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SUPPLY RESPONSE OF MAJOR CROPS IN PAKISTAN: A SIMULTANEOUS EQUATION APPROACH

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EXECUTIVE SUMMARY

This study estimates the own- and cross-price elasticities of five major crops (i.e. wheat, cotton, rice, sugarcane and maize) in Pakistan. Invoking the simultaneous supply relationship among crops, Zellner's Seemingly Unrelated Regression Method (SUR) is applied to estimate the supply response for each crop. The assumption of homogeniety of degree zero of the supply response function allowed the normalization of crops prices with respect to fertilizer price in each equation.

The Autoregressive Integrated Moving Average (ARIMA) model was applied to estimate the expected normalized price series of each crop. The expected normalized prices were used to estimate the supply response functions from which short- and long-run own-, cross- and fertilizer-price elasticities were estimated.

Farmers are responsive to output and fertilizer price changes and they adjust their resources in different crops accordingly. Short-run own-price and fertilizer price elasticities of all the five major crops are significant, at least at the 20 percent significance level.

The price support has little potential to increase overall agricultural productivity. The food crops like wheat and maize have low own-price elasticities, although price support in these crops will have a little effect on the production of other crops (because low cross-price elasticities with respect to food-crop prices). On the other hand, cash crops like cotton and rice have relatively high own-price elasticities, but price changes of these crops will have very strong negative effect on the production of other crops (because of high cross-price elasticities with respect to cash-crop prices).

However, input prices are the exception. Fertilizer price affects the production of all the crops. The effect is relatively stronger in cash crops compared to the food crops. Therefore, a policy to improve the market efficiency that can provide inputs at low prices to all the farmers will enhance productivity of all the crops. Deregulation rather than subsidy is considered to be a better choice to this end.

Technology is an important non-price factor affecting the crop production. Per annum growth rate in the production of food crops having greatest national and international concern to meat the rapidly increasing population requirements like wheat and rice is highest (by almost 5%). Cotton and sugarcane also have an impressive growth rate of 4% during last 29 years. This emphasises to strengthen the agriculture research and other infrastructures so that a flow of new inputs and technologies can be maintained.

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1 INTRODUCTION

The response of farm production to expected commodity prices is a key relationship in agriculture policy development. Both the level and composition of production are major objectives of economic policies. The agricultural supply relationship is the result of the decisions of a large number of farmers working under different environments with different motivations. Therefore, a sound policy designed to obtain a desired level and composition of production rests on a thorough understanding of: (a) how farmers decide what and how much to produce, (b) what policy instruments and other factors affect their decisions to produce a particular commodity, and (c) how the decision to produce one commodity affects the production levels of other commodities. These questions are the issues to be addressed in this report.

In the context of the whole farm enterprise mix, a decision to produce one crop affects other crops in three ways. Firstly, different crops may demand the same resources at the same time; thus 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 the same resources are required but at different times of the year. Thirdly, 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 among crops may be competitive, complementary, or independent of each other. This paper studies the nature of these crop production relationships by simultaneously estimating the supply response of major crops (i.e. wheat, cotton, rice, sugarcane and maize) in Pakistan.

A study on supply response of the major crops using a simultaneous system approach can improve the reliability of supply parameters which are the foundation for most agricultural policy analysis. Once the direction and magnitude of interactions among crops and the factors influencing supply are determined, planners can more easily assess the effect of price policy on output. The estimated parameters of supply response are particularly useful in welfare analysis to estimate the effects of alternative price policy options on producers.

In the next section, the literature on supply response in general, and estimates on supply response for Pakistan in particular, are reviewed. The third section develops a theoretical framework for a simultaneous supply response model and a price expectation model. The fourth section describes and interprets the results of the price expectation model and the results of estimation of short- and long-run supply response of the major crops. Section five summarizes the results. The last section discusses the implications of the results for agricultural policy formulation.

2. REVIEW OF LITERATURE

An empirical review of supply response studies for many countries is found in Askari and Cummings (1977) and Henneberry (1986). All the studies reviewed have estimated the supply response of each crop in isolation from other crops.

In Pakistan, likewise, there have been some efforts to estimate single crop supply response. The results of these studies are given in Table 2.1. Average short-run own-price elasticities of supply of wheat, rice, cotton, sugarcane and maize are estimated to be 0.17, 0.21, 0.28, 0.41 and 0.15, repectively. Few estimates are available for cross-price elasticities.

Tweeten (1986) conducted the first study reporting a full system of own- and cross-price elasticities of supply for four major crops and for livestock in Pakistan. He first estimated the own-price elasticity of each crop and then used these estimates to calculate cross-price elasticities applying the factor share approach. His short- and long-run cross-price elasticities were mostly very small (the highest short-run cross-price elasticity of supply was -0.043 and the highest long-run -0.114).

3. THEORETICAL MODEL

3.1. Supply Response Model

In general, in a system of (m) crops, the supply response of i-th crop can be assumed as a function of own output price, prices of all the competing or complementary crops, and prices of inputs and technology used in crop (i). That is:

$$Y^{*}_{it} = f(P^{*}_{it}, P^{*}_{jt}, P^{*}_{nt}, T_i) \qquad [1]$$

where,

$i \neq j = 1,2,3 \ldots m-1$ = all other crops excluding crop(i);

m = number of crops in (m) system of simultaneous equations.

$n = 1,2,3 \ldots g$ = inputs;

Y^{*}_{it} is desired production of crop (i) in period (t);

P^{*}_{it} is expected own-output price in period (t);

P^{*}_{jt} is expected price of j-th outputs in period (t);

P^{*}_{nt} is expected price of n-th input in period (t); and

T is trend variable to serve as a proxy for technology[1];

Table 2.1. Short-run Own- and Cross-Price Elasticities Estimated/Calculated By Other Studies

REFERENCE	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	---	0.40	---	---	---	---
	Cotton Yield	---	n.s	---	---	---	---
Cummings (1975)	Output						
	i) Wheat	0.1(ns)	---	---	---	---	---
	ii) Cotton	---	0.40	---	---	---	---
	iii) Rice	---	---	0.12	---	---	---
Hamid et. al., (1987)	Acreage						
	i) Wheat	0.09	---	---	---	---	-0.09
	Yield						
	i) Wheat	0.34	-0.03	---	---	---	---
Ahmad et. al., (1983)	Acreage						
	i) Wheat	0.10	---	---	---	---	---
	ii) Rice	---	---	0.160	---	---	---
	iii) Sugarcane	---	-0.11	---	0.41	---	---
	iv) Cotton	---	0.15	---	-0.26	---	---
	Output						
	i) Wheat	0.28	---	---	---	---	---
	ii) Rice	---	---	---	---	---	---
	iii) Sugarcane	---	---	---	0.70	---	-0.57
	iv) Cotton	---	0.38	---	---	---	-0.53
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)	Acreage						
	i) Wheat	ns	---	---	---	---	---
	ii) Cotton	---	0.055	---	---	---	---
	iii) Rice	---	---	0.342	---	---	---
	iv) Sugarcane	---	---	---	0.242	---	---
	v) Maize	---	---	---	---	0.148	---
AVERAGE OWN PRICE ELASTICITY		0.17	0.28	0.21	0.41	0.15	

(i) = Irrigated, (b) = Barani

* Mean of the significant coefficients for different regions of Punjab

Supply response estimated in this study is specified as follows:

$$Y^{*}_{it} = A_i \; P^{*}_{it}{}^{(C_{ii})} \prod_{i \neq j=1}^{m-1} P^{*}_{jt}{}^{(C_{ij})} \, P^{*}_{nt}{}^{(C_{in})} \, e^{(D_i)T} e^{U_i} \qquad [2]$$

where,

A_i is the intercept;
C_{ii}, C_{ij}, are long-run own- and cross-price supply elasticities, respectively;
C_{in} is long-run fertilizer-price elasticity;
D_i is long-run growth rate in productivity due to improvement in technology;
e is the natural logarithm base, 2.7;
U_i is the random error term; and
all the other variables are as in [1].

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, negative if substitutes, and zero if independent.

