YIELD RESPONSE IN PAKISTAN AGRICULTURE: A COINTEGRATION APPROACH

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ABSTRACT

We seek to quantify and evaluate the supply (yield) response of wheat and cotton in Pakistan using cointegration analysis and annual data for 1960-96. The results reveal that wheat supply is significantly influenced by the prices of wheat, cotton and fertilizer, the percentage area under high yielding wheat varieties, and the rabi season (winter) water availability. The cotton supply is found to be significantly influenced by the real cotton price, the real fertilizer price, and the irrigated area. The wheat supply was found to be inelastic both in the short- and long-run. However, cotton supply was elastic in the long-run.

Keywords: Pakistan, supply response, wheat, cotton, cointegration.

INTRODUCTION

One of the most important issues in agricultural development economics is supply response since the responsiveness of farmers to economic incentives largely determines agriculture's contribution to the economy. Agricultural pricing policy plays a key role in increasing both farm production and incomes 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 to the manufacturing sector, and increasing exports. Price support is a main instrument: the prices 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 the actual prices.

Wheat is the main staple food in Pakistan but recent declining growth rates of production and increasing imports has cast doubt on the efficacy of its price support policy. The government views its policy as playing an important role in increasing wheat production and farm incomes (Government of Pakistan, 1988) but other 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). Cotton is the most important cash crop; it has been one of the major contributors to overall agricultural growth since the early 1980s and earns large export revenues. In addition to the lint, cotton seed for oil and meal accounts for about 80 per cent of the national oilseed production.

All previous studies on agricultural supply response in Pakistan use time series data and classical regression analysis; most use Nerlove's (1958) restrictive adaptive expectations/partial adjustment model(s). However, most economic time series are trended over time and regressions between trended series may produce significant results with high $R^2 s$, but may be spurious (Granger and Newbold, 1974). This casts doubts on the validity of their results.

Our aim is to re-examine the yield response of wheat and cotton in Pakistan. We use cointegration analysis and Johansen's (1988) procedure to overcome the problem of spurious regression, and we test the restrictions associated with imposing Nerlovian partial adjustment.

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, while Section 5 concludes.

MODEL SPECIFICATION

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 affects the wheat crop in two ways. First, it leaves less time for farmers to prepare land for wheat resulting in some land remaining fallow. Second, any delay in wheat plantings, resulting from a delay in cotton harvest, affects its yield (Pinckney, 1989).

We have examined acreage response of major crops in Pakistan elsewhere (Mushtaq and Dawson, 2002) but estimates of acreage response are not entirely satisfactory when yield is changing as in the case of Pakistan where wheat and cotton yields show upward trends. Here we extend our analysis of acreage response and estimate yield response. We specify two yield response models, one each for wheat and cotton. We hypothesize that within each model, yield and respective output prices are jointly determined. Two types of exogenous variables are also specified. First, excessive rainfall during the growing season may affect yield and a rainfall variable is specified for each crop. Second, the Green Revolution has resulted in technological advances and the percentage area under high yielding wheat varieties is used to represent this, rabi (winter) water availability and irrigated area is used as a proxy for technology.

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

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

where z_t is a (n×1) vector of endogenous variables, x_t is (q×1) vector of exogenous variables, δ is a (n×1) vector of parameters, A_i are (n×n) matrices of parameters, Ψ is a (n×q) matrix of parameters, and u_t is an (n×1) vector of random variables with $E[u_t]=0$. In the wheat yield model, $z_t=[WY_t,WP_t,CP_t,FP_t]'$, where WY_t is the respective wheat yield and WP_t, CP_t and FP_t are respective wheat, cotton and fertilizer prices, and $x_t=[HYWA_t, RBWA_t, RFW_t]'$, where $HYWA_t$ is the percentage area under high yielding wheat varieties, $RBWA_t$ is rabi water availability and RFW_t is respective growing season rainfall. Similarly, in the cotton yield model, $z_t=[CY_t,CP_t,FP_t]'$, where CY_t is respective cotton yield and CP_t and FP_t are respective cotton and fertilizer prices, and $x_t=[IA_t,RFC_t]'$, where IA_t is the irrigated area and RFC_t is growing season rainfall for cotton.

