pp. 514-605].

where P^d is the price after taking the appropriate difference of degree d to the original series, w_t is white noise or random error with specified lag, and r_i and v_i are the parameters to be estimated for autoregressive and moving averages, respectively.

The best schemes are selected, based on the following diagnostic checking: (a) the statistical properties of the coefficients, (b) a Chi-square test devised by Box and Pierce (1970), based on residual autocorrelations, and (c) the best forecast values of the schemes.

3. EMPIRICAL ESTIMATION

Estimates of Crop Price Expectation Function

The autocorrelation function for each normalized-price series showed a rapid decline as the number of lags became large, implying no drifting effect in any series, so that each series was stationary. Therefore, no difference was taken and the original normalized-price series was used for prediction. Different AR and MA schemes were tried for each series, using the Time Series Processor (TSP) programme. The best model for each series was selected on the basis of the diagnostic test explained above.

The results of the final model are presented in Table 2. Different orders of MA coefficients were significant in each normalized-price series, showing that different lags in price-shocks affect the present year's expected prices in each case. The coefficient of AR(1) was significant in each model, implying that the previous year's price information affects the current year's price expectation. In each case, the AR(1) coefficient was less than one, a necessary condition for a series to be stationary.

The expected and actual normalized prices of the five major crops are shown in Figure 1. The expected prices track the turns in the actual prices in each case.

Estimates of Supply Response Functions

The supply response function for the five major crops as expressed in Equation (4) was estimated, using the SUR procedure in Equation (5). Time-series data of production and wholesale prices for the period 1957–86 are used in this analysis. A complete print-out of the data used in this paper can be found in the Appendix in Ali (1988).

The use of expected normalized prices rather than real prices as regressors reduced multicollinearity in prices. The simple correlation in actual prices was higher than 0.96, whereas the correlation in expected normalized prices reduced to less than 0.66.

Table 2

ARIMA Process Schemes and the Results of Price Expectation Function Estimation for 1957-1986

Crop Price Ratios	Predicted Schemes (<i>p, q, d</i>) ^a	<i>r</i> 1	<i>v</i> 3	<i>v</i> 4	<i>v</i> 5	<i>v</i> 6	<i>v</i> 7	<i>u</i>	Chi-square ^b
Wheat/Nitrogen	(1,2,0)	0.480	—	—	-0.38	-0.454	—	0.747	5.697
Cotton/Nitrogen	(1,1,0)	0.565	—	-0.596	—	—	—	2.489	5.428
Rice/Nitrogen	(1,1,0)	0.603	—	—	—	—	-0.814	6.360	10.04
Sugarcane/Nitrogen	(1,1,0)	0.526	—	—	—	-0.568	—	0.112	5.632
Maize/Nitrogen	(1,1,0)	0.664	-0.277	—	—	—	—	1.242	6.716

^a(*p, q, d*) implies that the *p*-order of autoregressive, *q*-order of moving average and *d*-degree of difference are used.

^bBased on the residual autocorrelation of the final model. The table value of Chi-square with 24 degree of freedom at 99 percent confidence interval is 10.86.

*r*1 is autoregressive coefficient of order one.

*v*1 ... *v*7 are moving average coefficient of different degrees.

u is constant around which the series fluctuates. If a given series is stationary, the mean fluctuates randomly about a constant mean. The formula to calculate *u* is as follows [Hall and Lilien (1986)]:

$$u = \frac{a}{1 - r_1 - r_2 \dots r_p}$$

where *a* is constant of Equation (6).

