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Economics of *Barani* (Rainfed) Farming and Farm Household Production Behaviour in Pakistan

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INTRODUCTION

Agriculture research and development efforts in Pakistan have traditionally been focused on raising the farm productivity of irrigated areas. Among other factors, the underlying causes for this irrigated bias could be attributed to: the importance given to the irrigated areas in the overall planning framework; the dominance of the irrigated farm lobby at all levels of research, politics, and government; the relative progressiveness of irrigated farmers in terms of adoption of new technologies; and the presence of risk-reducing natural conditions prevailing on irrigated farms, e.g., certainty of subsidised water supply when it is most needed. Further, like other parts of Asia, the Green Revolution has helped the irrigated farmers in Pakistan to raise the productivity of their major crops, such as wheat, cotton, and rice. On the other hand, the rainfed[1] areas of Pakistan have drawn little benefit from the Green Revolution. The average yields achieved on the rainfed areas remain significantly lower than the yields derived by the traditional irrigated farmers. The rainfed farmers are also subject to subsistence farming conditions with per capita incomes well below the national average.[2] Given the size of the area under rainfed conditions and the problems faced by the rainfed farmers, there have been attempts by the government, international donor agencies, and non-government organisations to come up with strategies to raise the productivity as well as income of the rainfed farmers. Such efforts, however, must take into account the production behaviour of the farm-households under rainfed conditions.

The objective of this paper is to analyse the production behaviour of *barani* farm-household while using the profit-function approach developed and advanced by Lau and Yotopoulos (1971, 1972, 1973, 1979).[3] Since its conception, the profit function technique has been used extensively as an alternative approach to analyse farm-

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[1]The terms 'rainfed' and '*barani*' are used interchangeably.

[2]BARD (1989); Government of Pakistan (1988).

[3]For benefits of using profit function approach as a preferred alternative to other techniques, see Jones and Moussa (1991), pp. 21-22.

household production behaviour.[4] Specifically, the study will test the profit maximisation hypothesis in the context of the utilisation level of variable inputs in wheat production,[5] as the central question in the theory of production is whether farm-households strive for profit maximisation. Second, the paper will attempt to determine whether wheat farming in the rainfed areas of Pakistan exhibits constant returns to scale. Third, the profit-function approach will be used to test the hypothesis of equal relative economic efficiency of the farmers belonging to different rainfall zones.

The paper is organised as follows. The model employed in this study is discussed in Section 2. Section 3 provides an empirical specification of the model and outlines the estimating procedures. This section also presents a brief discussion on the data and variable construction. The empirical results, along with policy implications, are presented and analysed in Section 4. Section 5 summarises the conclusions drawn from the study.

THE MODEL

To describe the nature of farm production in the *barani* areas of Pakistan, it is assumed that farm households' production decisions can be analysed separately from their consumption decisions[6] and the production function is of Cobb-Douglas form:

$$Y = A\, L^{\alpha 1} K^{\alpha 2} F^{\alpha 3} S^{\alpha 4} N^{\alpha 5} Z^{\beta} \quad \ldots \quad (1)$$

where Y is wheat output plus its by-product (wheat straw) in wheat equivalents; L is labour services in man-days; K is capital services in hours;[7] F is fertiliser in kilograms; S is seed rate in kilograms; N is animal input in animal-days; and Z is land input in acres. The study assumes that, while the use of L, K, F, S and N can be varied, Z is fixed in a single production period. As demonstrated by Lau and Yotopoulos (1971, 1972, 1979), if the underlying production function is of Cobb-Douglas form, then the corresponding estimating equation for the normalised restricted profit function, Π^* (P_j, Z), would be:

$$\begin{aligned} ln\, \Pi^* &= ln\, A^* + \alpha_1^*\, ln\, P_L + \alpha_2^*\, ln\, P_K + \alpha_3^*\, ln\, P_F + \alpha_4^*\, ln\, P_S + \alpha_5^*\, ln\, P_N \\ &+ \beta^*\, ln\, Z + \delta_L D_L + \varepsilon_1 \quad \ldots \quad (2) \end{aligned}$$

[4]The profit function approach has been applied in a wide range of situations to analyse issues related to agricultural production. See, for example, Lau and Yotopoulos (1971, 1972, 1973); Sidhu (1974); Somel (1979); Tamin (1979); Lau, Myers and Chou (1979); Adulavidhaya, *et al.* (1979); Kuroda (1979); Khan and Maki (1979, 1980); Lau and Yotopoulos (1979) and Jones and Moussa (1991).

[5]Wheat is a major *Rabi* crop in the *barani* region.

[6]The model, therefore, is based on the restrictive separability assumption.