EMPIRICAL METHOD

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

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, and 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 cointegration in (1), we transform it into its vector error correction form:

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

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×n) matrices of parameters with $\Gamma_i=-(I-A_1-A_2-\ldots-A_i)$, (i=1,…,k-1), and $\pi=I-\pi_1-\pi_2-\ldots-\pi_k$.

This specification provides information about short-run and long-run adjustments to the changes in z_t through the estimates of $\hat{\Gamma}_i$ and $\hat{\pi}$ 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 cointegrating relationships among the variables in z_t is given by the rank of the π-matrix: if π is of reduced rank, the model is subject to a unit root; and if $0<r<n$, where r is the rank of π, 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 cointegrating vectors, that is the cointegrating relationships between the non-stationary variables. Johansen (1988) uses the reduced rank regression procedure to estimate α and β and the trace test statistic is used to test the null hypothesis of at most r cointegrating vectors against the alternative that it is greater than r.

In each model, we expect one cointegrating vectors, with, for example, $WY_t=f(WP_t,CP_t,FP_t)$. Further, for each cointegrating vector, we estimate its error-correction representation in which the Nerlovian partial adjustment model is nested and we test whether the restrictions are valid.

Harris (1995, p.96) notes that there are three realistic models (denoted as Models 2-4) implicit in (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 cointegration 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 cointegration vectors.[1] We test between these models following the Pantula principle (Harris, 1995, p.97), testing the joint hypothesis of both rank and the deterministic components (Johansen, 1992).

DATA AND RESULTS

Annual data relate to yield (kg/ha), real wholesale prices (Rupees/40kg), irrigated area (million ha), percentage area under high yielding wheat varieties (000 ha), rabi water availability (MAF), and growing season rainfall (mm). Real wholesale prices are nominal prices deflated by the GDP deflator (1995=100). Both models are estimated for 1960-96 period.

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 yields and prices are I(1) and all rainfall series are I(0). Non-trended model shows that irrigated area (IA_t), percentage area under high yielding wheat varieties ($HYWA_t$), and rabi water availability ($RBWA_t$) are I(1), while the trended model shows the opposite. The trend is significant and we conclude these series are I(0). Notwithstanding this conclusion, we also carried out the tests of Zivot and Andrews (1992), where the null is 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 null and alternative hypotheses. Little consensus emerged and we prefer the results from the ADF-tests.

Table 1. Unit Root (ADF-) Tests (Ho: 1 unit root).

Variable (1960-96)	Non-trended Model	Trended Model
WY_t	-1.15	-3.22
CY_t	-1.53	-2.70
WP_t	-0.31	-1.93
CP_t	-1.49	-2.99
FP_t	-1.67	-2.01
IA_t	-0.85	-5.17
$HYWA_t$	-2.54	-3.95
$RBWA_t$	-1.53	-3.60
RFW_t	-6.25	-6.48
RFC_t	-8.34	-8.24
Crit. Value	-2.93	-3.50

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 four where k=0,1,2,3; for both models k=1. We now use the Johansen procedure and trace statistics to test between Models 2-4 and to test for the presence and number of cointegrating vectors in both models using the Pantula principle. The results are presented in Table 2. For both models we conclude that there is one cointegrating vector (i.e., a unique long-run equilibrium relationship) and Model 2 (restricted intercepts and no trends) is the appropriate model.

Table 2. Determining the Rank and Model - Trace Statistics.

H_o	Model 2	Model 3	Model 4
Wheat Yield Model			
r=0	52.03 (49.95)	47.97 (48.88)	80.06 (63.00)
r≤1	27.89 (34.87)*	23.84 (31.54)	35.36 (42.34)
r≤2	11.69 (20.18)	8.50 (17.86)	17.99 (25.77)
r≤3	2.51 (9.16)	0.60 (8.07)	4.35 (12.39)
Cotton Yield Model			
r=0	35.02 (34.87)	32.81 (31.54)	39.92 (39.34)
r≤1	7.63 (20.18)*	7.26 (17.86)	9.44 (25.77)
r≤2	3.32 (9.16)	3.13 (8.07)	3.49 (12.39)

Notes: 1. Critical values (95% confidence level) in parentheses (Pesaran, Shin, and Smith); 2. * indicates where the null is not rejected using the Pantula principle.

