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Acreage response in Pakistan: a co-integration approach

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Abstract

This paper seeks to quantify the acreage responses of wheat, cotton, sugarcane and rice in Pakistan using co-integration techniques and impulse response analysis. Results indicate that acreages of wheat and basmati rice do not respond significantly to shocks in own-price while cotton, sugarcane and high yielding variety (HYV) rice do, and that long-run equilibrium is re-established after about 4 years. Irrigated area is an important determinant of acreage.

JEL classification: O13; Q11

Keywords: Pakistan; Acreage response; Wheat; Cotton; Sugarcane; Rice; Co-integration

1. Introduction

One of the most important issues in agricultural development economics is supply response since the responsiveness of farmers to economic incentives determines agriculture's contribution to the economy. Agricultural pricing policy plays a key role in increasing farm production and fundamental to an understanding of this price mechanism is supply response (Nerlove and Bachman, 1960).

In Pakistan, the aims of agricultural policy are, inter alia, fair incomes for farmers, low food prices for urban consumers, cheap raw materials for manufacturing, and increasing exports. Price support is a main instrument: the prices of major commodities have been set below world prices using subsidies and trade barriers; guaranteed prices, maintained by official procurement, act as floors and domestic market forces determine actual prices (FAO, 1996, pp. 146–150).

Wheat is a cash crop and the main staple food. Recently, growth rates of wheat production have been declining and wheat imports have been increasing: between 1960 and 1980 production increased from 3.8 million tonnes (mt) in 1960 to 11.5 mt in 1980 with an average annual growth rate of 5.51%, but this declined to 2.33% between 1981 and 1996; annual imports averaged 0.9 mt in the 1980s, but increased to 2.1 mt between 1990 and 1996 (FD, 1997). These trends have cast doubt on the efficacy of price policy. The government views its policy as playing an important role in increasing wheat production (NCA, 1988), but some interest groups regard it as being responsible for the sector's declining performance because prices are kept low to provide cheap flour to urban consumers (Hussain and Sampath, 1996).

Rice is a cash crop and the second most important foodgrain. Rice policy aims to encourage farmers to produce exportable surpluses particularly of

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traditional basmati rice for which Pakistan has a comparative advantage. Cotton is the most important cash crop; it has been a major contributor to total agricultural growth since the early 1980s and earns large export revenues. Sugarcane is also a cash crop; since 1966 increasing demand for white sugar has caused imports to increase.

There is a large empirical literature on agricultural supply response and reviews include Askari and Cummings (1977), and Hennebery and Tweeten (1991). For Pakistan, studies include Krishna (1963), Cummings (1975), Tweeten (1986), Pinckney (1989), Khan and Iqbal (1991), Ashiq (1992), and Hussain and Sampath (1996), all of which use time series data with classical regression analysis and Nerlove (1958) adaptive expectations/partial adjustment model(s). Farooq et al. (2001) use cross-section data and a profit function approach. The general conclusion is that farmers in Pakistan respond rationally to economic incentives. However, most economic time series are trended over time and regressions between trended series may produce significant, but spurious results (Granger and Newbold, 1974). This casts doubts on the validity of these previous results.

Our aim is to re-examine acreage responses of wheat, cotton, sugarcane and rice in Pakistan. We use co-integration analysis and Johansen (1988) procedure to overcome the problem of spurious regression, and we test the restrictions implied by imposing Nerlovian partial adjustment. Other supply response studies that use Johansen's procedure (Hallam and Zanoli, 1993; Townsend and Thirtle, 1994; Schimmelpfennig et al., 1996) are extended by examining impulse responses which explore important long-run dynamics. The structure of the paper is as follows: Section 2 discusses model specification, Section 3 discusses our empirical method, Section 4 discusses the data and results and Section 5 concludes.

2. Model specification

Fig. 1 shows the crop seasons for wheat, cotton, sugarcane and rice in Pakistan. Wheat and cotton are both complementary and competing crops: they are complementary in that they can both be sown on the same land in any year; they are competing in that two-thirds of wheat planting takes place after cotton cultivation and a high cotton price provides an incentive to farmers to keep cotton in the fields for longer than is usual to increase the number of pickings. This leaves less time for wheat sowing and as a result some land may remain fallow in the rabi season. Sugarcane typically is a 12/18-month crop although it can be left in the ground for a further growing period if favourable economic conditions exist in which case it becomes a 'ratoon' crop (when new shoots grow from the sugarcane root after cropping). Sugarcane competes