Equation [2] is not measurable because the dependent variable, the desired level of production, is unobservable. However, the actual value of production can be used in place of the desired value of production if the Nerlovian adjustment process is assumed. Due to technological rigidities in production, this process assumes that the farmers may not be able to fully adjust their production according to their desires. However, farmers may be able to change crop production in any year (Y_{it}) only to the extent of a fraction of the difference between the production they would like to achieve (Y^{*}_{it}) and the actual production in the preceding year (Y_{t-1}) (Nerlove, 1958). That is:

$$Y_{it}/Y_{it-1} = (Y^{*}_{it}/Y_{it-1})^{B_i} \qquad [3]$$

where B_i is the coefficient of adjustment for crop (i). Substituting the values of Y^{*}_{it} from [3] into [2] will give:

$$Y_{it} = A_i \; P^{*}_{it}{}^{(B_i \cdot C_{ii})} \prod_{i \neq j=1}^{m-1} P^{*}_{jt}{}^{(B_i \cdot C_{ij})} \, P^{*}_{nt}{}^{(B_i \cdot C_{in})} \, Y_{it-1}^{(1-B_i)} \, e^{(B_i \cdot D_i \cdot T_i)} \, e^{U_i} \qquad [4]$$

In log (Ln) linear form [4] can be expressed as:

$$LnY_{it} = LnA^{*}_i + C^{*}_{ii}LnP^{*}_{it} + \sum_{i \neq j=1}^{m-1} C^{*}_{ij}LnP^{*}_{jt} + C^{*}_{in}LnP^{*}_{nt} + (1-B_i)LnY_{it-1} + D^{*}_i T_i + U_i \qquad [5]$$

where,

$C^{*}_{ii} = C_{ii} \; B_i$ = short run own-price elasticity;
$C^{*}_{ij} = C_{ij} \; B_i$ = short run cross-price elasticity;
$C^{*}_{in} = C_{in} \; B_i$ = short run fertilizer-price elasticity;
$D^{*}_i = D_i \; B_i$ = short-run growth rate of crop (i) due to improvement in technology

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 (that increasing the prices of all the crops and inputs with the same proportion does not affect the output), one price can be deleted from each equation, using that price to normalize other prices. Any price can be used as denominator. In this study the fertilizer price in each equation was used to normalize the other prices. Thus [5] becomes:

$$LnY_{it} = LnA_i^{\bullet} + C_{ii}^{\bullet} Ln(P_{it}^{\bullet}/P_{nt}^{\bullet}) + \sum_{i \neq j=1}^{m-1} C_{ij}^{\bullet} Ln(P_{jt}^{\bullet}/P_{nt}^{\bullet}) + (1-B_i) LnY_{it-1} + D_i T + U_i \qquad [6]$$

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

Until recently, the i-th crop was treated as independent of the j-th crop. However, there are reasons to believe that each crop has a contemporaneous relationship with other crops. Firstly, mistakes in the production decision of one crop affect other crops, in the whole farm context. Assume farmers mistake to produce more wheat than the above relationship dictates. This may leave very little resources for competing crops and more resources for complementary crops. Thus, deviation from the specified relationship in one crop in one year leads to deviations in other crops also. Secondly, there are some missing variables common to all the equations; weather is one of them. This omission may also cause the contemporaneous relationship of the error term across equations. For example, heavy rains in July-August adversely affect flower setting in cotton, while they are good for rice cultivation. Therefore, the error term in each crop equation is assumed to be contemporaneously correlated but independent over time. This can be written as:

$$E(U_{it}\ U_{jt}) = Z_{ijt}.I \qquad i \neq j = 1,2,3,4,5 = \text{Crops} \qquad [7]$$

$$E(U_{it}\ U_{jt}) = Z_{ijt} \qquad \text{if} \quad t = t$$

$$= 0 \qquad \text{if} \quad t \neq t$$

where,

Z is the covariance matrix of the error term between crop i and j, I is the identity matrix of order (m x m) and (n) is number of observations;

U_{it} and U_{jt} are the error term in i-th and j-th crop, respectively in period (t).

Zellner (1962) called a system of equations having an error structure as in [7] a "seemingly unrelated regression" (SUR) model and suggested the joint estimation of the parameters by GLS using the following relationship (Pindyck and Rubinfeld, 1976).

$$C = [X'(Z)^{-1}X]^{-1}[X'(Z)^{-1}Y] \qquad [8]$$

where,

C is the ($\sum_{i}^{m} k_i$ x 1) order matrix of coefficients to be estimated (k_i is the number of independent variables in each crop); (m is the number of equations or crops).

$X = X_i.I = X_i$ is the data matrix of independent variables of of crop (i). X_i is of order (n x k_i), I is of order (m x m);

Y is a data vector of the dependent variable (production) of the order (nm x 1); and

Z is the inverse of the variance-covariance matrix of the order (mn x mn) Z is estimated from the residuals of OLS estimates of each equation.

Two important points have to be noted when estimating the systems of equations in [6] using the formulation in [8]: (a) the possibility of serial correlation in time series data; (b) the fact that 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 the large samples. Durbin-Watson statistics for serial autocorrelation are also biased: 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 a comparatively large data set (29 years in this study) helped to minimize the asymptotic bias of the estimates (Narayana and Shah, 1984).

Malinvaud (1966) showed the bias in Durbin-Watson statistics to test autocorrelation when a lagged dependent variable is present on the right hand side of the equation. In response, Durbin (1970) developed a statistic to test autocorrelation in this situation which is[3]:

$$h = r \sqrt{n / (1 - n.\ V(b))} \qquad [9]$$

where,

r = 1 - (0.5).(Conventional Durbin-Watson statistic);

n = Number of observations. This statistic is appropriate for samples having more than 30 observations. In this study, the sample is fairly large because it uses the 1957-86 time series;

V(b) = Variance of the lagged dependent variable coefficient

The h statistic has a standard normal distribution. If h > 1.645, the hypothesis of zero autocorrelation would be rejected at 5 percent.

The statistical package "Regression Analysis on Time Series" (RATS) was employed to estimate the coefficients in the systems of equations [6] using the formulation in [8]. Serial autocorrelation was tested using [9].

3.2. Crop Price Expectation Model

The system of equations in [6] expressed the production relationship in terms of expected prices. The expected prices can be estimated by taking weighted average of the previous years' prices, with equal or declining weights to each year. Tweeten (1986), for example, used declining weights, for the previous three years' prices to calculate expected prices of the present year. The main problem of attaching weights in this way is that it does not isolate the stationary and random effects. Secondly, in most cases, the weights are assigned without any empirical basis. The decision rule about expectation is, therefore, heavily based on the researchers' subjective assessment.

Almon Lag procedure can also used to estimate the effect of past prices (or investment) on production with certain assumptions on the type of effect. For example, Braha and Tweeten (1986) used the Almon lag procedure to estimate the effect of previous research and education investment on production, assuming the effect first increases from zero and then it declines to zero. This procedure leads to other statistical problems like multicollinearity because of many price variables in the estimating equation.

The Nerlovian adaptive expectation model, as cited in literature, has been used very often to estimate the effects of past prices on production. This model is based on the hypothesis that the current year's expected prices are revised in proportion to the difference between actual and expected prices of the previous year. Narayana and Parikh (1981) proved that the model attached the same weights to the previous expected price and random disturbance in each period, and hence was not a meaningful expectation function. The presence of a secular trend in a variable can also lead to a result where the expectation coefficient would exceed one.