The Johansen model is a form of error correction model (ECM) and, where only one cointegrating vector exists, its parameters can be interpreted as estimates of the long-run cointegrating relationship between the variables concerned (Hallam and Zanoli, 1993). The cointegrating vectors normalised on yield are:

$$\text{Wheat:} \quad WY_t = 0.693WP_t - 0.264CP_t - 0.498FP_t + 4.776 \tag{3}$$

$$\text{Cotton:} \quad CY_t = 1.092CP_t - 0.676FP_t - 5.441 \tag{4}$$

The coefficients represent estimates of long-run elasticities of wheat yield with respect to wheat, cotton and fertilizer prices, and cotton yield with respect to cotton and fertilizer prices.

Finally, we estimate the corresponding error correction model for each cointegrating vector using a general-to-specific method and test whether the restrictions implied by Nerlovian partial adjustment are valid using a Wald test. Results are presented in Table 3. The ECM for wheat (with cotton entirely similar) is:

$$\begin{aligned}\Delta WY_t = \delta_0 + \sum_{i=1}^{4}\delta_{1i}\Delta WY_{t-i} + \sum_{i=1}^{4}\delta_{2i}\Delta WP_{t-i} + \sum_{i=1}^{4}\delta_{3i}\Delta CP_{t-i} + \sum_{i=1}^{4}\delta_{4i}\Delta FP_{t-i} + \delta_5 HYWA \\ + \delta_6 RBWA + \delta_7 RF - \alpha(WY_{t-1} - \beta_1 WP_{t-1} - \beta_2 CP_{t-1} - \beta_3 FP_{t-1})\end{aligned} \tag{5}$$

The results indicate that wheat yield is dependent on the prices of wheat, cotton and fertilizer, the percentage area under high yielding wheat varieties, water availability during rabi season, and rainfall. A one per cent increase in the wheat price increases the wheat yield by 0.155 per cent in the short run and by 0.693 per cent in the long run. A one per cent increase in the cotton price decreases the wheat yield by 0.121 per cent in the short run and by 0.264 per cent in the long run. Although fertilizer price has an insignificant effect in the short run, a one per cent increase in its price decreases the wheat yield by 0.498 per cent in the long run. A one per cent increase in the percentage area under HYVs results an increase of 0.064 per cent in the wheat yield in the short run.[2] Rabi water availability seems to have had a large short-run effect: a one per cent increase results an increase of 0.410 per cent in the wheat yield. Rainfall has a negative effect on the wheat yield: a one per cent increase in rainfall decreases the wheat yield by 0.043 per cent.[3]

The results for cotton show a similar degree of fit. The real cotton price, the real fertilizer price, the irrigated area and rainfall have significant effects on cotton yield. A one per cent increase in the cotton price increases the cotton yield by 0.283 per cent in the short run and by 1.09 per cent in the long run. A one per cent increase in the fertilizer price decreases the cotton yield by 0.305 per cent in the short run and by 0.676 per cent in the long run. The irrigated area has the largest short-run effect: with a one per cent increase in the irrigated area resulting in an increase of 1.29 per cent in the cotton yield. Rainfall has a significant negative effect on the cotton yield: a one per cent increase in rainfall decreases the cotton yield by 0.061 per cent.[4]

Table 3. The error correction model estimates for wheat and cotton yield.

Regressors	*Coefficient for Wheat*		*Coefficient for Cotton*	
	Short-Run	**Long-Run**	**Short-Run**	**Long-Run**
Constant	-	4.776 (2.27)*	-	-5.441 (2.01)
Δ WP_t	0.155 (1.37)**	0.693 (1.50)**		
Δ CP_t	-0.121 (-1.51)**	-0.264 (-1.65)**	0.283 (1.84)*	1.09 (3.53)*
Δ FP_t	-	-0.498 (-1.36)**	-0.305 (-2.15)*	-0.676 (-3.71)*
HYWA	0.064 (3.56)*			
RBWA	0.410 (4.43)*			
IA			1.29 (4.04)*	
RF	-0.043 (-1.77)*		-0.061 (-2.54)*	
EC_{t-1}	-0.425 (-3.95)*		-0.411 (-3.86)*	
Diagnostic Tests				
R^2	0.42		0.42	
LM-χ^2 (1)	1.97		0.031	
LM-χ^2 (2)	5.13		1.85	
LM-χ^2 (3)	5.16		1.86	
LM-χ^2 (4)	5.71		3.11	
RESET-χ^2 (1)	1.38		0.044	
Jarque-Bera Normality-χ^2 (2)	2.29		0.432	
Wald Test-χ^2 (2)	4.32		5.28	

Notes: 1) t-ratios in the parentheses; 2) (*) (**) Indicates significance at the 5 and 10 per cent levels respectively.