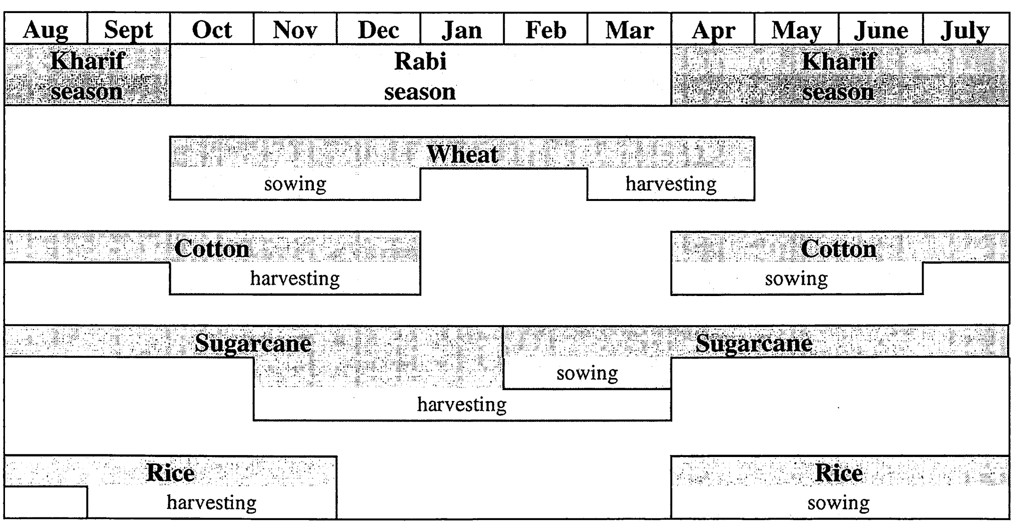

Fig. 1. Crop seasons.

directly with cotton for land and, since two-thirds of the land under wheat follows cotton harvesting, it competes indirectly with wheat. There are two varieties of rice, basmati and high yielding variety (HYV) rice developed at the International Rice Research Institute (IRRI) in the Philippines. Rice does not compete with other crops due to water/irrigation requirements, but there is competition between the two varieties.

Farm output is the product of area (acreage) and yield. In many supply response studies, acreage planted is preferred, first because it measures intended supply and second because yield is subject to more random variation than acreage due to factors outside the farmers' control such as the weather. Here, we examine acreage response only and two models are specified, one for wheat/cotton/sugarcane (WCS), and one for basmati and IRRI (HYV) rice (BIR).[1]

We hypothesise that within each model, acreages and respective output prices are jointly determined. Two types of exogenous variables are also specified. First, excessive rainfall during the sowing season may affect planting so a rainfall variable is specified for each crop. Second, the green revolution has resulted in technological advances, and central to this, inter alia, is irrigation; hence, irrigated area is used as a proxy for technology.

Since acreages and prices are jointly determined, we use Sims' (1980) vector autoregression (VAR) methodology and specify:

$$z_t = \delta + A_1 z_{t-1} + A_2 z_{t-2} + \cdots + A_{p-1} z_{t-p+1} + \Psi x_t + u_t \qquad (1)$$

where z_t is a $(n \times 1)$ vector of endogenous variables, x_t is $(q \times 1)$ vector of exogenous variables, δ is a $(n \times 1)$ vector of parameters, A_i are $(n \times n)$ matrices of parameters, Ψ is a $(n \times q)$ matrix of parameters, and u_t is an $(n \times 1)$ vector of random variables with $E[u_t] = 0$. In the WCS model, $z_t = [\mathrm{WA}_t, \mathrm{CA}_t, \mathrm{SA}_t, \mathrm{WP}_t, \mathrm{CP}_t, \mathrm{SP}_t]'$, where WA_t, CA_t and SA_t are acreages of wheat, cotton and sugarcane, and WP_t, CP_t and SP_t are their respective prices. Furthermore, $x_t = [\mathrm{IA}_t, \mathrm{RFW}_t, \mathrm{RFC}_t, \mathrm{RFS}_t]'$, where IA_t is irrigated area, and RFW_t, RFC_t and RFS_t are respective sowing season rainfall. Similarly, in the BIR model, $z_t = [\mathrm{BRA}_t, \mathrm{IRA}_t, \mathrm{BRP}_t, \mathrm{IRP}_t]'$, where BRA_t and IRA_t are acreages of basmati and IRRI rice, and BRP_t and IRP_t are their respective prices. In this model, $x_t = [\mathrm{IA}_t, \mathrm{RFR}_t]'$, where RFR_t is sowing season rainfall for rice.

[1] An anonymous referee has raised the issue of yield being an important component of total supply. We have estimated the yield response of each crop using models and methods similar to those used here for acreage response, but the results were poor. This is perhaps not surprising since yield response is a short-run issue for which (long-run) co-integration techniques are ill-suited.

