The Pakistan Development Review
32:4 Part II (Winter 1993) pp. 751–769

The Demand for Inputs and the Supply of Output in Pakistan: Estimating a Fixed-effects, Distributed-lag Model for Wheat Farmers

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INTRODUCTION

Agricultural growth in Pakistan over the past 3 decades has been very impressive, averaging 3.3 percent annually over the period 1965–80, and accelerating to 4.3 percent per year over the period 1980–90. But as impressive as these numbers are, questions arise regarding the success of the agricultural sector in terms of meeting food and employment needs, the potential for continuing or increasing growth rates in the future, the likely sources of future agricultural growth, and the technologies, policies, and institutional arrangements necessary to achieve that growth.

The truth is that agriculture in general, and food production in particular, have been working hard to just to keep pace with other sectors and with the food needs of the domestic population. Agriculture was the slowest growing sector in Pakistan over the past 30 years, with general economic expansion moving along at an average of 5.2 percent annually over the 1965–80 period, and of 6.3 percent per year over the decade of the 1980s. In addition, in spite of very substantial production and productivity gains for most major crops, the average index of food production per capita remained constant over the 1980–90 period, while the total volume of cereal imports nearly doubled to over 2,048,000 metric tons [World Development Report (1992)].

And the future could be worse. Growth rates in agricultural productivity may not continue at historical levels, and the population growth rate is likely to continue

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Authors' Note: Sincere thanks go to Dipa Nag-Chowdhury, Holly M. Hapke, Jafar Raza, Sumiter Broca, and the many efficient and dedicated assistants in the IFPRI-Pakistan office for their work in organising thousands of computer records into useful data. Without their efforts, this research could never have been undertaken. Special thanks also go to Lourdes Hinayon and Julie Witcover for manuscript preparation and review, respectively. Important insights were provided by Sohail J. Malik and Zakir Hussain. All errors are ours. This research was completed under USAID to Pakistan Grant Number 391-0492-G-00-1791-00 for the Ministry of Food and Agriculture, Government of Pakistan.

at (or around) 3.0 percent annually for some time, thereby almost guaranteeing a population of over 150 million by the end of the century, and perhaps 250 million by the year 2025. Frighteningly, some estimates of the hypothetical size of a stationary Pakistani population are as high as 400 million people by the middle of the next century [World Development Report (1992)].

That is a lot of mouths to feed and able-bodied individuals to employ, and agriculture will clearly have to do its share in meeting both needs, though rural-to-urban migration and intersectoral shifts in employment and growth emphases towards non-agricultural sectors suggest that a disproportionately large share of the burden will be borne by these sectors. But agriculture must grow, and the challenges for the 1990s (and indeed the next 25 years) is to identify potential sources of growth, and select and implement policies that promote it.

Historically, promoters of agricultural growth have focused their attention on bringing more area under plow, principally via the extension of large-scale irrigation projects, and on generating and disseminating higher-yielding varieties of basic cereal crops. As we look to the future, it is not clear whether these will continue to be the principal sources of growth over the next quarter-century. Indeed, the absolute amount of net cropped area (currently about 27 percent of total surface area in Pakistan, after an increase of 0.4 percent per year over the 1965–89 period) may even fall in the future due to urban encroachment and environmental degradation (principally soil salinity and waterlogging). Irrigated area (which stands at an astonishing 63 percent of total agricultural area) will be difficult and very expensive to increase broadly. In addition, yields among Pakistan's most productive farmers may not increase very much at all [Government of Pakistan (1991); World Development Report (1992)]. Therefore, we must look for different sources of productivity increases to fuel agricultural growth, and help meet poverty and environmental management goals as well. Potential sources of future growth are: increases in gross cropped area via reduction in fallow periods, with proper care taken not to degrade the natural resource base; increases in labour productivity; increases in the application of traditional and chemical fertilizers, in both rainfed and irrigated areas; improvements in the quality of existing large-scale irrigation systems; increases in area serviced by small-scale irrigation projects, with particular focus on tubewell irrigation; and, generally improving farm management practices [Nag-Chowdhury and Vosti (1992)]. The sources of future agricultural growth will certainly differ across regions, as will the policies needed to promote growth. It is noteworthy that much of Pakistan's future agricultural growth may have to come from its currently poorest and least productive farmers [Raza and Vosti (1992)].

Perhaps our best indicator of likely sources of future agricultural growth is the set of factors that influenced very recent agricultural change. The more we know about how farmers make resource (including human resource) allocation decisions, the more likely we are to identify the technological and policy "hooks" on which to hang our hopes for the future of Pakistani agriculture [Reardon and Vosti (1992)].

This paper uses a 1986–89 panel of farm-level data from several regions in

Pakistan to examine the factors influencing the supply of wheat, and the demand for the various purchased and farm-produced inputs that go into wheat production. An analytical framework capable of capturing farm-level fixed effects and allowing for inter-farm differences in responses to changes in the agroeconomic environment is introduced. A fixed-effects, distributed-lag model derived from this framework is estimated, and the results interpreted. Conclusions and policy implications derived from the empirical results are presented, and avenues for future research are suggested.