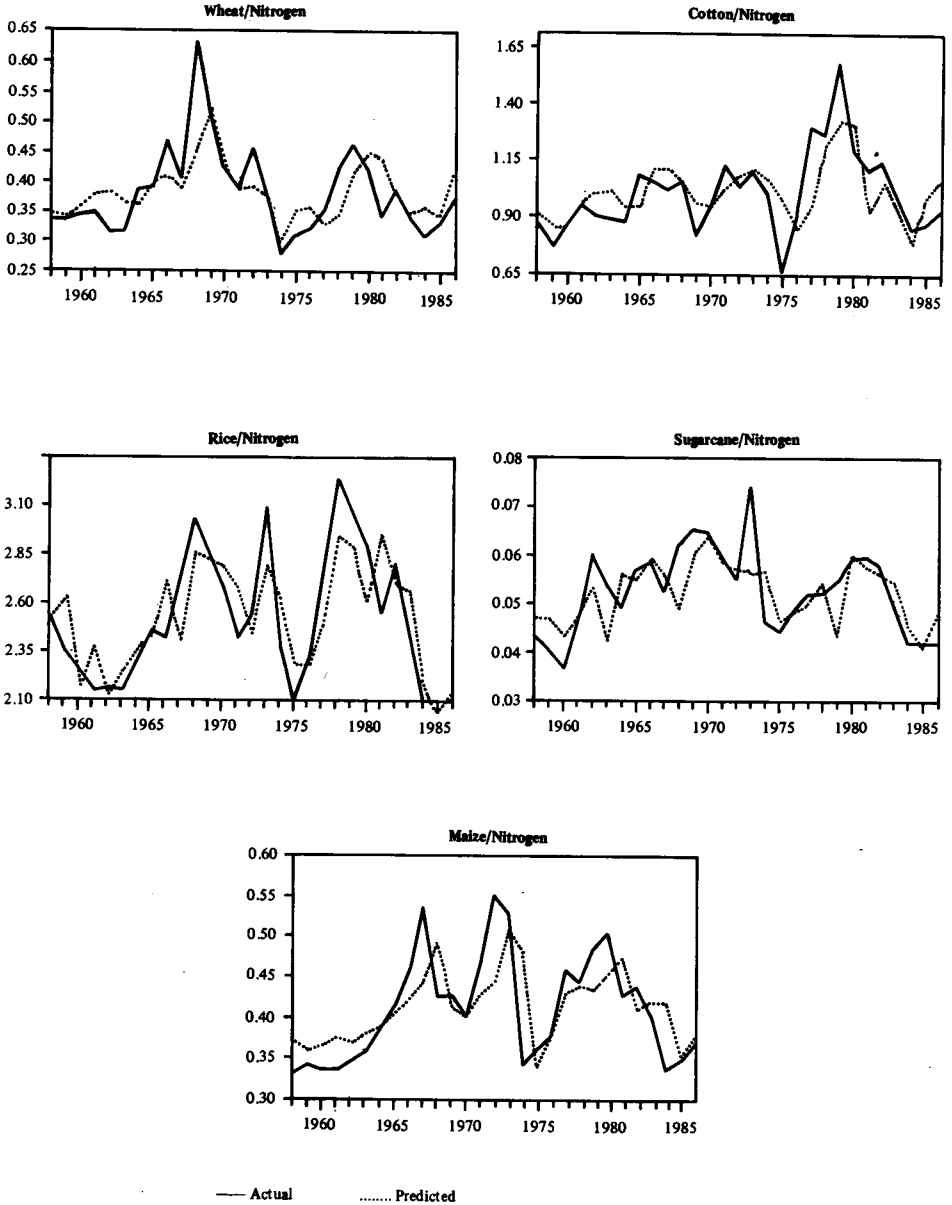


Fig. 1. Actual vs. Predicted Normalized Prices.

Short-run Own-price, Input-price, and Trend Elasticities

The estimated short-run own-price and cross-price supply elasticity matrix is presented in Table 3. The results are much improved compared with the single-equation OLS results (not reported here) in terms of the standard errors of the coefficients. The hypothesis of zero autocorrelation cannot be rejected at the 5 percent level.

The fertilizer-price elasticities are the highest for cash crops such as cotton, sugarcane, and rice, and are the lowest for food crops such as wheat. A 10-percent increase in fertilizer price will decrease the production of cash crops by about 3.5 percent, while the production of wheat will decrease by only 2.5 percent. Maize is not responsive to fertilizer price.

All own-price elasticities are highly significant, except in the case of wheat, in which it is significant at the 20-percent level. A 10-percent increase in the price of wheat will bring only 2 percent increase in the production of wheat. The relatively insignificant and small own-price elasticity of wheat, which is in line with the findings of other studies reviewed earlier, may be due to the fact that few alternatives are available to the farmers in the *Rabi*⁴ season. A 10-percent increase in the price of cotton will bring about 7 percent increase in the production of cotton in the short-run, which is on the high side, and indicates the ability of cotton growers to replace the area of other competing crops relatively easily and improving the productivity through production intensification.