3. Empirical method

Many time series are non-stationary and in general OLS regressions between such data are spurious. The presence of a unit root in the autoregressive representation of a time series leads to non-stationarity, and such series, referred to as being integrated of order one ($I(1)$), must be first-differenced to render them stationary (or integrated of order zero). Where $I(1)$ series move together and their linear combination is stationary, they are referred to as being co-integrated and the problem of spurious regression does not arise. Co-integration implies the existence of a meaningful long-run equilibrium (Granger, 1988). Since a co-integrating relationship cannot exist between two variables which are integrated of a different order, we first test for the order of integration of each series.

We begin by testing for the presence of unit roots in the individual time series using the augmented Dickey–Fuller (ADF) test (Dickey and Fuller, 1981; Said and Dickey, 1984), both with and without a deterministic trend. The number of lags in the ADF-equation is chosen to ensure that serial correlation is absent using the Breusch–Godfrey statistic (Greene, 2000, p. 541).

To examine the hypotheses of integration and co-integration in Eq. (1), we transform it into its vector error-correction form:

$$\Delta z_t = \delta + \Gamma_1 \Delta z_{t-1} + \Gamma_2 \Delta z_{t-2} + \cdots + \Gamma_{p-1} \Delta z_{t-p+1} + \pi z_{t-p} + \Psi x_t + u_t \qquad (2)$$

where z_t is a vector of $I(1)$ endogenous variables, $\Delta z_t = z_t - z_{t-1}$, x_t is vector of $I(0)$ exogenous variables and π and Γ_i are $(n \times n)$ matrices of parameters with $\Gamma_i = -(I - A_1 - A_2 - \cdots - A_i)$, $(i = 1, \ldots, k-1)$, and $\pi = I - \pi_1 - \pi_2 - \cdots - \pi_k$. Eq. (2) provides information about short- and long-run adjustments to changes in z_t through Γ_i and π, respectively. The term πz_{t-k} provides information about the long-run equilibrium relationship between the variables in z_t.

Information about the number of co-integrating relationships among the variables in z_t is given by the rank of π, denoted by r: if π is of reduced rank, the model is subject to a unit root; and if $0 < r < n$, π can be decomposed into two $(n \times r)$ matrices α and β, such that $\pi = \alpha\beta'$, where $\beta' z_t$ is stationary. Here, α is the error-correction term and measures the speed of adjustment in Δz_t and β contains r distinct co-integrating vectors, that is the co-integrating relationships between the non-stationary variables in z_t. Johansen (1988) uses the reduced rank regression procedure to estimate α and β, and trace statistics are used to test the null hypothesis of at most r co-integrating vectors against the alternative that the number of co-integrating vectors is greater than r. Testing for r can also be undertaken using maximal eigenvalue tests. However, from Monte Carlo experiments, Cheung and Lai (1993) suggest that the trace statistic "... shows more robustness to both skewness and excess kurtosis in 'the residuals' than the maximal eigenvalue test." Finally, two diagnostic multivariate tests of the residuals are presented: first, we test for first-order autocorrelation using the LM-test of Godfrey et al. (1988, pp. 176–186), and second, we test for normality using the test of Doornik and Hansen (1994).

In the WCS model, we expect three co-integrating vectors, one for each crop, with, e.g. $\text{WA}_t = f(\text{WP}_t, \text{CP}_t, \text{SP}_t)$ (and not CA_t or SA_t); in the BIR model, we expect two co-integrating vectors, one for each variety. As an indication of which variables adjust when disequilibrium is present, we test for weak exogeneity of each variable using a likelihood ratio (LR) statistic (Johansen and Juselius, 1990); this tests the null hypothesis that the corresponding row of α is zero. Further, for each crop acreage, we estimate its error-correction representation in which the Nerlovian partial adjustment model is nested (Hendry et al., 1984), and we test whether the restrictions associated with the model are valid (Nickell, 1985).

Harris (1995, p. 96), notes that there are three realistic models (denoted as models 2–4) implicit in Eq. (2). Model 2 is where there are no linear trends in the levels of the endogenous $I(1)$ variables and the first-differenced series have a zero mean; here, the intercept is restricted to the co-integration space. Model 3 is where there are linear trends in the levels of the endogenous $I(1)$ variables and there is an intercept in the short-run model only. Model 4 is where any long-run linear growth is not accounted for by the model and a linear trend is present in the co-integration vectors.[2]

We test between models 2 and 4 following the Pantula principle (Harris, 1995, p. 97), testing the joint hypothesis of both rank and the deterministic components (Johansen, 1992).

Impulse response analysis (Lütkepohl, 1993, pp. 43–56) is used to investigate the interrelationships among the variables and to assess adjustments to long-run equilibrium. Since deviations from the long-run equilibrium are stationary, any shock to the system generates time paths which eventually return to a new equilibrium provided no further shocks occur. Impulse responses are generated under the assumption that the π-matrix is of the rank determined by the trace statistics, and they are orthogonalised to account for contemporaneous correlation between equations. Each impulse response is the response of a variable to a shock of one standard error in another variable.