ANALYTICAL FRAMEWORK

A Static Model of Input Demand and Output Supply

The starting point for analysing farm input and output decisions is the set of crop production functions

$$Y_{ij} = \alpha_i + f_j(X_{ij}, A_{ij}), \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where i indexes a farm, j indexes a crop, Y is the output harvested, X is the vector of variable inputs (such as tractor and bullock services, fertilizer, labour, etc.), and A is cropped area. The individual crop production functions represent the agricultural technology in use, and indicate the maximum physical output that can be obtained from the applied inputs. Of special interest here is the unobserved, farm-specific intercept, α_i that may represent the managerial ability of the farmer or the unobserved attributes of the farm, such as soil quality.

The restricted farm profit function can then be derived under the assumption that farmers maximise total farm profits, for a given season,

$$\Pi = \Sigma_j \, p_j \, Y_j - \Sigma_j \, q \, X_j, \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where p_j is the price of crop j and q is the vector of input prices, subject to their total land constraint, viz.,

$$\Sigma_j A_j = A, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

where A is the total amount of land (size of operational holding) available.

While the crop production functions assume technical efficiency on the part of farmers, the restricted farm profit function assumes price (or allocative) efficiency.[1] It is possible to derive the profit function from the individual crop production functions, and *vice versa*.[2] The profit function is:

[1]Although this assumption can be tested, given availability of appropriate data.

[2]While this is possible in principle, the derivation may not always be tractable, depending upon the functional form assumed for the production or profit functions.

$$\Pi_i = \Pi(p_1, p_2 \ldots, p_n, q, A_i, \alpha_i). \qquad \ldots \qquad \ldots \qquad (4)$$

The demand functions for variable inputs X are given by the relation:

$$X(p_1, p_2, \ldots, p_n, q, A_i, \alpha_i) = -\partial\Pi(\cdot)/\partial q, \qquad \ldots \qquad \ldots \qquad (5)$$

while the output supply function (not to be confused with the production function) for crop j is given by:

$$Y_j(p_1, p_2, \ldots, p_n, q, A_i, \alpha_i) = -\partial\Pi(\cdot)/\partial p_j.^3 \qquad \ldots \qquad \ldots \qquad (6)$$

Equations (5) and (6) represent the reduced-form system of input demand and output supply equations. There are several points worth noting about this demand system. *First*, since the farmer is assumed to maximise total profits and since there may opportunities for substituting across various inputs and across crops, all input and output prices enter the demand relation for each input and the supply relation for each crop. Thus, not only will the rental price of bullocks influence the demand for bullock services and that for tractor services (which may be close substitutes), but they may also affect the demand for fertilizer. Likewise, the prices of all possible crops that can be cultivated will influence the demand for each factor and the supply of every crop. This realistic approach to demand interrelationships is consistent with theory and common sense, but differs greatly from standard single-equation, single product estimation production [see, for example, Government of Pakistan (1991a), p. 3].

Second, within the above model, total cropped area as well as the area under individual crops are choice variables for the farmer; therefore, these do not enter the system of input demand and output supply equations. Instead, what enters the system is the variable A–the size of operational holding–which is treated as a fixed factor of production in the short term. Of course, to the extent that farmers can lease in and lease out land for cultivation, even the size of operational holding is not a fixed factor in the medium or long term. However, since tenancy contracts may be difficult to adjust in the short run, the assumption that the size of the operational holding is not a variable factor in the short run is not unrealistic.

Third, the unobserved, farm- (or farmer-) specific effect, α_i, enters the system of input demand and output supply equations. Indeed, this is an important reason why ordinary least squares estimates of the crop production functions in (1) are likely to be biased. In OLS estimates of a production function, any fixed effects, such as α, are included in the disturbance term. Since the demand for all inputs will necessarily depend on these unobserved endowments (e.g., managerial ability, soil quality, locational advantage, etc.), the disturbance term in the production function

[3] These relations are proven in McFadden (1970) and Lau (1969).

is correlated with the included independent variables. As a result, OLS estimates of the production function will be biased.

Fourth, the effects of prices and fixed factors obtained in the input demand and output supply system are *mutatis mutandis* (as opposed to *ceteris paribus*) effects. This means that the estimated effect of wages on, say, the demand for tractor services reflects the (total) effect on tractor use of a change in wage rates after allowing all other inputs and outputs to also adjust to the wage rate change. Thus, even though labour and tractor services may be complementary inputs, an increase in wage rates could reduce output and thereby the demand for tractor services. If this (negative) output effect is larger than the (positive) substitution effect, the demand for tractor services could fall with an increase in wages.

The estimated parameters of the reduced-form demand model can be used to analyse the impact of policy changes on a number of behavioural variables. For instance, the estimated model can be used to simulate the effects of, say, a higher procurement price for wheat (holding other prices and policy variables constant) on the demands for labour (hired and family, male and female), bullock and tractor services, fertilizer, and other inputs. The model also allows us to trace the simultaneous impact of several different policy changes–say, a reduction in fertilizer and tractor subsidies–on input use.

It is possible to control for the unobserved fixed effects, α_i, in estimating the reduced-form input demand and output supply equations with panel data. Assuming a linear functional form for the demand/supply equations,[4] Equations (5) and (6) can be written as:

$$X_{it} = \alpha_i + a\, p_{it} + c\, q_{it} + d A_{it}, \qquad \ldots \qquad \ldots \qquad (7)$$

and

$$Y_{it} = \alpha'_i + a' p_{it} + c' q_{it} + d' A_{it}. \qquad \ldots \qquad \ldots \qquad (8)$$

First-differencing the two equations yields:

$$\Delta X_i = a \Delta p_i + c \Delta q_i + d \Delta A_i, \qquad \ldots \qquad \ldots \qquad (9)$$

and

$$\Delta Y_i = a' \Delta p_i + c' \Delta q_i + d' \Delta A_i, \qquad \ldots \qquad \ldots \qquad (10)$$

where ΔZ is the first-difference operator (viz., $\Delta Z = Z_{it} - Z_{i,t-1}$). Estimation of the first-differenced Equations (9) and (10) by the ordinary least squares method provides unbiased and consistent estimates of parameters in Equations (7) and (8).