If expectation reflects a secular trend in a variable, it seems reasonable to assume that farmers observe the level of the variable over time and are also aware of any random shocks (which may be of a short-term nature) to which the variable has been subjected. The future expected value of the variable should adequately account for this long-run trend and occasional random shocks. Autoregressive Integrated Moving Average (ARIMA) model was applied in this study to estimate the expected price of a crop because it has the flexibility to forecast the value of a variable by being able to identify separately the stationary and random components of each of its past values. The ARIMA process for a time series, P_t, can generally be written as (Narayana and Shah, 1984):

$$r(B)E^dP_t = a + v(B)w_t \qquad [10]$$

Where,

- d = the degree of difference applied to the original time series;
- E = the differencing operator, i.e. $E\,P_t = P_t - P_{t-1}$, and $E^2P_t = E(EP_t) = EP_t - EP_{t-1}$ and so on;
- B = the backward-shift operator, i.e. $B^nP_t = P_{t-n}$;
- $r(B)$ = $1 - r_1B^1 - r_2B^2 - r_3B^3 \ldots r_pB^p$, i.e. p is the order of autoregressive process;
- $v(B)$ = $1 - v_1B_1 - v_2B^2 - v_3B^3 \ldots v_q\,B^q$, i.e. q is the order of moving average process;
- r_i, v_i = parameters to be estimated for autoregressive and moving average, respectively;
- w_t = white noise or random error; and
- a = a constant determining the level of the time series process.

The mean of the constant series (u) is given as: (Pindyck and Robinfeld, 1978, P: 520)

$$u = \frac{a}{1 - r_1 - r_2 \ldots r_p} \qquad [11]$$

If a given series is stationary, the mean fluctuates randomly about a constant mean; this means that the stochastic process remains invariant over time. If the time series is not stationary, it does not have a natural mean. Some nonstationary series can be converted into stationary series by applying an appropriate degree of difference (d) to the original series.

If the original price series of a crop shows a secular trend, which may be judged from the rate at which the autocorrelation function declines (Pindyck and Robinfeld 1978, 504), then an appropriate difference of the series is taken. After making this adjustment, different ARIMA schemes were tried using the following formulation (Hall and Lilien, 1986):

$$P_t^d = u + v_1w_{t-1} + v_2\,w_{t-2} + \ldots + v_qw_{t-q} + r_1P_{t-1}^d + r_2\,P_{t-2}^d + \ldots + r_p\,P_{t-p}^d \qquad [12]$$

where P_t^d is the price in period (t) after taking appropriate difference of degree (d). Other variables are as defined in [10].

Best schemes were selected based on the following diagnostic checking; (a) observing the statistical properties of the coefficients, and (b) conducting a Chi-square Box and Pierce (1970) test based on the residual autocorrelations, and (c) comparing the forecast values of different schemes.

4. EMPIRICAL ESTIMATION

4.1. Estimates of Crop Price Expectation Functions

The ARIMA model, used to estimate predicted prices, applies three tools in estimating the predicted prices: (i) degree of differencing (d); (ii) autoregressive (AR) process of order (p)-- AR(p) means that p-order autoregression is used; and (iii) moving average (MA) process of order (q)-- MA(q) means that moving average of q-order is applied, whereas (p,q,d) implies that p-order autoregression, q-order moving average, and d-degree of differencing, are applied to the series.

To see if a normalized price series contained drifting effect (that is, the series is non-stationary, originally), the auto-correlation properties of the series were analyzed. This phase is called identification. The autocorrelation function for each normalized price series declined as the number of lags became large, implying that there was no drifting effect in any series and each series was stationary. Therefore, the original series, without any difference, was used for prediction. Different AR and MA schemes were tried for each normalized price series using the Time Series Processor (TSP) program. A best model for each series was selected based on R^2 value and significance level of each autoregressive and moving average parameter.

The results of the final model are presented in Table 4.1. Each coefficient of the final model for each normalized crop price series was significant at least at the 20 percent level.

The diagnostic test, Chi-square, was applied. The probability of the residual to be non-white or non-random was less than 1 percent in each case. Therefore, the hypothesis that the residual of the expected price model is white-noise or random was not rejected with 99 percent confidence. Moreover, the standard error of the error term for the selected model was lower than for any other model. This establishes the validity of each estimated model.

Significance of MA coefficients implied that present year's normalized prices depend upon the shocks in previous years' normalized prices. Different MA coefficients of different order were significant in each normalized price series, meaning that different lags in price-shocks effect the present year's expected prices in each case.

The coefficient of AR(1) was significant in each model implying that previous years' 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 price series to be stationary.

The expected versus actual normalized prices of the major crops,

Table 4.1. ARIMA Process Schemes and Results of Price Expectation Function Estimation for 1957-19

Prices of	Predicted Schemes (p,q,d)[a]	r1	v3	v4	v5	v6	v7	u	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) is the p-order of autoregressive, q-order of moving average and d-degree of difference.
(b) Based on the residual autocorrelation of the final model. The table value of Chi-square with 24 degree of freedom at 99% confidence interval is 10.86.
ri is autoregressive coefficient;
vi is moving average coefficient;and
u is constant around which the series fluctuates.

are shown in Figure 4.1. The expected prices were close to and able to track the turns in the actual prices in each case.

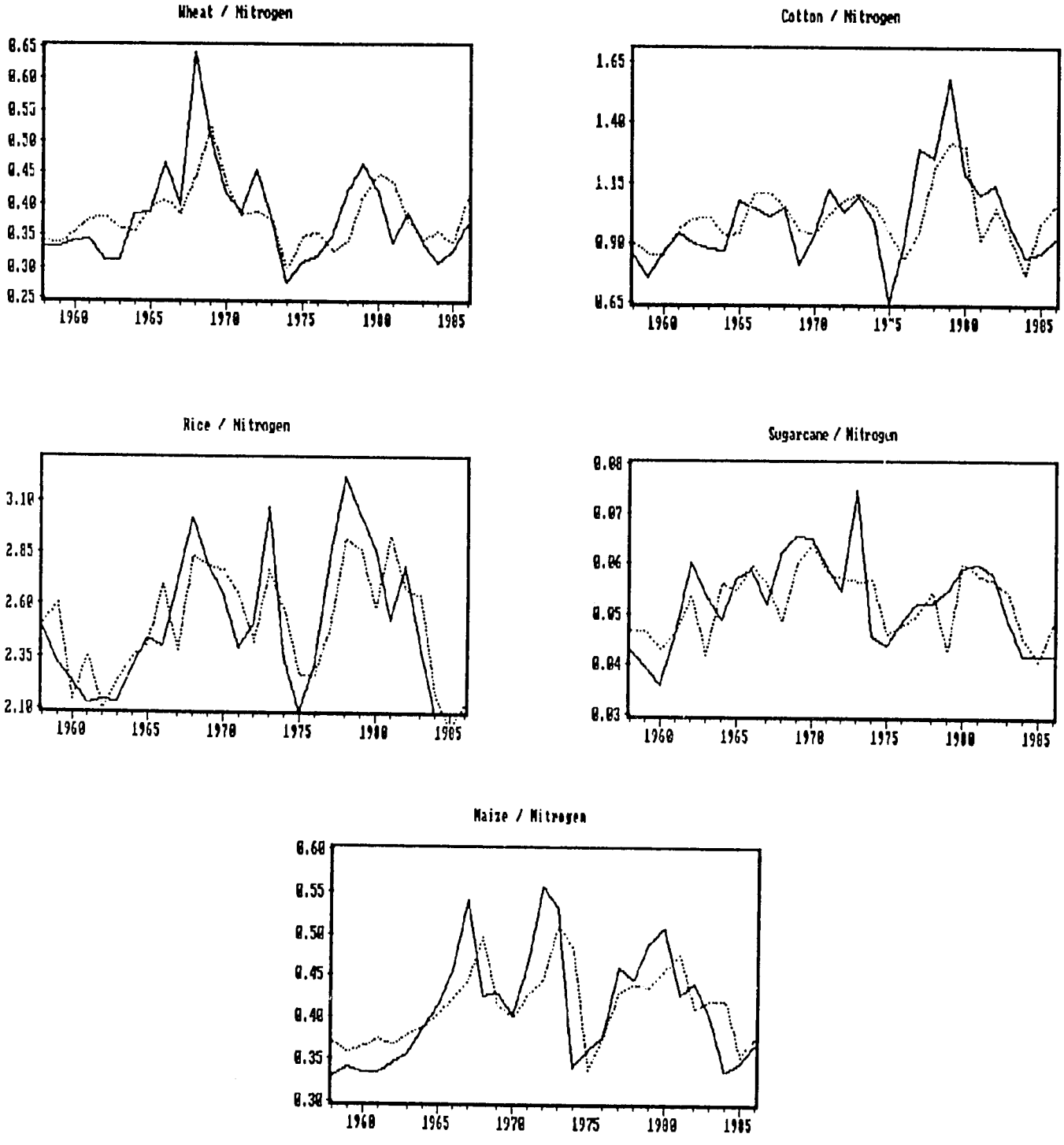
4.2. Estimates of Supply Response Functions

The supply response functions for the five major crops as expressed in [6] were estimated using formulation in [8]. Equation [6] is elaborated for each crop in Appendix A-1. Time series data for the period of 1957-86 are used in this analysis. The data on production and prices, except for maize and for the last two years, are basically, the same as in Tweeten's (1985) study. The prices are the wholesale prices. The sources of data are published and unpublished data of the agriculture Livestock Marketing Advisor, Ministry of Food, Agriculture and Cooperatives, and data supplied by Tweeten to the author. Production and price data used in this analysis are shown in Appendix A-2.