4. Data and results

Annual data are acreages (in '000 ha), real wholesale prices (nominal prices deflated by the GDP deflator in 1995, Rs./40 kg), irrigated area (million ha) and sowing season rainfall (mm). The WCS model is estimated for 1960–1996, while the BIR model is estimated for 1967–1996 when HYV rice was available. Summary statistics and sources are presented in Appendix A.

Table 1 reports the results of testing the series (in logarithms) for unit roots using ADF-tests both with and without a linear trend. Both models indicate that all acreages are $I(1)$ except for the acreage of IRRI rice (IRA_t), where stationarity is shown in the non-trended model and a unit root cannot be rejected in the trended

[2] Model 1 accounts for no intercepts and no deterministic trends in the co-integrating space, which is unrealistic. Model 5 is appropriate if the data exhibit quadratic trends in level form, which is difficult to justify when the variables are in log form since it implies an ever increasing or decreasing growth rate.

Table 1
Unit root (ADF-) test statistics (H_0: 1 unit root)

Wheat/cotton/sugarcane (WCS) model			Rice (BIR) model		
Variable (1960–1996)	Non-trended model	Trended model	Variable (1967–1996)	Non-trended model	Trended model
WA_t	−1.85	−3.02	BRA_t	−1.08	−2.67
CA_t	−0.83	−3.17	IRA_t	−2.87	−3.00
SA_t	−1.40	−1.90	BRP_t	−0.87	−1.09
WP_t	−0.31	−1.93	IRP_t	−1.29	−1.69
CP_t	−1.49	−2.99	IA_t	−4.88	−3.18
SP_t	−0.61	−1.32	RFR_t	−5.81	−5.75
IA_t	−0.85	−5.17			
RFW_t	−5.28	−5.24			
RFC_t	−5.32	−5.40			
RFS_t	−6.14	−6.11			
Critical value	−2.60	−3.18		−2.60	−3.18

Note: Critical values (90% confidence level) are taken from Fuller (1976, p. 373).

model. However, the trend is significant in the trended model; thus, we prefer this model and conclude that IRA_t is also $I(1)$. ADF-tests also show that all prices are $I(1)$, while the rainfall series are $I(0)$. For irrigated area (IA_t), the non-trended model shows that the full sample (1960–1996) is $I(1)$ and the restricted sample (1967–1996) is $I(0)$, while the trended model shows the opposite. The trend in the former sample is significant while that in the latter is not, and we therefore conclude the both series are $I(0)$.

Notwithstanding this conclusion, we also carried out the tests of Zivot and Andrews (1992), where the null hypothesis posits a unit root and the alternative is a trend with a single structural break, and Perron (1997), where there is a structural break in both the null and alternative hypotheses. Little consensus emerged and we prefer the results of the ADF-tests.

The first step of the Johansen procedure is to select the order of the VAR for each model. We use the LR-statistic, adjusted for small samples (Sims, 1980), to test the null hypothesis that the order of the VAR is k against the alternative that it is three, where $k = 0$, 1 and 2. For both models, $k = 1$. Second, we use a LR-test of the significance of the exogenous $I(0)$ variables; insignificant variables in the WCS model are RFW_t and RFC_t, while RFR_t is insignificant in the BIR model. Hence, these variables are excluded. In contrast, IA_t is significant in both VAR models.

We now use the Johansen procedure and trace statistics to test between models 2 and 4 and to test for the presence and number of co-integrating vectors in both models using the Pantula principle. The results are presented in Table 2. Model 2 is preferred in both cases; for the WCS model, $r = 3$ and for the BIR model, $r = 1$. However, in the BIR model, the relevant trace statistics are close to their corresponding critical values and there is a strong theoretical prior that $r = 2$. Accordingly, we conclude that there are three co-integrating vectors in the WCS model and two in the BIR model.

Tests of reduced rank using maximal eigenvalue statistics confirm these results although there is some ambiguity in the WCS model: for model 4, the test of

Table 2
Determining the rank and model—trace statistics

H_0	Model 2	Model 3	Model 4
Wheat/cotton/sugarcane (WCS) model			
$r = 0$	163.87 (97.87)	159.25 (91.40)	168.58 (110.60)
$r \leq 1$	96.95 (71.81)	92.92 (66.23)	101.33 (82.88)
$r \leq 2$	54.80 (49.95)	54.11 (45.70)	62.23 (59.16)
$r \leq 3$	26.71 (31.93)[a]	26.28 (28.78)	34.35 (39.34)
$r \leq 4$	8.09 (17.88)	7.66 (15.75)	10.82 (23.08)
$r \leq 5$	1.91 (7.53)	1.58 (6.50)	2.87 (10.55)
Rice (BIR) model			
$r = 0$	158.02 (49.95)	150.19 (45.70)	151.90 (59.16)
$r \leq 1$	31.29 (31.93)[a]	26.63 (28.78)	27.74 (39.34)
$r \leq 2$	12.61 (17.88)	8.01 (15.75)	9.09 (23.08)
$r \leq 3$	4.92 (7.53)	0.80 (6.50)	1.42 (10.55)

Note: Critical values (90% confidence level) in parentheses are taken from Pesaran et al. (2000).