[4]The assumption of the fixed effect, α_i, entering linearly in the input demand and output supply equations is critical to the estimation.

A Dynamic Model of Demand Adjustment

So far we have assumed a static framework in which farmers can respond to price and other policy changes instantaneously. In fact, adjustment may be slow and spread out over several years. If this is the case, the current demand for inputs should be a function not merely of current prices but of past prices as well. Rewriting the input demand and output supply Equations in (7) and (8), we would have:

$$X_{it} = \alpha_i + \beta_0 Z_{it} + \beta_1 Z_{i,t-1} + \cdots + \beta_k Z_{i,t-k}, \quad \ldots \quad (11)$$

$$Y_{it} = \alpha'_i + \beta'_0 Z_{it} + \beta'_1 Z_{i,t-1} + \ldots + \beta'_k Z_{i,t-k}, \quad \ldots \quad (12)$$

where the vector Z includes all the independent variables, p_1, p_2 ...., p_n, q, and A. Estimation of (11) and (12) would require an infinite time series of data; however, if one makes the assumption that the β_j's decline geometrically, i.e., $\beta_1 = \lambda\ \beta_0$, $\beta_2 = \lambda^2\ \beta_0$, $\beta_3 = \lambda^3 \beta_0$, ..., $\beta_k = \lambda^k\ \beta_0$, and $0 < \lambda < 1$, Equations (11) and (12) reduce to:

$$X_{it} = \alpha_i + \beta_0 Z_{it} + \beta_0 \lambda Z_{i,t-1} + \ldots + \beta_0 \lambda Z_{i,t-k}, \quad (11a)$$

$$Y_{it} = \alpha'_i + \beta'_0 Z_{it} + \beta'_0 \lambda' Z_{i,t-1} + \ldots + \beta'_0 \lambda' Z_{i,t-k}. \quad (12a)$$

For the time period $t-1$, we have:

$$\lambda X_{it-1} = \alpha_i + \beta_0 \lambda Z_{i,t-1} + \ldots + \beta_0 \lambda\ Z_{i,t-k-1}, \quad \ldots \quad (11b)$$

$$\lambda Y_{it-1} = \alpha'_i + \beta'_0 \lambda' Z_{i,t-1} + \ldots + \beta'_0 \lambda' Z_{i,t-k-1}. \quad \ldots \quad (12b)$$

Subtracting (11b) from (11a) and (12b) from (12a), we get

$$X_{it} - \lambda X_{it-1} = \beta_0\ Z_{it} \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

$$Y_{it} - \lambda Y_{it-1} = \beta'_0\ Z_{it}, \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

or

$$X_{it} = \lambda X_{it-1} + \beta_0\ Z_{it} \quad \ldots \quad \ldots \quad \ldots \quad (15)$$

$$Y_{it} = \lambda Y_{it-1} + \beta'_0\ Z_{it}. \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

This is a standard distributed-lag model, with the lagged value of the dependent variable occurring on the right-hand side of the equation. Note that the distributed-lag model not only permits the assumption of farmers gradually (as opposed to instantaneously) adjusting to price and other exogenous changes, but it also controls for unobserved fixed effects, α_i. In this sense, it is superior to the static fixed-effects model (contained in Equations (9) and (10) [Behrman *et al.* (1992); Koyck (1954)].

Functional Form

The only major question that remains is of functional form. If the underlying profit function is of the generalised quadratic form, viz.,

$$\Pi = \alpha + b_0 p + \tfrac{1}{2} b_1 p^2 + b_2 q + \tfrac{1}{2} b_3 q^2 + \tfrac{1}{2} b_4 p q + b_5 A + \tfrac{1}{2} b_6 A^2 + \tfrac{1}{2} b_7 p A + \tfrac{1}{2} b_8 q A + \tfrac{1}{2} b_9 p \alpha + \tfrac{1}{2} b_{10} q\alpha + \tfrac{1}{2} b_{11} A \alpha, \quad \ldots \quad (17)$$

where the subscripts i and t have been dropped, the input demand and output supply equations can be obtained as the first derivatives of the profit function with respect to q and p, respectively (see Equations (5) and (6)).This yields:

$$-X = b_2 + b_3 q + \tfrac{1}{2} b_4 p + \tfrac{1}{2} b_8 A + \tfrac{1}{2} b_{10} \alpha \quad (18)$$

$$Y = b_0 + \tfrac{1}{2} b_4 q + b_1 p + \tfrac{1}{2} b_7 A + \tfrac{1}{2} b_9 \alpha. \quad (19)$$

Thus, the appealing feature of the generalised quadratic profit function is that the resulting input demand and output supply equations are linear in parameters.

To control for fixed effects, α, the Equations in (18) and (19) can be estimated in first-differenced form. As discussed earlier, a dynamic adjustment model would lead essentially to the same estimating equations, but with the lagged value of the dependent variable as an additional right-hand side variable.