The use of expected normalized prices rather than real prices as regressors in estimating equation [6] reduced the multicollinearity among prices. The simple correlation were higher than 0.96 among all actual crop prices while correlation were less than 0.66 among all expected normalized prices.

The estimated model using the SUR procedure in [8] is given in Table 4.2. These results are much improved compared to the OLS results (not reported here) in terms of the standard errors of the coefficients. The hypothesis of zero serial autocorrelation is tested using the h statistic [9]. The calculated values of the statistic are less than 1.6475 in every case, implying that the hypothesis of zero autocorrelation cannot be rejected at 5 percent level.

Fig 4.1 Actual Vs Predicted Normalized Prices



_____ Actual ..... Predicted

Table 4.2. Estimated Parameters of the Supply Response Functions of Five Major Crops in Pakistan

Production of	Intercept	Normalized prices of: Wheat	Cotton	Rice	Sugarcane	Maize	Fertilizer	Lag Coefficient	Trend Coefficient	R2	Durbin Watson	h
Wheat	5.61 **** (1.259)	0.228 ** (0.139)	-0.151 * (0.149)	0.173 * (0.180)	-0.026 ns (0.127)	0.004 ns (0.232)	a	0.304 *** (0.147)	0.035 **** (0.008)	.95	1.95	0.22
Cotton	4.5 **** (1.697)	0.225 ns (0.273)	0.715 *** (0.302)	-0.329 * (0.360)	0.053 ns (0.240)	-0.206 ns (0.456)	a	0.466 **** (0.168)	0.02 **** (0.007)	.76	2.14	-0.86
Rice	1.384 ** (0.889)	0.136 * (0.112)	-0.098 * (0.103)	0.407 **** (0.151)	0.063 ns (0.101)	-0.084 * (0.077)	a	0.788 **** (0.116)	0.01 ** (0.007)	.97	2.02	-0.08
Sugarcane	7.445 **** (1.086)	0.003 ns (0.148)	-0.149 * (0.153)	0.162 ns (0.197)	0.524 **** (0.131)	-0.112 ns (0.239)	a	0.353 **** (0.101)	0.023 **** (0.005)	.91	1.76	0.79
Maize	5.973 **** (0.918)	0.056 ns (0.094)	-0.207 *** (0.099)	0.058 ns (0.124)	-0.095 * (0.08)	0.359 *** (0.147)	a	0.024 ns (0.146)	0.03 **** (0.005)	.95	2.16	-0.68

****, ***, **, * significant at 1, 5%, 10%, 20% levels.

Figures in parentheses are standard error of the coefficients.

ns = not significant at least at 20% level of significance.

(a) Fertilizer price elasticity in an equation was not directly estimated.

4.2.1. Short-Run Elasticities

The short-run own- and cross-price supply elasticity matrix is presented in Table 4.3. The coefficients of Tables 4.2 and 4.3 are the same except that Table 4.3 also includes the estimates of fertilizer-price elasticities. Fertilizer-price elasticity in each crop was calculated as the negative of the sum of all the coefficients for price ratios. Only those coefficients significant at 20 percent or better, using the one tail test, are reported in Table 4.3 and are used in the calculation of fertilizer-price elasticity.

The short-run fertilizer-price elasticities are highest for cash crops such as cotton, followed by sugarcane and rice, and lowest in food crops such as wheat. Maize is not responsive to fertilizer price.

All own-price elasticities are highly significant except in case of wheat, which is significant at 20 percent. The relatively insignificant and small own-price elasticity of wheat, which is in line with other studies reviewed earlier, may be caused by few alternatives available to the farmers in Rabi season.

The own-price elasticity in each case is higher than the absolute value of fertilizer-price elasticity except in wheat where both are almost equal. This implies that the advantage in terms of output increase of only one crop (cross effects are not included), through a 10 percent increase in the output price (price support policy), will be greater or at least equal to the benefit resulting from a 10 percent decrease in the fertilizer price (input subsidy policy).

However, if we consider the benefit of price support versus input subsidy in the whole farm context, the result will be different. An increase in fertilizer price affects the output of all crops and to counterbalance this effect, the prices of all the crops need to be increased. As the sum of fertilizer price elasticities for all the crops is more, in absolute value, than the individual own-price elasticity of every crop, therefore input subsidy is a better choice than price support in only one crop. For example, a 10 percent decrease in fertilizer price will bring a 13.7 percent (0.248+ 0.386+0.361+0.375) increase in total agricultural production while an equal increase in one of the output-prices, say cotton, will increase its production by only 7.2 percent. Some of the increase in output due to individual crop price supports will be defeated due to cross-price elasticities. However, if price support increases the prices of all the crops, it will improve the terms of trade of agriculture versus industry and decrease the relative prices of inputs. This will have the same favorable impact on the production of agricultural output as subsidizing inputs.

Table 4.3. Short-Run Supply Elasticities of Five Major Crops in Pakistan (a)

Crop	Supply Elasticity With Respect to Price: Wheat	Cotton	Rice	Sugarcane	Maize	Fertilizer	Trend coefficient
Wheat	0.228 * (0.139)	-0.151 * (0.149)	0.173 * (0.180)	0	0	-0.250 * (0.272)	0.035 **** (0.008)
Cotton	0	0.715 *** (0.302)	-0.329 * (0.360)	0	0	-0.386 * (0.446)	0.02 **** (0.168)
Rice	0.136 * (0.112)	-0.098 * (0.103)	0.407 *** (0.151)	0	-0.084 * (0.077)	-0.361 ** (0.228)	0.01 ** (0.007)
Sugarcane	0	-0.149 * (0.153)	0	0.524 **** (0.131)	0	-0.375 ** (0.201)	0.023 **** (0.005)
Maize	0	-0.207 *** (0.099)	0	-0.095 * (0.08)	0.359 *** (0.147)	0	0.03 **** (0.005)

****, ***, **, * significant at 1%, 5%, 10%, 20% levels.

Figures in parentheses are standard error of the coefficients.

ns = not significant at least at 20% level of significance.

(a) Fertilizer price elasticity in an equation was not directly estimated. It is the negative of of the sum of all the significant cross-and own-price elasticities in an equation. The standard error of the input price elasticity was calculated as the square-root of the sum of the variance of all the significant cross-and own-price elasticity coefficients. (addition of variance rule. Madala, 1977, p. 26).