The trend coefficient is positive and significant for each crop. The coefficient for this variable estimates the effect of improvement in technology which increases the marginal productivity of various inputs like water and fertilizer and thus enhances their use. The change in the output in response to the input price is estimated by the coefficient for the price of fertilizer, a variable input of major importance in crop production.

Comparing the results of this study with those of Tweeten (1986), the only study with comparable results, and other studies in Table 1, we find that elasticities are higher in our study than in Tweeten's study, and also greater than the average of all the earlier studies reviewed. Moreover, the signs of cross-price elasticities are different from those in Tweeten's study. Our study shows that the relationship between crops may be complementary instead of being always competitive as assumed in Tweeten's study.

Short-run Cross-price Elasticities

Four points need to be considered before discussing cross-price elasticities:

⁴ The *Rabi* season is from October to March.

Table 3

Estimated Parameters of the Supply Response Functions of Five Major Crops in Pakistan

Crops	Intercept	Prices of						Lag Coef- ficient	Trend Coefficient	R ²	Durbin Watson	h ^b
		Wheat	Cotton	Rice	Sugarcane	Maize	Fertilizer ^a					
Wheat	5.610**** (1.259)	0.228** (0.139)	-0.151* (0.149)	0.173* (0.180)	-0.026ns (0.127)	0.004ns (0.232)	-0.250* (0.272)	0.304*** (0.147)	0.035**** (0.008)	0.95	1.95	0.22
Cotton	4.500**** (1.697)	0.225ns (0.273)	0.715*** (0.302)	-0.329* (0.360)	0.053ns (0.240)	-0.206ns (0.456)	-0.386* (0.446)	0.466**** (0.168)	0.020**** (0.007)	0.76	2.14	-0.86
Rice	1.384** (0.889)	0.136* (0.112)	-0.098* (0.103)	0.407**** (0.151)	0.063ns (0.101)	-0.084* (0.077)	-0.361** (0.228)	0.788**** (0.116)	0.010** (0.007)	0.97	2.02	-0.08
Sugarcane	7.445**** (1.086)	0.003ns (0.148)	-0.149* (0.153)	0.162ns (0.197)	0.524**** (0.131)	-0.112ns (0.239)	-0.375** (0.201)	0.353**** (0.101)	0.023**** (0.005)	0.91	1.76	0.79
Maize	5.973**** (0.918)	0.056ns (0.094)	-0.207*** (0.099)	0.058ns (0.124)	-0.095* (0.08)	0.359*** (0.147)	0.057 (0.194)	0.024ns (0.146)	0.030**** (0.005)	0.95	2.16	-0.68

****, ***, **, * significant at the 1, 5, 10, and 20 percent level, respectively.

Figures in parenthesis are standard errors of the coefficients.

ns = not significant, at least at the 20 percent level of significance.

^aFertilizer price elasticity was not directly estimated in an equation. The indirect procedure to calculate the fertilizer price elasticity is explained in footnote No. 2 of the main paper.

^bThe "h" statistic applied to test the autocorrelation in this study was developed by Durbin (1970) in response to the criticism by Malinvaud (1966) of using a traditional Durbin-Watson statistic when a lagged dependent variable is present on the right-hand side of the equation. For more details and for formulation of the h-statistic, see [Johnston (1970), page 170]. The decision rule in h-statistic is that if the value of h-statistic is greater than 1.645, the hypothesis of zero-autocorrelation is rejected at the 5 percent level.

(a) the turn-around time (given in Figure 2); between two crops when those crops are grown in different parts of the year; (b) the proportions of the acreages of competing crops in a given cropping-zone when two crops are grown at the same time – a dominant crop (i.e., one having a large proportion of the area) is expected to affect minor crops (i.e., those having small proportions of the area) in a given region without being affected by minor crops; (c) percentage of the total area of a crop that lies in a particular crop region when two crops are raised simultaneously – if most of the total area of a crop lies in a one-crop region, the production of the crop will be especially vulnerable to changes in the prices of competing crops in that region and the reverse will be true if the total area of a crop is spread in different crop regions; and (d) if two crops have small percentages of their respective total acreages in each other's cropping zone, it indicates that the two crops are grown in two separate zones – in this case, the effect of change in the price of one crop on the other crop depends upon the ability or otherwise of those zones to expand or contract in response to price changes.