EMPIRICAL MODEL

The model developed above treats cropping pattern as a choice variable, and enables us to analyse the demand for inputs used in all crops and the output supply of all crops. However, for the purposes of this exercise, we have confined the analysis to a single crop, viz., wheat, one of the principal agricultural outputs in Pakistan [Hapke and Vosti (1992)]. We have used the IFPRI Pakistan panel data for three rounds: *Rabi* 1986-87, *Rabi* 1987-88, and *Rabi* 1988-89. This provides us with 720 observations over three rounds.

In all, information on one output (viz., harvested quantity of wheat in maunds–1 maund = 40 kilograms) and thirteen inputs is available for the three rounds. The inputs are hired labour use (in days per season), family male labour, family female labour, tractor use (hours), bullock use (days), farm manure use (number of carts), fertilizer use (total as well as DAP, urea, and nitrogen) (number of 50 kilogram bags), number of weedings, number of irrigations after planting, and number of ploughings. Descriptive statistics and variable labels appear in Table 1.

Table 1

Descriptive Statistics and Variable Labels

	Descriptive Statistics – Wheat Production		
Variable Description	Units of Measure	Mean	Standard Deviation
Bullock Hire Rate	1986 Rupees per Day	147.9	268.1
Bullock Days	Days	11.9	1.3
Canal-irrigated Land	Acres	8.4	11.8
DAP	50 Kg Sacks	2.1	5.0
Female Family Labour	Days	3.2	87.2
Hired Labour	Days	19.6	84.9
Male Family Labour	Days	63.4	11.3
Manure	Carts	3.7	8.0
Nitrogen	50 Kg Sacks	1.0	3.0
Number of Irrigation	Number	2.4	2.8
Number of Ploughings	Number	4.0	2.6
Number of Weedings	Number	0.2	0.7
Rainfed Land	Acres	2.3	6.4
Rural Wage	1986 Rupees per Day	38.7	12.0
Total Family Labour	Days	66.7	13.1
Total Fertilizer	Sacks	7.0	7.2
Tractor Hire Rate	1986 Rupees per Hour	65.3	5.7
Tractor Hours	Hours	6.8	20.1
UREA	50 Kg Sacks	3.4	4.7
Well-irrigated Land	Acres	0.0	50.4
Wheat Harvested	Maunds	64.0	86.2
Wheat Price	1986 Rupees per Maund	90.4	13.1

The resulting input demand and output supply system has one output price (viz., wheat) and three input prices (rental price of bullocks, rental price of tractor services, and wage rate for labour) as explanatory variables (all expressed in terms of 1986 Rupees). In addition, fixed factors of production in the system are acres of rainfed land, canal-irrigated and well-irrigated land in the operational holding. Dichotomous variables for the different *Rabi* seasons are also included as shift variables.

Household-level input and output prices were not used because differences in "unit values" (amount paid or received per unit of an input or output quantity) reported by households may reflect quality variations rather than genuine price variation. Instead, prices reported by farm households were averaged over the four districts and three rounds. As a result, the price variation in the sample is somewhat limited. In addition, data on fertilizer prices were not available at the time this model was estimated and therefore were not included in this demand system. This obvious shortcoming will hopefully be remedied in subsequent versions of this paper.

EMPIRICAL RESULTS

Parameters estimates from the fixed-effects, distributed-lag model of the input demand and output supply system are reported in Table 2. *T*-ratios appear beneath each of the parameter estimates, and summary statistics for each equation appear in the final two columns of Table 2. Since the system is linear in parameters, the coefficients represent the change in input use or output quantity due to a unit change in price or land holding. The corresponding elasticities, evaluated at the sample means of variables, are calculated and reported in Table 3.

Several points can be made about these estimates. *First*, a large number of estimated effects in the demand system are significant. For example, the majority of the 56 price effects estimated (tractor hire rate, bullock hire rate, wheat price, and wage rate) were statistically significantly different from zero at the 10 percent level. Canal-irrigated land is significant in 10 of the 14 equations estimated, while rainfed land is significant in 9 equations. The parameters are thus estimated with a high level of precision. The explanatory power of the regressions is also generally high; for example, the included prices, fixed factors, and lagged dependent variable account for 77 percent of the variation in wheat output. The R^2's of the other equations are also relatively high.

Second, the estimated effects of the rental price of tractor services are very large in magnitude. The tractor price elasticity of input demand and output supply (see Table 3, Column 1) ranges from –39 (for family female labour use) to 19 (for manure demand), suggesting very strong links between mechanisation costs and the use of other farm inputs.