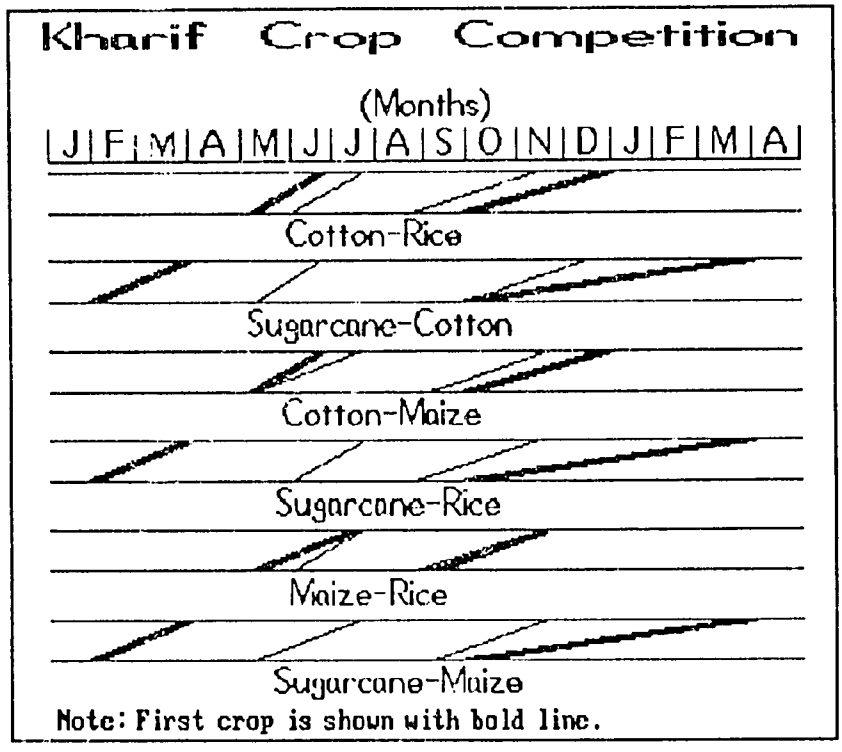
Although the direct comparison is not valid because of differences in the methodology used, short-run own-price elasticities estimated in this study are higher than the average of all the earlier studies reviewed in Section 2, Table 2.1.

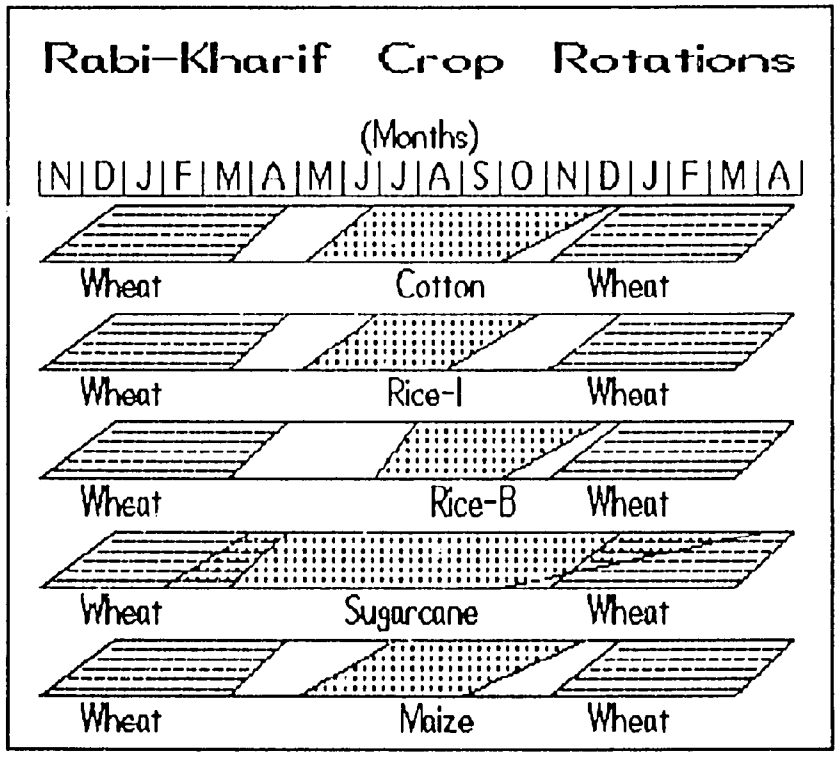
The trend coefficient is positive and significant in each crop. The coefficient for this variable estimates the effect of improvement in technology which increases the marginal productivity of various inputs like water and fertilizer and thus enhances their usage. The change in output in response to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

Before discussing cross price elasticities, two factors should be taken into account:

a) The duration for which each crop is grown. The turn around time of a crop after harvest of the previous crop is given in Figure 4.2; and

Fig. 4.2 Kharif Crop Competition and Rabi-Kharif Crop Rotation





b) If two crops are grown in the same period:

i. whether are they grown in different regions, and the ability or otherwise of these regions to expand and contract in response to price changes, and

ii. the proportion of acreage of competing crops in a given cropping zone. A dominant crop (having a large proportion of the area) is expected to affect the minor crops (having a small proportion of the area) in a given region without being affected by minor crops. For example, consider a production possibility curve PP in Figure 4.3. The slope of the price ratio between crop A and crop B is shown as YY. The optimum area under each crop will be OC (Crop A) and OE (Crop B). Clearly crop A is a dominant crop and crop B is a minor crop because a large proportion of the total area of the region is under crop A and crop B has only a minor proportion. Now if the relative price is changed in favor of crop B (ZZ), the percentage change in the area of crop B will be large (EF/OE) and significant, while percentage change in the area of crop A (DC/OC) will be very small and insignificant. The proportion of kharif crops, in the total area of a crop zone during 1984, assumed to be a normal year, are given in parentheses in Table 4.4. The vertical sum of a crop region is equal to hundred.

iii. The percentage of total area (in Pakistan) of a crop in one crop region. Assume total area of a crop in Pakistan is X. If EF area in Fig 4.3 of crop B is very small compared to its total area in Pakistan (X), then EF/X will also be very small. In this case, the countrywide effect on the area of crop B in response to the price change will not be very significant, although the change in area of crop B in proportion to the area of the crop in the crop region (EF/OE) will be significant. The percentage of total area of a crop in different crop regions is given in Table 4.4. The horizontal sum of area of a crop is equal to hundred.

In the Rabi season, wheat occupies about 70 percent of the cropped area. It is down in November-December and harvested in March-April. The only crop with which wheat cultivation time overlaps is sugarcane. Thus, there may be a possibility that wheat area competes with sugarcane. However, sugarcane is a small crop compared to wheat, in terms of area occupied by each crop. Therefore, the effect of sugarcane prices on wheat production is not significant, although the sign is negative.