[a] Indicates that the null hypothesis is not rejected using the Pantula principle.

the null hypothesis that $r \leq 2$ is not rejected, while that of $r \leq 3$ is rejected; for model 2, the null hypothesis that $r \leq 3$ is not rejected, suggesting three co-integrating vectors. From the eigenvalues of the companion matrix, the moduli of the three largest roots in the WCS model are 0.88, 0.70 and 0.70 which suggests that $r = 3$, while the two largest roots in the BIR model are 0.93 and 0.93 which suggests that $r = 2$.

In the WCS model, the LM-test for first-order autocorrelation of the residuals (Godfrey et al., 1988, pp. 176–186) yields $\chi^2 = 43.80$ ($p = 0.17$) and the normality test (Doornik and Hansen, 1994) yields $\chi^2 = 15.32$ ($p = 0.22$). Corresponding tests in the BIR model are $\chi^2 = 13.01$ ($p = 0.67$) and $\chi^2 = 4.51$ ($p = 0.81$). Both sets of tests suggest that the residuals are well-behaved.

We now impose just-identifying restrictions on the co-integrating vectors as implied by theory so that in each model each acreage is a function of prices, e.g. $\mathrm{WA}_t = f(\mathrm{WP}_t, \mathrm{CP}_t, \mathrm{SP}_t)$; the parameters in the co-integrating vectors (β) can now be interpreted as long-run acreage elasticities. Results are presented in Table 3. Using Wald tests (Harris, 1995, p. 116) and the 90% confidence level, all β's are significant except for CP_t in the sugarcane equation (vector 3 in the WCS model), and for BRP_t in the IRRI rice equation (vector 2 in the BIR model). In the WCS model, own-price elasticities are positive, those for wheat, cotton and sugarcane are 0.93, 0.30 and 5.01, respectively. Further, wheat, cotton and sugarcane compete for land, while cotton and sugarcane are complementary, as might be implied by Fig. 1. In the BIR model, own-price elasticities are around 0.4 for both (competing) varieties. Table 3 also shows the results of testing the null hypotheses of weak exogeneity which are rejected for all acreages and for the sugarcane price implying that long-run adjustment from disequilibria takes place largely through acreages.

In general, our own-price acreage elasticity estimates are similar to previous results which are summarised in Table 4. Two exceptions are wheat and sugarcane. Tweeten (1986), Pinckney (1989), Khan and Iqbal (1991), Ashiq (1992), and Hussain and Sampath (1996) find wheat elasticities between 0.11 and 0.46, whereas our estimate is almost unitary. Similarly, Tweeten (1986), and Khan and Iqbal (1991) find sugarcane elasticities between 0.47 and 0.70 (although the latter also estimate a yield elasticity of 4.35), while our estimate is roughly 5. Our elasticity for cotton compares with the results of previous studies which range between 0.12 and 0.54; similarly, for rice, other estimates range between 0.27 and 0.62.

The parameters in the co-integrating vectors (β) are interpreted above as ceteris paribus long-run elasticities, i.e. the wheat elasticity, e.g. characterises

Table 3
Co-integrating and adjustment vectors, and tests of weak exogeneity

	Co-integrating vectors (β)			Adjustment vectors (α)			Weak exogeneity
	Vector 1	Vector 2	Vector 3	Vector 1	Vector 2	Vector 3	
Wheat/cotton/sugarcane (WCS) model							
WA_t	−1	0	0	−0.361 (0.06)	0.046 (0.05)	−0.037 (0.01)	21.31 [0.00]
CA_t	0	−1	0	0.303 (0.10)	−0.481 (0.10)	0.039 (0.01)	10.99 [0.01]
SA_t	0	0	−1	−0.139 (0.13)	0.163 (0.12)	−0.079 (0.02)	37.90 [0.00]
WP_t	0.928 (17.35)	−0.210 (6.36)	−6.627 (16.22)	0.267 (0.38)	−0.647 (0.35)	0.011 (0.05)	3.57 [0.31]
CP_t	−0.121 (2.88)	0.296 (11.39)	0.442 (1.38)	−0.535 (0.51)	0.743 (0.47)	−0.102 (0.07)	5.29 [0.15]
SP_t	−0.678 (23.38)	0.086 (4.78)	5.006 (22.65)	−0.953 (0.61)	−0.067 (0.57)	0.027 (0.08)	22.87 [0.00]
Intercept	3.885 (10.02)	2.900 (12.03)	24.355 (8.21)				
Rice (BIR) model							
BRA_t	−1	0		−0.372 (0.10)	0.020 (0.02)		10.43 [0.01]
IRA_t	0	−1		0.053 (0.13)	−0.841 (0.02)		117.79 [0.00]
BRP_t	0.464 (2.86)	−0.258 (1.99)		−0.545 (0.25)	0.018 (0.04)		3.96 [0.14]
IRP_t	−0.523 (3.32)	0.382 (3.02)		−0.498 (0.27)	0.019 (0.04)		2.88 [0.24]
Intercept	0.996 (2.44)	2.415 (7.39)					