Third, estimated wheat price effects are consistent with the *a priori* predictions of the analytical framework. The profit maximisation model predicts the impact of output price on output supply and most input demands to be positive. The estimated model indicates a very strong supply response (with an elasticity of harvested output with respect to the wheat price of 3.0), and strong positive effects of wheat price on the demand for manure and fertilizer (especially urea and nitrogen). However, wheat prices are estimated to significantly depress the demand for family labour, especially family female labour. These negative effects on labour demand probably reflect an income effect: increase in wheat prices (the dominant

Table 2

Input Demand Equations, Dynamic Model Estimates, Pakistan Panel, 1986-87 to 1988-89

Dependent Variable	Estimate	Intercept	Lagged Dependent Variable	*Rabi* 1987-88	*Rabi* 1988-89	Tractor Hire Rate	Bullock Hire Rate	Wheat Price	Wage Rate	Operational Holding (Acres): Rainfed	Operational Holding (Acres): Canal-irrigated	Operational Holding (Acres): Well-irrigated	*F*-Ratio	*R*-Square
Wheat	Parameter	–564.353	0.603	–41.511	–32.360	7.273	–0.01	1.945	–1.391	1.446	2.094	2.334	235.540	0.769
Harvested	*T*-ratio	–5.3	24.5	–3.2	–1.9	6.9	–1.0	3.4	–4.4	4.8	11.8	0.3		
Hired Labour	Parameter	–184.987	0.482	–13.051	–20.566	2.656	0.007	0.659	–0.845	1.627	0.970	–3.528	21.890	0.236
	T-ratio	–1.7	9.0	–1.0	–1.1	2.6	0.7	1.1	–2.7	5.4	5.7	–0.4		
Family Male	Parameter	396.406	0.698	–73.744	–36.226	2.224	0.036	–2.962	–5.391	0.641	0.073	1.797	148.020	0.676
Labour	*T*-ratio	3.3	13.1	–4.8	–1.8	2.0	3.1	–4.3	–15.1	1.9	0.4	0.2		
Family	Parameter	254.586	0.201	30.378	34.569	–2.266	–0.019	–1.385	–0.108	–0.001	0.062	0.031	26.470	0.272
Female Labour	*T*-ratio	10.6	6.8	10.2	8.7	–10.0	–8.2	–10.4	–1.6	0.0	1.7	0.0		
Tractor	Parameter	3.116	0.747	–7.475	–5.857	0.180	–0.004	–0.044	–0.090	0.252	0.112	0.436	54.570	0.435
Hours	*T*-ratio	0.1	18.8	–2.4	–1.4	0.8	–1.6	–0.3	–1.3	3.7	2.9	0.2		
Bullock Days	Parameter	68.852	0.631	–18.979	–7.466	0.816	0.009	–0.625	–1.327	0.034	0.068	0.257	63.650	0.473
	T-ratio	1.8	10.3	–4.0	–1.2	2.3	2.5	–3.0	–12.2	0.3	1.2	0.1		
Manure	Parameter	–56.487	0.048	–4.633	–3.844	0.911	–0.001	0.143	–0.227	–0.031	–0.033	–0.608	12.430	0.149
	T-ratio	–2.9	1.5	–2.0	–1.2	5.0	–0.3	1.4	–4.3	–0.6	–1.2	–0.5		
Total	Parameter	–65.324	0.435	11.378	–8.797	1.010	0.001	0.260	–0.355	0.192	0.198	–0.597	31.120	0.305
Fertilizer	*T*-ratio	–3.0	7.3	–4.3	–2.5	4.9	0.3	2.2	–5.8	3.1	5.7	–0.4		
DAP	Parameter	–12.092	0.090	–3.347	–0.945	0.280	–0.002	0.023	–0.150	0.119	0.088	0.186	12.020	0.145
	T-ratio	–1.1	1.3	–2.4	–0.5	2.6	–1.4	0.4	–4.6	3.7	4.9	0.2		
Urea	Parameter	–38.948	0.208	–5.503	–4.708	0.540	0.000	0.164	–0.138	0.094	0.096	–0.299	19.600	0.217
	T-ratio	–3.7	3.7	–4.2	–2.7	5.4	0.2	2.8	–4.6	3.3	5.7	–0.4		
Nitrogen	Parameter	–16.747	0.123	–1.380	–1.698	0.189	0.000	0.086	–0.037	0.068	0.025	–0.368	6.530	0.084
	T-ratio	–2.4	2.3	–1.6	–1.4	2.8	0.3	2.2	–1.8	3.4	2.4	–0.7		
No. of	Parameter	2.845	0.002	0.042	0.678	–0.027	–0.001	–0.010	–0.008	0.002	–0.001	–0.097	7.000	0.090
Weedings	*T*-ratio	1.7	0.2	0.2	2.4	–1.6	–3.7	–1.1	–1.5	0.5	–0.6	–0.8		
No. of	Parameter	–18.342	0.117	–3.143	–2.404	0.367	0.001	0.012	–0.069	–0.011	0.014	–0.135	59.800	0.458
Irrigations	*T*-ratio	–3.5	1.9	–4.7	–2.8	7.3	2.5	0.4	–4.7	–0.8	1.8	–0.4		
No. of	Parameter	–21.705	0.083	–2.758	–2.363	0.478	0.000	0.016	–0.14	0.022	0.011	–0.198	82.510	0.538
Ploughings	*T*-ratio	–4.8	1.7	–5.0	–3.3	10.7	1.1	0.7	–11.2	1.9	1.7	–0.6		

Table 3

Elasticities of Input Demand, Dynamic Model Estimates, Pakistan Panel, 1986-87 to 1988-89