Fig 4.3 Production Possibility Curve

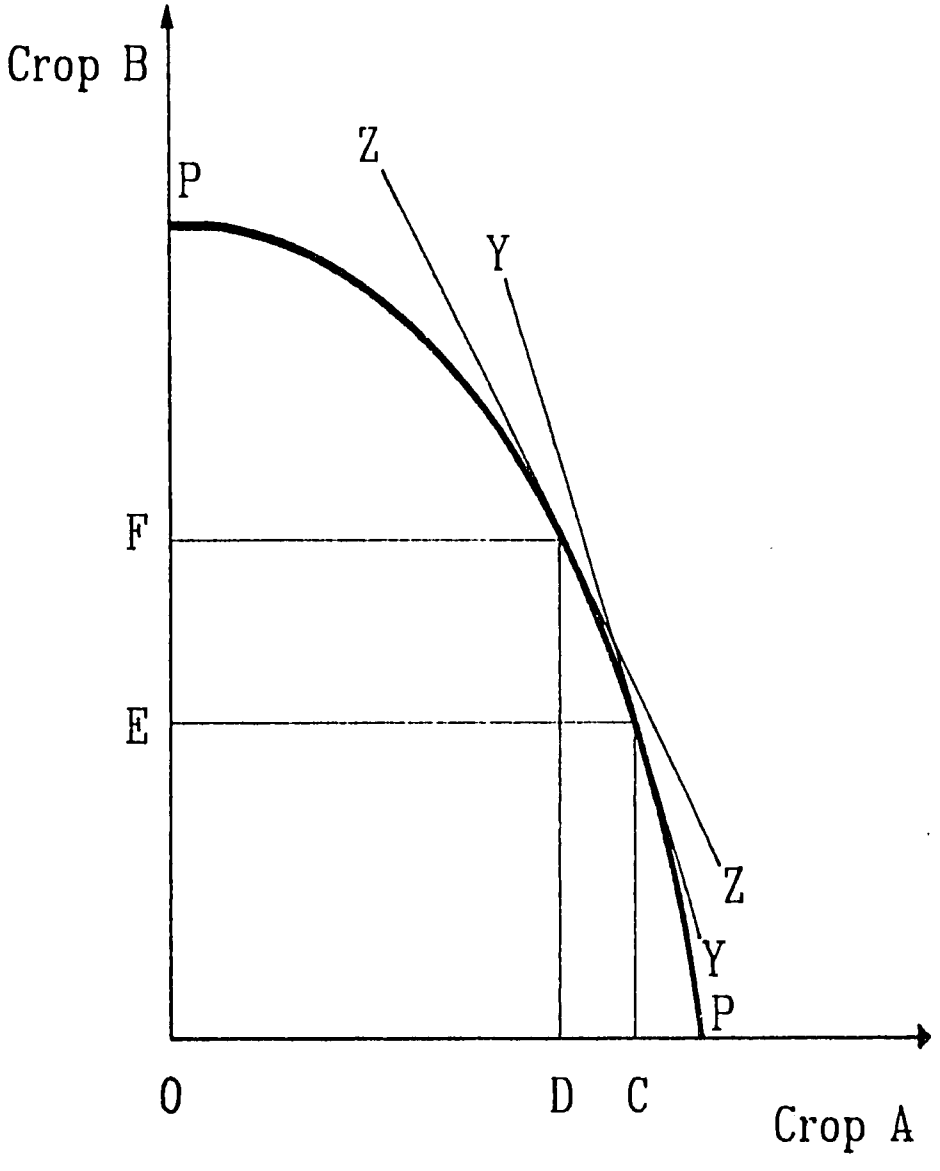


Table 4.4. Relative Acreage Share of Four Major Kharif Crops in Each Cropping Zone[a]

CROPS	% OF TOTAL AREA OF THE CROP IN THE ZONE OF				
	COTTON	RICE	SUGARCANE	MAIZE	TOTAL
COTTON	90	4	6	0	100
	(69)	(4)	(23)	(0)	
RICE	15	79	4	2	100
	(10)	(81)	(13)	(9)	
SUGARCANE	50	21	25	4	100
	(16)	(11)	(40)	(8)	
MAIZE	19	4	19	50	100
	(5)	(4)	(24)	(83)	
TOTAL	(100)	(100)	(100)	(100)	

Figures in parentheses are the relative strengths of different crops in a crop region (the vertical sum is 100). The figures without parentheses are the percentages of the total area of a crop falling in a particular region (the horizontal sum is 100).

[a]Districtshaving highest ratio of a crop acreage relative to the total area of four crops is referred as the cropping zone for that crop.

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

Wheat production is complementary to rice production because increasing the rice price also increases wheat production and vise-versa. Rice has two distinct varieties[5]: IRRI rice is a short duration variety and does not compete for resources with wheat because both are grown in different time periods. Hence, price changes of any of the two crops affect 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 preparation for wheat planting, thus affecting wheat production. The contribution of Basmati rice is only 35 percent compared to the 65 percent share of IRRI. So, in total, the IRRI effect dominates. Even in Basmati rice, only 20 percent of the area goes beyond November 21, the optimum time for wheat cultivation while the mean harvesting date is November 8. Moreover, the old long-duration Basmati variety does not seem to delay wheat cultivation because a new short-duration variety (Basmati-385) did not improve timeliness in wheat cultivation. (Sharif et. al., 1988).

There is no chance of rice being affected if it follows wheat because in this rotation there is at least two months' time available for land preparation for rice.

It is easy to demonstrate no relationship between rice and wheat production. In contrast, this 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 its cultivation helped to improve the water logged and saline soils. Thus, wheat yields improved in rice zones because of better soils due to rice cultivation. If rice comes after wheat, the income effect of rice enables farmers to use more inputs for wheat. 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 27 percent of the Kharif cropped area. 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 that explains the insignificant relationship between cotton production and wheat price.

Maize and sugarcane occupy very small percentages of cotton zone area (5 percent and 16 percent, respectively). This explains the insignificant relationship between cotton production and 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 are grown in different regions. However, these regions, to some extent, can and have been expanded or contracted according to the relative price situation of the crops.

Rice is a Kharif crop and occupies 26 percent of Kharif cropped area. It is sown in June-July and harvested in September-November. Rice production is complementary with wheat and competitive with cotton, as explained earlier. Sugarcane price does not affect rice production because only 11 percent of the rice zone area is under sugarcane while 79 percent of the area is under rice (thus sugarcane is a minor crop and rice is a dominant crop). Similarly, maize price does not affect rice production because only 4 percent of the rice-zone area is under maize production.

Sugarcane is a perennial crop and occupies 8 percent of Kharif cropped area. It is sown in February-March and harvested during November-March. Sugarcane has a competitive relationship with cotton only. The negative relationship between cotton prices and sugarcane production is because a high proportion of the total sugarcane area (50 percent) falls in the cotton zone. However, it is still a minor crop since only 16 percent of the cotton zone area is under sugarcane. Therefore, 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 most of these crops are sown in different cropping regions. The insignificant relationship between maize price and sugarcane production is difficult to explain. Though little sugarcane is grown in the maize zone (only 4 percent of the total sugarcane area is planted in maize zone), 24 percent of the sugarcane zone area is planted in maize, where the maize crop could possibly compete with sugarcane. This study is unable to assess the recent phenomenon of sugarcane substitution with rice in lower Sind. Nor was the study able to detect a significant relationship between sugarcane production and wheat price, even though they can be grown in the same geographical area and have an overlapping crop period. This may be due to sugarcane being specifically grown in mill zone areas on commercial farms. Thus, they may have been grown on separate farms having different management skills.

Maize for grain purposes is sown in May-July and harvested during September-November. Maize occupies 6 percent of Kharif cropped area. The production of maize is affected by cotton and sugarcane prices because a large proportion (19 percent) of the crop falls in each cotton and sugarcane zones. However, it is still a minor crop in cotton zones. Only 5 percent of the cotton zone area is cultivated under maize crop. Therefore, maize prices, as explained earlier, do not affect cotton production. Maize production is also not affected by the price changes of wheat and rice because it has a different crop period from wheat, and because very little maize is grown in the rice zone.

4.2.2. Long-Run Elasticities

Long-run elasticities are calculated by dividing the short-run elasticities by one minus the coefficient of lagged production (Table 4.5). The coefficients of lagged production are highly significant in all crops except maize. These coefficients are less than one, which causes long-run elasticities to exceed short-run elasticities. These results are consistent with theory. Again, long-run supply elasticities with respect to fertilizer price are highest for cash crops, i.e, rice followed by cotton and sugarcane. Wheat has a comparatively low fertilizer price elasticity of supply. Fertilizer prices do not affect maize production.

Long-run productivity growth rates, in this study, are highest in those food crops where there is strong national and international concern, to meet the requirements of rapidly increasing population, for example, wheat and rice, followed by cash crops like cotton and sugarcane. Although an international organization, CIMMYT, is working for the improvement in production technologies in maize, it failed to benefit from international breeding research. This is mainly because the crop is cross-pollinated and the seed of the new

Table 4.5. Long-Run Supply Elasticities of Five Major Crops in Pakistan (a)

Crop Production	Supply Elasticity With Respect to Price: Wheat	Cotton	Rice	Sugarcane	Maize	Fertilizer	Trend coefficient
Wheat	0.327	-0.2169	0.2485	0	0	-0.359	0.050
Cotton	0	1.3390	-0.616	0	0	-0.722	0.037
Rice	0.641	-0.4622	1.9198	0	-0.396	-1.702	0.047
Sugarcane	0	-0.2302	0	0.8098	0	-0.579	0.036
Maize	0	-0.207	0	-0.095	0.359	0	0.030

(a) Calculated as short run elasticities divided by one minus lag coefficient

high-yielding varieties gets polluted from the old low-yielding varieties after every three-four years. Therefore, in absence of a strong seed supply system in Pakistan, advantages of new varieties have not been realized.

Rice and cotton have long-run own-price elasticities greater than one implying that these crops are elastic. Own-price elasticity of sugarcane is quite high but less than one. Wheat and maize are quite inelastic crops.