Note: Wald tests for coefficients of the β's, and standard errors for the αs in parentheses, and p-values are given in square brackets.

Table 4
Comparison of long-run own-price acreage elasticities

Source	Sample period	Wheat	Cotton	Sugarcane	Rice
Krishna (1963)	1913–1945	0.14–0.22	1.08–1.62	0.30–0.60	0.59
Cummings (1975)	1949–1968	0.22	0.28–0.47	–	0.17
Tweeten (1986)	1962–1983	0.27	0.54	0.70	0.43
Pinckney (1989)	1967–1984	0.20	–	–	–
Khan and Iqbal (1991)	1956–1986	0.11	0.12	0.47	0.53
Ashiq (1992)	1975–1987	0.46–0.49	–	–	0.46–0.62
Hussain and Sampath (1996)	1970–1993	0.21	–	–	–
Farooq et al. (2001)	1995–1996	–	–	–	0.27
Present study	1960–1996	0.93	0.30	5.01	–
	1967–1996	–	–	–	0.38–0.46

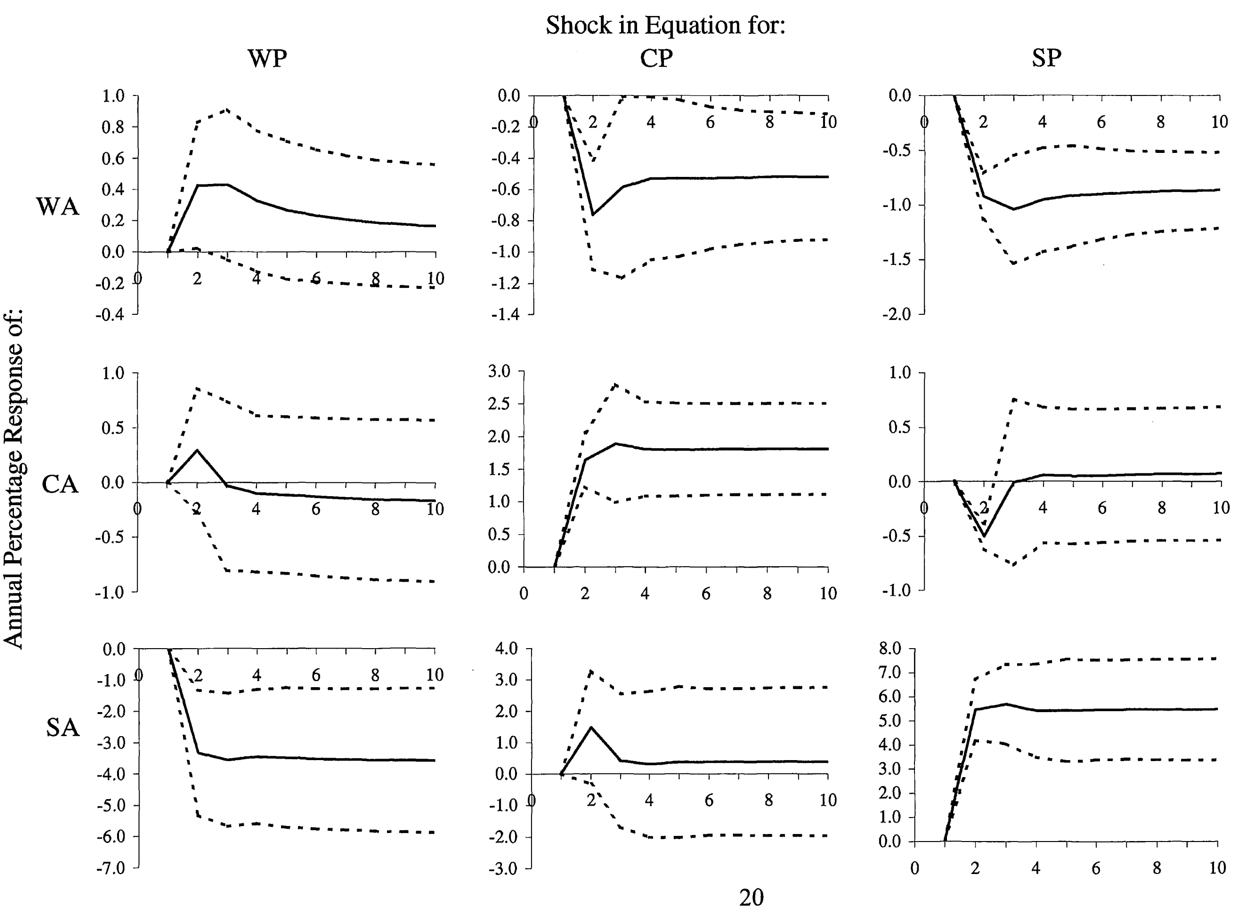

Fig. 2. Impulse responses in the WCS model.