Elasticity of	With Respect to						
					Operational Holding (Acres)		
	Tractor Hire Rate	Bullock Hire Rate	Wheat Price	Wage Rate	Rainfed	Canal-irrigated	Well-irrigated
Wheat Harvested	**8.094**	–0.026	**2.960**	**–0.935**	**0.051**	**0.308**	0.001
Hired Labour	**9.735**	0.062	3.302	**–1.869**	**0.189**	**0.469**	–0.003
Family Male Labour	**2.392**	**0.090**	**–4.355**	**–3.501**	**0.022**	0.010	0.000
Family Female Labour	**–38.571**	**–0.755**	**–32.247**	**–1.107**	0.000	**0.139**	0.000
Tractor Hours	1.855	**–0.088**	–0.627	–0.559	**0.083**	**0.153**	0.001
Bullock Days	**4.867**	**0.128**	**–5.100**	**–4.783**	0.007	0.054	0.000
Manure	**18.353**	–0.026	3.946	**–2.761**	–0.020	–0.088	–0.003
Total Fertilizer	**10.509**	0.014	**3.697**	**–2.230**	**0.063**	**0.273**	–0.002
DAP	**9.828**	–0.129	1.092	**–3.191**	**0.132**	**0.407**	0.002
Urea	**11.485**	0.008	**4.762**	**–1.767**	**0.064**	**0.269**	–0.002
Nitrogen	**13.868**	0.031	**8.607**	**–1.665**	**0.158**	**0.247**	–0.007
No. of Weedings	**–9.135**	**–0.481**	–4.822	–1.562	0.024	–0.065	–0.008
No. of Irrigations	**10.252**	**0.083**	0.470	**–1.173**	–0.010	**0.053**	–0.001
No. of Ploughings	**8.194**	0.019	0.384	**–1.453**	**0.012**	**0.025**	–0.001

Notes: Figures in bold indicate statistical significance at the 10 percent level.

crop for many households) improves income and prompts the substitution of purchased inputs for family labour.

Fourth, the bullock price elasticities are generally small in magnitude. The own-price effect of bullock rental rates on the demand for bullock services is estimated to be positive (although, at 0.128, the elasticity is small). This slightly positive slope to the bullock "demand curve" is quite plausible if bullock ownership is common among sample households, and price variations over time are a consequence of demand, and not supply, shifts. Increased bullock rental rates led to increased demand for family male labour (as a consequence of increased bullock use), but reduced demand for family female labour.

Fifth, the estimated wage rate effects on labour demand and output supply are generally well-behaved. They are consistently estimated to be significantly less than zero. The results suggest that a one percent increase in the wage rate reduces harvested wheat output by about 1 percent, hired labour use by 1.9 percent, and family male labour by 3.5 percent. These results suggest that as the market wage increases, male family members switch from own farming to other activities (including paid, wage labour). Female members participate less frequently in wage labour markets and do not seem to substitute for males (family or hired) as wages rise.

The estimated effect of the wage rate on bullock use is highly negative (elasticity of –4.8), again confirming the strong complementarity between bullock and human labour. The statistically insignificant wage elasticity of tractor services indicates that there is a greater degree of complementarity between bullocks and labour than between tractors and labour. Finally, the estimated effects of the wage rate on fertilizer demand (particularly, DAP) are very strongly negative. A one percent increase in wages is estimated to reduce the demand for DAP by as much as 3.2 percent, indicating strong complementarity between fertilizer and labour use.

Sixth, the effects of the quantity of land holding by access to irrigation on input demand and output supply are also generally in line with *a priori* expectations. Of the two types of irrigation, only canal irrigation appears to have a strong impact on input demand and output supply; well irrigation had virtually no significant effects on farmer behaviour, perhaps due to the limited presence of tubewells in our sample of wheat farmers. All of the estimated land holding effects that are significantly different from zero are positive, implying that an increase in land holding (almost regardless of access to canal water) increases the harvested quantity of wheat and the demand for most inputs. However, the elasticities based on estimated parameters for canal-irrigated areas are generally much larger than the rainfed elasticities. For example, an increase in canal-irrigated land is observed to have much larger effects on wheat supply than an increase in rainfed land (elasticities of 0.31 and 0.05, respectively), suggesting that canal-irrigated land is roughly six times as productive as rainfed land. The elasticities of fertilizer and tractor use with respect to canal-irrigated land are two to three times as large as those with respect to rainfed land.

The coefficients on the lagged dependent variable (the λ's) in the distributed-lag model indicate the speed of farmer response over time. The smaller the value of λ, or the larger the value of the "adjustment parameter" (1–λ), the smaller is the lag between the independent variables and the dependent variables. The estimates in Table 4 imply that the speed of responding to price and other agroeconomic changes is the longest for tractor use, family male labour, bullock labour, and output, but that farmers do adjust inputs, such as fertilizer, family female labour, weeding, ploughing and irrigation practices, rapidly as prices or other factors change. However, due to market rigidities and supply constraints, other inputs take much longer to fully adjust to the price and other shocks.

Table 4

Estimates of λ and the Speed of Adjustment

Variable	Estimate of λ	Adjustment Parameter (1 – λ)
Wheat Harvested	**0.603**	**0.397**
Hired Labour	**0.482**	**0.518**
Family Male Labour	**0.698**	**0.302**
Family Female Labour	**0.201**	**0.799**
Tractor Hours	**0.747**	**0.253**
Bullock Days	**0.631**	**0.369**
Manure	0.048	0.952
Total Fertilizer	**0.435**	**0.565**
DAP	0.090	0.910
Urea	**0.208**	**0.792**
Nitrogen	**0.123**	**0.877**
No. of Weedings	**0.002**	**0.998**
No. of Irrigations	**0.117**	**0.883**
No. of Ploughings	**0.083**	**0.917**

Notes : Figures in bold indicate statistical significance at the 10 percent level.