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

Comparing the results of this study with Tweeten (1986), the only study with comparable results, the own-price elasticities are higher than Tweeten's elasticities. Moreover, the sign and magnitude of cross-price elasticities are different. This study shows that the relationship between crops may be complementary instead of always competitive as assumed in Tweeten's study. Moreover, most of the cross-price elasticities calculated in this study, except insignificant ones, are more than twice the cross-price elasticities in Tweeten's study.

The basic difference between the Tweeten study (1986) and this study is that the former employs a mathematical approach while this study uses a statistical approach. The advantage of this approach is that the standard error of the coefficients is known so that the significance level of each coefficient can be calculated.

4.3. Validity of the Model

The validity of the model was tested by comparing the fitted and actual values of production in each crop. The regression results of predicted production on actual production show that the intercept is not significantly different from zero and the slope is not significantly different from one in each case except for cotton (Table 4.6). In cotton, the same results are obtained if the abnormal year 1983 is deleted. This implies that predicted and actual production move in the same direction.

5. SUMMARY AND CONCLUSIONS

Estimating the own- and cross-price elasticities of supply of different crops can help policymakers to obtain the desired level and composition of agricultural commodities. This study attempts to estimate the own- and cross-price elasticities of major crops (i.e. wheat, cotton, rice, sugarcane and maize) in Pakistan, by incorporating the simultaneous supply response relationships among these crops.

The assumption of homogeneity of degree zero of the supply response function allowed the normalization of crop prices with respect to fertilizer price in each equation. Using the price ratios in the regression equation reduced the multicollinearity problem among different crop prices that might be a major detriment in estimating the own- and cross-price elasticities together.

The Autoregressive Integrated Moving Average (ARIMA) model was applied to estimate expected normalized prices which, in turn, were used in estimating the supply response of each crop. Expected prices were not only the function of trend prices but also of previous shocks in prices.

The assumption of interdependence among all the crops allowed the use of Zellner's Seemingly Unrelated Regression Method. This improved the estimated coefficients compared to the OLS procedure in terms of their standard errors.

Farmers are responsive to output and fertilizer price changes and they adjust their resources not only in a crop experiencing a price

Table 4.6. Regression Coefficient of Predicted Vs Actual Production (Both in Log Form) Of Five Major Crops in Pakistan

Commodities	Regression Coefficient of		
	Intercept	Slope	R2
Wheat	0.302 n (0.311)	0.966** (0.035) ((0.97))	0.96
Cotton	1.484 ** (0.593)	0.815** (0.074) ((2.50))	0.81
Rice	0.137 n (0.203)	0.982** (0.027) ((0.66))	0.98
Sugarcane	0.726 n (0.469)	0.927** (0.047) ((1.55))	0.93
Maize	0.246 n (0.242)	0.962** (0.037) ((1.02))	0.96

** Coefficients are significantly different from zero at 1% level of significance.

n Not significantly different from zero.

Figures in single parentheses are standard errors of the respective coefficients.

Figures in double parentheses are calculated "t" values against the hypothesis that the slope is equal to one. The critical t-value at the 10% level of significance is 1.70.

change, but also in other crops that may be grown in the area. Short-run own-price elasticities of all the five major crops are significant at least at the 20 percent significance 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 changes in any crop is necessary because this can affect the level of production of not only that one crop but may change the composition of all the crops.

Fertilizer price is a significant determinant of crop production. The long-run fertilizer price elasticities of supply are higher in cash crops like cotton, rice and sugarcane and comparatively low in case of food crops like wheat. Maize is not responsive to fertilizer price.

Production of cash crops like cotton and rice is quite elastic in the long-run, with long-run own-price elasticities greater than one. Sugarcane is also a very sensitive crop with respect to its own price, but long-run own-price elasticity is less than one, implying that a 1 percent change in sugarcane output price will bring a less than 1 percent change in its output. Food crops like maize and wheat are quite inelastic because a 10 percent change in output price of each crop will bring a corresponding change of only 3.3 percent and 3.6 percent, respectively, in their outputs.

Cross-price elasticities depend upon the turn-around time of a crop after the harvest of the previous crop, relative acreage share of a crop in a cropping zone, and percentage of the total area of a crop in other zones. Wheat price does not affect the production of any other crops in a competitive way. Rice production has a complementary relationship with wheat prices. Maize price also does not affect any other production except rice. So food crops having relatively low own-price elasticities also have little effect on the production of other crops.

On the other hand, cash crops have higher own-price elasticities but the price changes of these crops strongly affect the production of other crops. Cotton and rice have the highest own-price elasticities and price changes of these crops have the strongest effect on the production of other crops. Cotton price strongly and negatively affects the production of wheat, sugarcane, and maize while rice price affects cotton production negatively. Sugarcane price affects maize production.

Technology is an important non-price factor affecting crop production. Per annum growth rates in the production of food crops like wheat and rice are highest: 5 percent and 4.7 percent respectively. Cotton and sugarcane production increased by 3.7 percent and 3.6 percent, respectively, and maize production by almost 3 percent per annum during the last 29 years.

6. POLICY IMPLICATIONS

Cash crops are relatively more responsive to the own-price changes than food crops. Hence there is relatively more potential to increase the production of cash crops by increasing their prices than in the case of food crops. However, the price changes of these crops strongly affect the production of other crops due to high negative cross-price elasticities. So, a price support for one cash crop may hurt the output of other crops. Food crops have very low own-price elasticities, hence there is little potential to increase output by manipulating their prices and this will have little effect on the production of other crops.

Fertilizer prices have a significant effect on production, especially of cash crops. Low fertilizer prices stimulate production of all the crops. If the same objective is to be achieved through price support, prices of all the crops need to be increased. This clearly provides an option to increase production through low input prices or relatively sharp increases in input supplies, rather than price supports which can invoke a lot of criticism from the consumer's side apart from their cross-effects on other crops. Subsidies on inputs may be one way to keep input prices low. However, a subsidy creates inefficiency, resulting in welfare loss to the society, as well as anomalies in the system. The objective of providing inputs at low prices to all farmers can also be achieved, at no society cost, by promoting competition among private sector input suppliers, which will reduce the effective input prices. Clear evidence of the success of the privatization policy is the bumper cotton crop after deregulating the pesticide market. Although pesticide prices apparently increased after deregulation, open market competition removed the bureaucratic anomalies which restricted the supply of pesticides to only a few farmers at a low price, but to all other farmers at higher effective prices. The open market mechanism also improved the access of each farmer to input supplies, and his recognition of the importance of timeliness in input application.

Technology is an important non-price factor affecting crop production. Technology increased wheat and rice production by almost 5 percent per annum during 1957-86. Cotton and sugarcane production increased by 4 percent and maize production by 3 percent per annum. This implies a need to strengthen agriculture research and other infrastructures so that the flow of new inputs and technologies can continue to maintain the growth in productivity. Moreover, there is a need for economic analysis of technological change.

The analysis can be extended in many directions. Firstly, it should be disaggregated for different cropping zones. Own- and cross-price elasticities may be different in different cropping zones. 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 system does not affect the output of the major crop. Fourthly, the analysis of rice should be disaggregated into coarse and fine rice.

To estimate a more precise supply response both on national and regional levels, statistics on production and prices should be improved. Currently, there is no appropriate arrangement to collect farm-level prices. Supply elasticities will be more realistic if farmgate, rather than wholesale, prices are used in estimation.

NOTES

1. Ideally, 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.

2. Expanding [6] will give:

$$LnY_{it} = LnA_i^{*} + C_{ii}^{*}Ln(P_{it}^{*}) - \sum_{i \neq j=1}^{m-1} C_{ij}^{*}Ln(P_{jt}^{*}) + \sum_{i \neq j=1}^{m-1} C_{ij}^{*}Ln(P_{nt}^{*}) -$$

$$C_{ii}^{*}Ln(P_{nt}^{*}) + (1-B_i)LnY_{it-1} + D_i^{*}T + U_i$$

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

3. The small sample properties of the statistics are unknown. However, this study uses almost a large data set (29 observations). The statistics collapse if n. V(b) > 1. This was not the case in any of the crop tests.