Wheat occupies about 70 percent of the cropped area in the *Rabi* season. It is grown in November-December and harvested in March-April. The only other crop having the same cultivation time is sugarcane. Thus, there may be a possibility of wheat competing with sugarcane for area. However, sugarcane is a small crop compared with wheat in terms of the area devoted to its cultivation. Therefore, the effect of sugarcane prices on wheat production is not significant, although the sign is negative.

A tight schedule for growing wheat after cotton affects wheat production. This explains the negative and significant coefficient for the relationship between cotton prices and wheat production. These results are consistent with those of Byerlee *et al.* (1987).

Wheat production is complementary to rice production because an increase in the rice price also increases wheat production, and *vice versa*. Rice has two distinct varieties.⁵ IRRI rice is a short-duration variety and does not compete for resources with wheat because the two crops are grown at different times of the year. Hence, a change in the price of one of the two crops affects the marginal lands and other fixed resources not only for that crop but also for the other crop in the same direction. *Basmati* rice is a long-duration variety and sometimes may lead to hectic preparations for wheat planting, thus affecting wheat production. *Basmati* rice accounts for only 35 percent and IRRI rice for the remaining 65 percent of the total rice area in Pakistan. On the whole, therefore, the IRRI effect dominates. But even in the case of *Basmati* rice, only 20 percent of the area remains in the field

⁵ Ideally, IRRI and *Basmati* should be treated separately. Non-availability of variety-wise data since 1958 prevented this specification.

beyond November 21, the optimum time for wheat cultivation, whereas the mean harvesting date of *Basmati* is November 8 [Sharif *et al.* (1988)]. On the other hand, there is no chance of rice being affected if it follows wheat, because in the wheat-rice rotation there is at least two months' time available for the preparation of land for rice.

It is easy to demonstrate that there is no relationship between rice production and wheat production. However, our study suggests a complementary relationship between the two. It should be noted that rice cultivation, during the last 20 years, was extended to water-logged areas, and that it helped to improve the water-logged and saline soils. Thus, wheat yields improved in rice zones because of the better soils resulting from rice cultivation. The income effect of rice enables farmers to use more inputs for wheat, and *vice versa*. Moreover, fixed resources developed for wheat production can also be used for rice production, and *vice versa*.

Cotton is a *Kharif*⁶ crop and occupies about one-fourth of the area cropped in *Kharif*. It is sown in May-June and harvested in October-December. Sugarcane, wheat, and maize prices do not affect cotton production. There is enough turn-around time for cotton after wheat, which explains the insignificant relationship between cotton production and wheat price.

Maize and sugarcane occupy very small percentages (4.5 percent and 10–12 percent, respectively) of the cotton-zone area. This explains the insignificant relationship between cotton production and the maize and sugarcane prices. The minor crops (maize and sugarcane) are unable to affect the dominant crop (cotton).

Cotton strongly competes with rice, although these crops are grown in different regions. However, these regions, to some extent, can and do expand or contract according to the relative prices of the crops. A 10-percent increase in the price of cotton will decrease the production of rice by about 1 percent, and a 10-percent increase in the price of rice will decrease the cotton production by about 3 percent in the short run.

Rice is a *Kharif* crop and occupies about one-fourth of the area cropped in the *Kharif* season. It is sown in June-July and harvested in September-November. Rice production is complementary to wheat production and competitive to cotton production, as explained earlier. The sugarcane price does not affect rice production because only 10–15 percent of the rice-zone area has been under sugarcane and around 80 percent of it has been under rice. Thus sugarcane is a minor crop and rice is a dominant crop. Similarly, the maize price does not affect rice production because only up to 5 percent of the zone area has been under maize production.

Sugarcane is a perennial crop and occupies around one-tenth of the total area cropped in the *Kharif* season. It is sown in February-March and harvested during the

⁶*Kharif* season is from April to September.