CONCLUSIONS AND POLICY IMPLICATIONS

We have found that a distributed-lag model, in which farmers are presumed to adjust their inputs and outputs gradually over time in response to price and other changes, offers plausible estimates for the Pakistan panel of wheat farmers over the 1986–89 period, and highlights the nature of farm-level resource allocation and production decisions.

The model confirms the highly interrelated nature of input use, and the policies known to influence it. Where statistically significant, own-price elasticities were generally in line with theoretical predictions. More importantly, many of the cross-price elasticities were statistically significant and quite strong, emphasising the need for comprehensive analyses of the responses by farmers to policy shifts. For example, the model suggests that an increase in the price of wheat will not only increase output of wheat, but also increase the demand for key purchased and farm-produced inputs. Therefore, an increase in the price of wheat might more than offset any (supposed, but not estimated here) decrease in total fertilizer use brought about by the removal of a price control on that important input. In addition, the elasticities associated with input changes in response to a change in wheat prices are not equal, suggesting a change in production technology, which policy-makers need to be aware of.

The substitutability of agricultural mechanisation for some types of rural labour was borne out by the data, and this model. Increases in tractor use in response to a decrease in tractor hire rates (a likely, but not statistically demonstrable effect in these data), would lead to a decrease in the quantity of hired and family male labour used, and an increase in family female labour used. Therefore, areas experiencing rapid rates of agricultural mechanisation should pay close attention to rural unemployment, and potentially initiate programmes to increase off-farm, and perhaps non-agricultural employment opportunities.

Input demand and output supply responses to increases in land availability were uniformly positive, and particularly strong for canal-irrigated areas. The output relation is well known, but the implications of increased canal irrigation for hired labour and fertilizer use (strong increases in demand, for all cases) is a clearly beneficial side-effect, perhaps achievable without any additional price policy intervention.

Changes in rural wages clearly affect farm production, as well as input choice. Labour is a key ingredient to agricultural production, and its sparing use in the face of increases in wage rates is likely (according to this model) not to be fully compensated for by the use of other inputs. Indeed, use of virtually all other inputs declines along with labour input when wages rise. The most logical substitute for labour, mechanical traction, does not seem to react to wage increases, suggesting some imperfections in rental and purchase markets for tractors.

Finally, the speed with which different output and factors of production reacted to price and other agroecological changes differed greatly. Farming practices, such as the number of weedings, irrigations, and ploughings, were quickest to adjust–usually making complete transitions in a single period or season. Adjustments to fertilizer application rates were slightly slower, but still managed to complete the transition in a single season, more or less. Labour use displayed a more diverse pattern of adjustment. Family female labour adjusted quickly, followed by hired labour, ending with family male labour, which took several periods to make complete adjustments. Limited off-farm labour opportunities for females, functioning daily hired and other labour markets for males, and fairly rigid on-farm responsibilities for family males are likely explanations for differences in speed of adjustment across labour groups. Improvements in rural labour markets could speed transitions for some of these groups.

There are several ways in which the research reported in this paper will be extended. First, an attempt will be made to include fertilizer prices paid by farmers in the sampled provinces. This will enable estimation of fertilizer price elasticities. Second, multi-crop input demand and output supply systems could be estimated with data on several alternative crops during the *Rabi* season. Third, analysis will be extended to include a separate input/output demand system for the *Kharif* season. Fourth, we will attempt to control for differences across villages as regards key agroecological characteristics known to affect crop choice and production technology decisions. Fifth, we will attempt to decompose the "fixed effects" into farmer and farm-specific components relevant for policy and future research. Finally, the very large elasticities generated by this model suggest that the O.L.S. estimator may be inappropriate. Given the large number of "zeros" in the input/output matrix, we intend to experiment with a Tobit estimator designed for such circumstances.

REFERENCES

Behrman, J. R., Anil B. Deolalikar and Victory Lavy (1992) *Child Growth in Rural South India: Economic and Biological Determinants*. Washington, D.C.: World Bank.

Hapke, Holly M., and Stephen A. Vosti (1992) *The Role of Farm-level Output Diversification on Technical Change in Agriculture: Evidence from the IFPRI Panel*. Background paper prepared in conjunction with the ARD portion of the USAID/Pakistan Research Programme. Washington, D.C.: IFPRI.

Koyck, L. M. (1954) *Distributed Lags and Investment Analysis*. Amsterdam: North Holland Publishing Company.

Lau, L. J. (1969) Applications of Profit Functions. Stanford: Center for Research in Economic Growth. (Memos No. 86 A and 86B. Mimeographed.)

McFadden, D. L. (1970) *Cost, Revenue and Profit Functions*. Berkeley: University of California, Department of Economics. (Mimeographed).

Pakistan, Government of (1991) *National Agricultural Policy*. Islamabad: Ministry of Food, Agriculture, and Cooperatives.

Pakistan, Government of (1991a) *The Estimates of Fertilizer Demand and Import Requirements: Fertilizer Forecast 1991-92*. Islamabad: National Fertilizer Development Centre, Planning and Development Division.

Nag-Chowdhury, Dipa, and Stephen A. Vosti (1992) *Patterns and Trends in Agricultural Labour Use: Evidence from the IFPRI Panel*. Background paper prepared in conjunction with the ARD portion of the USAID/Pakistan Research Programme. Washington, D.C.: IFPRI.