4. The Rabi season is from October to March.

5. Ideally, IRRI and Basmati should be treated separately. Non-availability of variety-wise data since 1957 has prevented this specification.

6. Kharif season is from April to September.

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APPENDIX-1

SUPPLY RESPONSE EQUATIONS FOR EACH CROP

Supply response equation [6] can be elaborated for each crop as follows:

$$LnY_w = LnA^{\bullet} + A^{\bullet}_{ww}Ln(P^{\bullet}_w/P^{\bullet}_n) + A^{\bullet}_{wc}Ln(P^{\bullet}_c/P^{\bullet}_n) + A^{\bullet}_{wr}Ln(P^{\bullet}_r/P^{\bullet}_n) + A^{\bullet}_{ws}Ln(P^{\bullet}_s/P^{\bullet}_n) + A^{\bullet}_{wm}Ln(P^{\bullet}_m/P^{\bullet}_n) + (1-B_w)LnY_{wt-1} + C^{\bullet}_wT + U_w \quad [W]$$

$$LnY_c = LnA^{\bullet} + A^{\bullet}_{cw}Ln(P^{\bullet}_w/P^{\bullet}_n) + A^{\bullet}_{cc}Ln(P^{\bullet}_c/P^{\bullet}_n) + A^{\bullet}_{cr}Ln(P^{\bullet}_r/P^{\bullet}_n) + A^{\bullet}_{cs}Ln(P^{\bullet}_s/P^{\bullet}_n) + A^{\bullet}_{cm}Ln(P^{\bullet}_m/P^{\bullet}_n) + (1-B_c)LnY_{ct-1} + C^{\bullet}_cT + U_c \quad [C]$$

$$LnY_r = LnA^{\bullet} + A^{\bullet}_{rw}Ln(P^{\bullet}_w/P^{\bullet}_n) + A^{\bullet}_{rc}Ln(P^{\bullet}_c/P^{\bullet}_n) + A^{\bullet}_{rr}Ln(P^{\bullet}_r/P^{\bullet}_n) + A^{\bullet}_{rs}Ln(P^{\bullet}_s/P^{\bullet}_n) + A^{\bullet}_{rm}Ln(P^{\bullet}_m/P^{\bullet}_n) + (1-B_r)LnY_{rt-1} + C^{\bullet}_rT + U_r \quad [R]$$

$$LnY_s = LnA^{\bullet} + A^{\bullet}_{sw}Ln(P^{\bullet}_w/P^{\bullet}_n) + A^{\bullet}_{sc}Ln(P^{\bullet}_c/P^{\bullet}_n) + A^{\bullet}_{sr}Ln(P^{\bullet}_r/P^{\bullet}_n) + A^{\bullet}_{ss}Ln(P^{\bullet}_s/P^{\bullet}_n) + A^{\bullet}_{sm}Ln(P^{\bullet}_m/P^{\bullet}_n) + (1-B_s)LnY_{st-1} + C^{\bullet}_sT + U_s \quad [S]$$

$$LnY_m = LnA^{\bullet} + A^{\bullet}_{mw}Ln(P^{\bullet}_w/P^{\bullet}_n) + A^{\bullet}_{mc}Ln(P^{\bullet}_c/P^{\bullet}_n) + A^{\bullet}_{mr}Ln(P^{\bullet}_r/P^{\bullet}_n) + A^{\bullet}_{ms}Ln(P^{\bullet}_s/P^{\bullet}_n) + A^{\bullet}_{mm}Ln(P^{\bullet}_m/P^{\bullet}_n) + (1-B_m)LnY_{mt-1} + C^{\bullet}_mT + U_m \quad [M]$$

where subscripts w, c, r, s, m and n are for wheat, cotton, rice, sugarcane, maize and input (fertilizer only), respectively. $P^{\bullet}$ is expected price and Y is output. Y_{wt-1}, Y_{ct-1}, Y_{rt-1}, Y_{st-1} and Y_{mt-1} are the respective lag production by one year. T and U are as explained in [1] and [2].

APPENDIX A-2

ACTUAL PRODUCTION AND PRICES DATA USED IN THE ANALYSIS

	Production (000, Tonnes) Of					Prices (Rs. / 40 Kg) Of					
YEAR	Wheat	Cotton	Rice	Sugarcane	Maize	Wheat	Cotton	Rice	Sugarcane	Maize	Fertilizer (Nitrogen)
1957	3639.00	1788.00	844.00	8860.00	460.60	14.50	37.00	100.00	1.88	14.75	42.00
1958	3564.00	1785.00	876.00	11288.30	448.30	14 64	37.33	109.30	1.88	14.50	44.00
1959	3907.00	1658.00	992.00	12232.20	488.10	14.68	33.28	102.10	1.74	15.00	44.00
1960	3909.00	1713.00	995.00	11233.40	468.10	15.36	38.61	100.00	1.61	15.00	44.88
1961	3815.00	1767.00	1030.00	11640.90	439.30	15.51	42.08	95.34	2.08	15.00	44.88
1962	4027.00	1905.00	1127.00	14356.80	487.60	14.00	40.33	96.30	2.70	15.50	44.88
1963	4170.00	2153.00	1095.00	17993.20	508.40	13.99	39.13	96.04	2.41	16.00	44.88
1964	4161.00	2460.00	1192.00	16335.00	514.00	16.89	38.04	100.66	2.14	17.00	43.88
1965	4591.00	2220.00	1350.00	18318.40	538.00	16.35	45.20	102.69	2.41	17.50	42.12
1966	3916.00	2436.00	1317.00	22306.40	552.10	19.22	42.94	98.85	2.41	18.80	41.20
1967	4335.00	2722.00	1364.00	21592.20	603.60	16.48	42.02	112.66	2.14	22.44	41.48
1968	6418.00	3042.00	1499.00	18710.50	791.40	26.59	43.12	125.09	2.59	17.68	41.48
1969	6618.00	3101.00	2032.00	21971.30	625.90	22.73	36.51	125.44	2.95	19.38	44.92
1970	7294.00	3148.00	2401.00	26368.60	667.50	18.90	42.06	119.61	2.95	18.22	45.20
1971	6476.30	3189.10	2200.00	23167.00	717.70	19.22	55.53	118.68	2.95	23.04	49.56
1972	6890.40	4159.40	2262.00	19963.10	705.10	22.52	51.02	124.63	2.70	27.60	49.56
1973	7442.30	4125.60	2330.00	19947.50	705.90	22.89	66.53	187.52	4.55	32.40	61.08
1974	7628.90	3871.70	2455.00	23910.50	767.10	27.60	98.46	234.34	4.55	34.20	100.08
1975	7673.50	3728.60	2314.00	21241.90	746.90	39.59	83.83	268.67	5.63	46.56	128.40
1976	8690.70	3020.50	2617.00	25546.70	802.50	40.53	113.47	295.64	6.16	48.30	127.88
1977	9143.90	2557.30	2737.00	29523.00	763.80	41.64	152.69	335.31	6.16	54.55	118.28
1978	8367.20	3380.00	2950.00	30076.60	820.90	49.80	147.67	380.83	6.16	52.81	118.28
1979	9950.00	2782.60	3272.00	27325.50	798.60	52.42	178.60	343.57	6.16	55.54	113.32
1980	10856.50	4282.00	3216.00	27497.70	875.20	53.33	150.70	364.50	7.50	64.49	126.96
1981	11474.60	4201.00	3123.00	32359.40	970.40	54.97	178.19	409.44	9.65	69.19	161.72
1982	11304.20	4398.30	3430.00	36579.70	930.40	64.56	189.96	465.35	9.65	73.90	166.80
1983	12414.40	4843.90	3444.70	32533.50	1005.40	66.96	192.26	477.17	9.65	79.94	198.28
1984	10881.90	2907.70	3339.50	34287.30	1013.50	70.92	195.00	480.00	9.65	77.63	230.60
1985	11703.00	5930.40	3315.20	32139.60	1027.60	75.60	198.00	480.00	9.65	80.00	230.60
1986	13922.80	7154.50	3051.00	27856.30	1009.00	85.00	210.00	482.00	9.65	85.00	230.60