November–March period. Sugarcane competes only with cotton. A 10-percent increase in the price of cotton will decrease the production of sugarcane by about 1.5 percent in the short run. The negative relationship between the cotton prices and the sugarcane production is due to the fact that a high proportion (about 50 percent) of the total sugarcane area lies in the cotton zone. However, it is still a minor crop in the cotton zone. As such, the sugarcane price does not affect cotton production. Sugarcane production is not affected by a change in the price of any other crop. The insignificant relationship between sugarcane production and rice prices is easy to understand because these crops are mostly sown in different cropping regions. The insignificant relationship between the maize price and sugarcane production is difficult to explain. Though little sugarcane is grown in the maize zone, about one-fourth of the sugarcane-zone area has been under maize, so that maize is in a position to possibly compete with sugarcane. This study is unable to ascertain any significant relationship between sugarcane and rice in lower Sindh, where recently sugarcane has substituted rice. Nor were we able to detect any significant relationship between sugarcane production and wheat price, even though sugarcane and wheat can be grown in the same geographical area and have an overlapping crop period. This may be because sugarcane production is mostly restricted to commercial farms where unique management skills are used.

Maize for grain purposes is sown in May–July and harvested during September–November. Maize occupies about 6 percent of the total area cropped in the *Kharif* season. The production of maize has affected cotton and sugarcane prices because a large proportion (about one-fifth) of the crop falls in the cotton zone and another one-fifth in the sugarcane zone. However, it is still a minor crop in the cotton zone. Maize prices, thus, as explained earlier, do not affect cotton production. Maize production is also not affected by the changes in the prices of wheat and rice because its cropping period is different from that of wheat, and because very little maize is grown in the rice zone.

Long-run Elasticities

Long-run elasticities are calculated by dividing the short-run elasticities by one minus the coefficient of lagged production (Table 4). The coefficients of lagged production are highly significant for all crops except maize. Consistent with theory, these coefficients are less than one, implying that long-run elasticities exceed short-run elasticities.

Again, long-run supply elasticities with respect to the fertilizer price are the highest for cash crops, viz., rice followed by cotton and sugarcane. Wheat has comparatively low fertilizer-price elasticity of supply. Fertilizer price does not affect maize production. A 10-percent increase in the price of fertilizer will decrease the production of rice, cotton, sugarcane, and wheat by about 1.7, 0.7, 0.6, and 0.4

Table 4

Long-run Supply Elasticities of Five Major Crops in Pakistan^a

Crops	Supply Elasticity with Respect to						Trend Coefficient
	Prices of						
	Wheat	Cotton	Rice	Sugarcane	Maize	Fertilizer	
Wheat	0.327	-0.217	0.249	0	0	-0.359	0.050
Cotton	0	1.339	-0.616	0	0	-0.722	0.037
Rice	0.641	-0.462	1.920	0	-0.396	-1.702	0.047
Sugarcane	0	-0.230	0	0.810	0	-0.579	0.036
Maize	0	-0.207	0	-0.095	0.359	0	0.0030

^aCalculated as short-run elasticities divided by one minus lag coefficient.

percent, respectively, in the long run.

The short-run own-price elasticity in each case is higher than the absolute value of fertilizer-price elasticity, except in the case of wheat, where both are almost equal. This implies that the short-run productivity advantage of increasing only one output price will be greater than or at least equal to the benefit resulting from an equal percentage decrease in the fertilizer price. However, if we consider the benefit of single-crop price support versus improving the overall terms of trade for agriculture, in the long run, the result will be different. For example, a 10-percent decrease in fertilizer price will lead to about 6 percent ($0.359*0.6+0.722*0.15+1.702*0.15+0.579*0.06+0*0.04 = 0.61$) weighted average increase in total agricultural production, whereas an equal increase in the price of one output, say cotton, will bring only 1 percent weighted average increase in total agricultural productivity. Some of the increase in output due to the price support for a single crop will be neutralized by cross-price elasticities. Therefore, a systematic effort in improving the terms of trade for agriculture by increasing crop prices of all crops or lowering input prices will equally enhance agricultural production in the long run. The administrative cost and the effect on inflation and welfare of different sectors of the society, however, need to be carefully examined before recommending this policy.

Long-run productivity growth rates are the highest for those food crops for which there is great national and international concern to meet the requirements of

a rapidly growing population, e.g., wheat and rice, followed by cash crops like cotton and sugarcane. On an average, wheat, rice, cotton, and sugarcane were growing at the rate of 5.0, 4.7, 3.7, and 3.6 percent per annum, respectively. At the constant prices, the growth in wheat and rice production exceeds the population growth rate of 3.1 percent per annum in the country. Although an international organization, CIMMYT, is working for an improvement in maize production technologies, it has failed to benefit from international breeding research. This is mainly because the crop is cross-pollinated and the seeds of improved high-yielding varieties get polluted by those of the neighbouring low-yielding varieties after every 3-4 years. Therefore, in the absence of an efficient seed-supply system in Pakistan, the advantage of new varieties has not been fully taken.