Raza, Jafar, and Stephen A. Vosti (1992) *Examination of the 1991-92 National Input-Output Survey of Major Crops*. Background paper prepared in conjunction with the ARD portion of the USAID/Pakistan Research Programme. Washington, D.C.: IFPRI.

Reardon, Thomas, and Stephen A. Vosti (1992) Issues in the Analysis of the Effects of Policy on Conservation and Productivity at the Household Level in Developing Countries. *Quarterly Journal of International Agriculture.* (Forthcoming.)

World Development Report (1992) *Development and the Environment.* World Bank: Oxford University Press.

Comments on "The Demand for Inputs and the Supply of Output in Pakistan : Estimating a Fixed-effects, Distributed-lag Model for Wheat Farmers"

The empirical results from various field surveys on Pakistan's agriculture bear ample testimony to the vast scope for raising productivity through removing various economic, technical and institutional constraints which are hindering the path of agricultural development. The yields of the "progressive farmers" are substantially higher than those of the average yields obtaining in the country. In some cases the gap is 2-3 times. The timely provision of inputs by minimising supply constraints, provision of credit, if lack of resources constrain optimum use of modern inputs and technology and or solving marketing problems if it applies brakes on the progress and, above all, providing a conducive economic environment for farm production may provide some of the missing links in this direction.

The scope for increasing agricultural production through horizontal expansion of the cropped/cultivated area is limited especially in the short run, and is quite capital-intensive, even if possible, in the long run. Therefore, the bulk of the increase in farm production has to come from increasing the productivity of the land and other resources committed to agriculture. An analysis of the micro data which provides the empirical estimates for resource productivity is an important way to gain useful insights. It is in this context that the paper needs to be examined. In the introduction, the authors pose an important question about the continued success of the agriculture sector in meeting the food and employment needs of the expanding population in Pakistan and about the potential and sources for increasing its growth rate in the future. In this context, they emphasise the need for identifying the sources of agricultural growth, technology, policies and institutional arrangements necessary to achieve the desired results.

Based on the panel data, relating to 1986–89, the paper has estimated the impact of various factors on the supply of wheat as well as the demand for various inputs. Here it may be noted that given the considerable variation and diversity in the production relations in various regions of the country, it may have been useful, to the readers, if the authors had provided some details about their panel farmers, the basis for their selection, and the details of data collection, as it would help in appreciating the extent to which one can generalise from these results.

The data provided in Table 1 reveal tremendous variations in the use level of various inputs, as reflected by very high values of the standard deviations. It may be advisable to report these data on per acre or per hectare basis. At the same time, some of the values in this table are ridiculous. For instance, the mean value of irrigated land by wells is reported as zero while its standard deviation is 50.4.

Similarly, the information about the use of bullocks and the custom rate for their service as reported is confusing. The use of bullocks should be in terms of pair of bullocks and not in terms of a single bullock and the custom rate reported for a team of bullocks, if at all there is a market for bullock services in the countryside.

Disaggregating the data in view of the heterogeneity in production relations and cultural practices, i.e., separating the results for rainfed/*barani* and Canal irrigated regions, would have been helpful.

The profit function is an elegant tool for analysing production behaviour of the farmers but it is highly demanding in terms of its data requirements which sometimes may not be fully met. For example, estimating input elasticities from cross-section data may be constrained by the lack of sufficient variability in prices to allow a meaningful estimation. The explanation that household level input and output prices were not used because differences in unit value reported by households may reflect quality variations rather than genuine price variation does not seem very convincing. If accepted as such, then the very estimation of demand functions may be an exercise in futility. The real problem, I feel, is the lack of sufficient variation in the input price data. The authors' inability to include prices of fertilizer in their estimation because of the nonavailability of requisite data is rather surprising as these are the most readily available data.

Now let us discuss some of the results in Table 2: The wheat harvested equation. In this equation a noteworthy omission is that of fertilizers. Fertilizer is known to have played an important role in expanding wheat production. It is also a strategic input in various plans. Here we are trying to identify the sources of increase in wheat production and do not include fertilizers. The same can be said about seed.

It is interesting to find a strong relationship between wheat output and its prices. However, it is difficult to find an explanation for the positive impact of the increase in the tractor hiring rate on wheat output. The estimated effect of the wage rate on fertilizer demand is strongly negative, indicating a strong complementarity between fertilizer and labour use, according to the authors. Here it is worth mentioning that one of the arguments advanced in favour of the elimination of subsidy on fertilizer has been to reduce wasteful and inefficient use of fertilizers which were being substituted for practices involving labour use. The use of fertilizers by increasing production should provide for more labour use–a complementary relationship but how and why a higher wage rate should induce the use of less fertilizer seems rather odd, especially, when the analysis does not incorporate the impact of changing fertilizer prices.

The negative relationship between tubewell and inputs demand is rather strange. Given the kind of arguments to incorporate the impact of some farm-specific variable in the intercept, I find it difficult to explain its negative coefficient in several of the equations estimated and reported in Table 2 .

The finding that an increase in land holding increases the harvested quantity of wheat and the demand for most inputs is not surprising at all. Similarly, the students of Pakistani agriculture know quite well that an increase in canal-irrigated land would have a much larger effect on wheat supply than an increase in rainfed land.

Before concluding my observations, I would like to thank the organisers of the meeting for providing me the opportunity to participate in their annual meeting and to discuss an interesting paper. I am also grateful to the Chairman of this session and other participants for bearing with me.

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