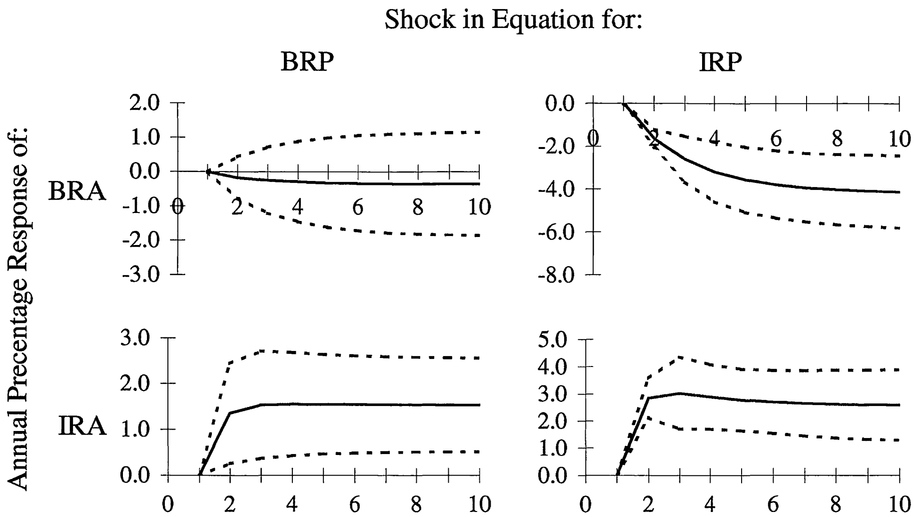

Fig. 3. Impulse responses in the BIR model.

the relationship between the wheat acreage and own-price, with all other variables remaining constant. This interpretation ignores other relationships between the variables which are summarised in the VAR (Lütkepohl, 1993, p. 380), e.g. a shock in WP_t may affect WA_t directly, but it may also influence CA_t, SA_t, CP_t and SP_t, which in turn affect WA_t indirectly. Accordingly, "... impulse responses may give a better picture of the relations between the variables" (Lütkepohl, 1993, p. 380). Thus, for each model, Figs. 2 and 3 show the structural impulse response functions of main interest, namely the acreage responses, over a 10-year horizon with 95% confidence bounds. Since each series is expressed in logarithms, the responses can be interpreted as annual percentage changes.

In Fig. 2, one standard error shocks in WP_t, CP_t and SP_t correspond to increases in their values of 13.05, 11.18 and 17.20%, respectively. The response of WA_t to a shock in WP_t is insignificant. In contrast, the responses of CA_t and SA_t to shocks in own-prices are significant; they increase by 1.81 and 5.49%, respectively in the long-run. Now consider, the cross-price effects. Wheat and cotton are competing crops: a shock in WP_t has an insignificant effect on CA_t, but a shock in CP_t reduces WA_t significantly by 0.52% in the long-run. Wheat and sugarcane are also competing crops: a shock in WP_t reduces SA_t significantly by 3.58%, while a shock in SP_t reduces WA_t by 0.87% in the long-run. A shock in CP_t (SP_t) has an insignificant effect on SA_t (CA_t). Long-run equilibrium is re-established after about 4 years.

In Fig. 3, one standard error shocks in BRP_t and IRP_t correspond to increases in their values of 16.36 and 8.15%, respectively. A shock in BRP_t has an insignificant effect on BRA_t, but increases IRA_t significantly by 1.54%. Similarly, a shock in IRP_t significantly increases IRA_t by 2.58% and reduces BRA_t by 4.12%. Long-run equilibrium is generally re-established after about 3 years.

Finally, we estimate an error-correction model for each crop acreage and test whether the restrictions implied by Nerlovian partial adjustment are valid. In particular, we use Wald tests to test the significance of the difference terms in each error-correction model estimated using general-to-specific methodology, starting with four lags (Hendry and Ericsson, 1991). Test statistics (p-values) are: for WA_t, $\chi_3^2 = 12.45$ (0.01); for CA_t, $\chi_2^2 = 6.11$ (0.05); for SA_t, $\chi_2^2 = 106.83$ (0.00); for BRA_t, $\chi_3^2 = 6.35$ (0.096); and for IRA_t, $\chi_6^2 = 25.55$ (0.00). Thus, at the 90% confidence level, the Nerlovian framework is inappropriate and we favour the more general dynamic adjustment implied by the error-correction specification for modelling agricultural supply response in Pakistan.