Production of cash crops like cotton and rice is quite elastic in the long run, with the long-run own-price elasticities being greater than one. Sugarcane production is also sensitive to own-price, but the long-run own-price elasticity is less than one, implying that a one-percent change in the sugarcane price will bring a less-than-one percent change in its output. Food crops like maize and wheat are quite inelastic because a 10-percent change in the output price of each crop will bring a change of only 3.3 and 3.6 percent, respectively, in their outputs.

Generally, own-price elasticities are high for cash crops and low for food crops. This is because the basic consideration in raising food crops is to meet family requirements, regardless of the market price of output. Fertilizer-price elasticities of food crops are also comparatively low because a major share of the food crops is grown on subsistence farms where little inputs are used.

4. SUMMARY, CONCLUSIONS, AND POLICY IMPLICATIONS

This study delineates a model to simultaneously estimate the price response of different crops, and empirically applies the model to estimate own- and cross-price elasticities of five major crops, which cover about 70 percent of the total cropped area in Pakistan. The data used in this study for expected wholesale prices, estimated through Autoregressive Integrated Moving Average (ARIMA) model, as well as for production related to the 1957-86 period. The assumption of homogeneity of degree zero of the supply response function allowed the crop prices to be normalized with respect to fertilizer price in each equation, which helped to solve the multicollinearity problem.

Farmers are responsive to output and fertilizer prices. Short-run own-price elasticities of all the five major crops are significant, at least at the 20-percent level. A price change in one crop affects the production of other crops in all of the three possible ways: competitive, complementary, and unrelated. This suggests that a careful analysis of price change for any crop is necessary because this can not only

affect the level of production of that particular crop but also change the composition of all the other crops. This also indicates that a price policy based on the single-crop cost of production methodology and a crisis in a particular crop is faulty because it does not take into account the cross-effect on the production of other crops. Based on these cross effects, there is a need to develop a systematic and comprehensive approach on which price policy should be based, and that can reflect the government priorities for certain crops.

Food crops having relatively low own-price elasticities have little effect on the production of other crops. On the other hand, changes in the prices of cash crops, which have higher own-price elasticities, strongly affect the production of other crops. Hence, the single-crop price support in response to a production crisis in that particular crop has little potential to increase overall agricultural productivity. However, a 10-percent systematic improvement in the terms of trade for agriculture will enhance agricultural productivity by about 6 percent in the long run, which is higher compared with other studies like Tweeten (1986).

Low input-prices can improve the terms of trade for agriculture and enhance the productivity of all crops. Subsidizing the inputs may be one way to keep the input prices low. However, if the additional demand created by subsidizing an input cannot be met by enhancing input supplies, as now is the case for fertilizer and has been applicable for pesticide supplies in Pakistan, it results in artificial shortages leading to a welfare loss to the society, as well as anomalies in the distribution system. The objective of providing inputs at low prices to all farmers can also be achieved by promoting competition among private-sector input suppliers. The open-market mechanism can improve the access of each farmer to input supplies, timeliness in input availability, as well as timeliness in its application.

Technology is an important non-price factor that enhances crop production. Food crops like wheat and rice, which are of the greatest national and international concern in meeting the requirements of a rapidly increasing population, have the highest production growth rates. This implies a need to strengthen agricultural research to maintain the flow of new inputs and technologies, and develop socio-physical infrastructures to improve efficiency of the complex technologies, both of which are more difficult than ever before but necessary for sustaining the growth in productivity.

The analysis can be extended in many directions. First, it should be disaggregated for different crop-zones, as own-price and cross-price elasticities may be different for each zone. Secondly, it should be done separately for acreage and yield. Thirdly, other crops, like oilseeds, fodder, fruits, vegetables, and pulses, should also be included in the analysis. This is possible only at a disaggregated level because, as noted earlier, a crop with only a small share in a bigger system does not affect the output of the major crop. Fourthly, the supply analysis for rice crop

should be segregated for the coarse and fine varieties of rice.

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