The coefficient on the error correction (EC) term has the expected sign and measures adjustments towards long-run equilibrium. The coefficients of -0.425 and –0.411 indicates that the deviation of wheat and cotton yield from the long-run equilibrium level is corrected by about 43 and 41 per cent respectively in the current period. A possible rationale for this slow adjustment may be the technical characteristics of agricultural production in Pakistan, i.e., as with industrial firms, farmers in the short run have a fixed capacity in terms of land, buildings and capital equipment and this may constrain the process of adjustment in response to rising output prices.

All diagnostic tests for model adequacy give acceptable results and are below the critical values. The error correction specification of the model is tested against the more restrictive partial adjustment model by imposing zero restrictions on the parameters of the difference terms. The Wald test yields a χ^2 of 4.32 for wheat and 5.28 for cotton. These values are below the 5 per cent critical values but above the critical values at the 10 per cent level, so at the 5 per cent level additional restrictions imposed by the partial adjustment model are accepted and it is not clear that the ECM is an improvement over the partial adjustment model.

SUMMARY AND CONCLUSIONS

This paper examines the supply (yield) response for wheat and cotton in Pakistan using cointegration analysis and annual data for 1960-96. The wheat yield is dependent on the prices of wheat, cotton and fertilizer, the percentage area under high yielding wheat varieties, water availability during rabi season, and rainfall. The cotton yield depends on the real cotton price, the real fertilizer price, the irrigated area and rainfall.

Our results for both wheat and cotton suggests that they are responsive to own prices and their supply can be increased by increasing their support price. However, an increase in the cotton price have significant negative effects on wheat yield. An alternative strategy for increasing wheat production could be to develop late sowing wheat varieties or early maturing cotton varieties so that wheat sowing and cotton harvesting do not coincide.

Our results also indicate that high fertilizer prices has a negative effect on the supply of these crops. This suggests that low fertilizer prices may enhance production of these crops. Subsidising the fertilizer price may be one way to increase crop output but if the additional demand created by subsidising an input cannot be met by enhancing input supplies, as now is the case for fertilizer in Pakistan, this results in shortages and additionally, it will cause disturbances in the distribution system. Therefore, the emphasis should be given to providing sufficient quantities of fertilizer rather than to providing fertilizer at subsidised rates and this can be achieved by promoting competition among private suppliers. The open market mechanism can improve the access to input supplies, timely input availability, as well as timely application.

Our results also indicate that technology and irrigation in particular are important non-price factors in explaining yield response. Thus to achieve policy objectives, instruments should include technological improvements which may include the development of irrigation schemes, raising productivity through the introduction of further HYVs, education and extension, and infrastructural development with the price policy playing an important secondary role.

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Notes:

[1] Model 1 accounts for no intercepts and no deterministic trends in the cointegrating 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 unlikely ever increasing or decreasing growth rate.

[2] A large part of the wheat acreage under HYVs is sown with improved but uncertified seeds. The annual supply of improved certified seeds between 1990-91 and 1993-94 averaged around 47000 tonnes, indicating that only 6 kgs/hectare of certified improved seeds were available to wheat growers (against an average seed rate of 90 kgs/hectare) (Government of Pakistan, 1993-94). Thus, a very small percentage of the wheat acreage is sown with certified improved seeds. About 40 per cent of the wheat acreage is cultivated with improved but disease-prone older varieties which are no longer recommended (Government of Pakistan, 1988).

[3] Rainfall for different months were tried and that for the months of January-February only appears to have a significant negative effect on the wheat yield. This is the time of grain formation and any amount of rainfall during this period affects the yield adversely, i.e., a one per cent increase in rainfall decreases the wheat yield by 0.043 per cent.

[4] Rainfall during the months of July-August adversely affects the cotton yield because this is the time of boll formation.