5. Summary and conclusions

Previous time series studies of agricultural supply response in Pakistan use classical regression and Nerlovian models which have well-known restrictive implications for dynamic adjustment. The results from these studies may be spurious because economic series tend to be non-stationary. This paper re-examines the acreage responses of wheat, cotton, sugarcane, basmati and HYV (IRRI) rice using the co-integration analysis which incorporates both a more general dynamic structure than Nerlovian models and overcomes the potential problem of spurious regression.

We estimate two models, one for wheat, cotton and sugarcane for 1960–1996, and the other for basmati and IRRI rice (BIR) for 1967–1996. In the WCS model, long-run own-price acreage elasticities are 0.93 for wheat, 0.30 for cotton and 5.01 for sugarcane. Wheat, and cotton and sugarcane compete for land, while cotton and sugarcane are complementary. In the BIR model, own-price elasticities are around 0.4 for both rice varieties with basmati and IRRI rice competing for land. Results also show that irrigation is important in explaining short-run acreage response.

The long-run ceteris paribus acreage elasticities are subject to the criticism that they do not account for all dynamic relationships between the variables in the model. Accordingly, impulse response analysis is used to investigate these interrelationships and to quantify adjustments to long-run equilibrium. In the WCS model, impulse responses show the effects of one standard error shocks in the prices of WCS: these correspond to increases in of 13, 11 and 17%, respectively. Results show that wheat acreage is unresponsive to own-price whereas cotton and sugarcane acreages respond significantly to own-prices, increasing in the long-run by 1.8 and 5.5%, respectively. The insignificant own-price response of wheat acreage is surprising, but arises from cotton and sugarcane acreages and their prices adjusting in the VAR towards long-run equilibrium. In particular, cotton and sugarcane prices both increase (by 11 and 13%, respectively in the long-run) providing incentives to farmers first to keep cotton in the fields for longer than is usual to increase the number of pickings, and second for sugarcane to become a ratoon crop. In both cases, there is less time for wheat sowing. Nevertheless, our results suggest some evidence that wheat, cotton and sugarcane compete for land.

In the BIR model, impulse responses show the effects of one standard error shocks in the prices of basmati and IRRI rice which correspond to increases of 16 and 8%, respectively. Results show that basmati acreage is unresponsive to own-price, whereas IRRI acreage responds significantly to own-price, increasing in the long-run by 2.6%. The insignificant own-price response of basmati acreage is surprising, but arises from increases in the price of IRRI rice (by 15% in the long-run) that provide an incentive for IRRI rice production. In both the WCS and BIR models, adjustment from disequilibrium takes 3–4 years and occurs largely through acreages rather than prices.

Our long-run ceteris paribus elasticity estimates of acreage response in general are similar to estimates in previous studies. However, our results show that the Nerlovian assumptions invoked by these studies are inappropriate for modelling the adjustment process of acreage response in Pakistan. We also argue that impulse response analysis is more informative in measuring acreage response to changes in prices than ceteris paribus elasticities are. From a policy-making perspective, the implied elasticities from impulse response analysis are smaller than the corresponding ceteris paribus elasticities.

Appendix A. Summary statistics

Variable	Units of measurement	Mean	S.D.	Minimum	Maximum
Wheat/cotton/sugarcane (WCS) model (1960–1996)					
WA_t	’000 ha	6673.30	1102.60	4639.00	8377.00
CA_t	’000 ha	1973.90	532.07	1128.60	3079.00
SA_t	’000 ha	736.18	174.37	388.10	1009.00
WP_t	Rs./40 kg	433.25	118.78	177.94	665.77
CP_t	Rs./40 kg	2171.60	662.74	946.22	3434.70

Appendix A. (*Continued*)

Variable	Units of measurement	Mean	S.D.	Minimum	Maximum
SP_t	Rs./40 kg	855.17	269.26	371.16	1525.50
IA_t	Million ha	14.30	2.24	10.41	17.58
Rice (BIR) model (1967–1996)					
BRA_t	'000 ha	774.43	250.51	400.00	1148.00
IRA_t	'000 ha	785.36	223.56	4.05	1056.00
BRP_t	Rs./40 kg	1108.30	344.30	540.50	1484.30
IRP_t	Rs./40 kg	495.45	159.36	238.48	793.55
IA_t	Million ha	15.01	1.84	10.59	17.58

Source: Acreages, prices and irrigated area—FD (1997). Sowing season rainfall—MFAL (1989) and Meteorological Department, Food and Agriculture Organisation (personal communication).

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