[7]K is a sum of mechanical services (e.g., tractor, cultivator, planter, sheller, thresher, etc.) required at different stages of wheat production.

where P_L, P_K [8], P_F, P_S, P_N are respectively farm-specific prices of labour, capital, fertiliser, seed, and animal inputs, all normalised by the price of output (wheat). D_L is the dummy variable taking the value of 1 for high rainfall zone and 0 for the low rainfall areas.

An interesting property of (2) is that, under the profit maximisation assumption, its differentiation with respect to factor prices provides the corresponding factor demand functions.[9] The demand for each variable factor of production, therefore, is given by:

$$V_j = -\partial \Pi / \partial P_j, j = L, K, F, S, N \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

(3) implies that the five variable factor share estimating equations are:

$$-P_L V_L / \Pi^* = \alpha_1^{**} + \varepsilon_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

$$-P_K V_K / \Pi^* = \alpha_2^{**} + \varepsilon_3 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

$$-P_F V_F / \Pi^* = \alpha_3^{**} + \varepsilon_4 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

$$-P_S V_S / \Pi^* = \alpha_4^{**} + \varepsilon_5 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

$$-P_N V_N / \Pi^* = \alpha_5^{**} + \varepsilon_6 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

Where V_L is total labour days; V_K is total capital services in hours; V_F is the total quantity of fertiliser in kilograms; V_S is the total quantity of seed in kilograms. V_N is the total animal days.

Equations (2) and (4–8) form a set of equations that can be used to test the hypothesis regarding profit-maximising behaviour of the rainfed farmers by estimating the parameters of the above set of equations.

If the rainfed farmers are price-takers, then their profit-maximisating behaviour can be tested by comparing the estimated coefficients, α_i^{**}'s, in the factor demand equations to the corresponding coefficient α_i^{*}'s, in the normalised profit function. For a given sample of farm-households, the two estimates do not have to be equal. However, if the farmers do maximise profit, then the test for profit-maximisation requires that $\alpha_i^* = \alpha_i^{**}$[10]

[8] P_K is a sum of hourly prices of mechanical services, required at all stages of wheat production. This includes the use of tractor, cultivator, planter, sheller, and thresher.

[9] This result is known as Hotelling-Shephard Lemma.

[10] For the derivation of this result, see Lau and Yotopoulos (1979), pp. 11–22.

The hypothesis that rainfed farming in Pakistan is characterised by constant returns to scale can be tested by finding out whether the sum of the elasticities of the normalised profit function with respect to fixed inputs is equal to one.[11] In the present case, with land as the only fixed factor, rainfed farming would exhibit constant returns to scale if $\beta^* = 1$.

THE DATA AND THE STATISTICAL METHODOLOGY

The study uses the data collected from a comprehensive cross-sectional survey of 156 farm-households from 30 *barani* villages of the Punjab and the North West Frontier Province (NWFP) in 1989.[12] The survey followed a two-stage sampling technique. First, by selecting the villages and then from sampled villages selecting the farm-households. The farms with negative profits, zero variable input cost, and zero cultivated land area were eliminated from the sample. Out of 156 farm-households, 23 were eliminated from the sample, leading to the final sample size of 123.

Following the usual assumptions regarding the stochastic disturbance terms,[13] the study applies the Zellner's (1962) method of imposing known constraints on the coefficients in the estimating equations.[14] As argued by Lau, Lin and Yotopoulos (1979), p. 27, this is an asymptotically efficient method under the given conditions.

EMPIRICAL RESULTS

The results of estimation of the model are presented in Table 1. The first column provides the coefficients of the model estimated through equation by equation

[11]A property of the normalised profit function is that if the underlying production function exhibits constant return to scale in variable as well as fixed inputs, then the normalised restricted profit function is characterised by constant return to scale in fixed inputs [Lau and Yotopoulos (1979), p. 109].

[12]The survey areas include, Haripur (high rainfall zone, with an average annual of 750 mm) in the North West Frontier Province, and Doultala and Mangial (low rainfall zone, with an annual average rainfall of 500 mm) in the Punjab.

[13]The additive error term is assumed to have zero mean and non-zero finite variance for each of the estimating equations of the model, i.e., Equation (2) and Equations (4–8). The additive term in (4–8) can arise from unequal abilities to maximise profit or difference between expected and actual or realised prices. The co-variances of the errors between different equations (Equation 2 coupled with one of the Equations 4–8) for any given farm are assumed to be non-zero, whereas, the co-variances of the errors of each equation corresponding to different farms are assumed to be zero [Kuroda (1979), p. 70].

[14]Given that the variables on the left-hand side of Equations (2) and (4–8) are the jointly dependent variables and the variables on the right-hand are the pre-determined variables (i.e., there are no endogenous variables on the right-hand side of the equations), ordinary least squares applied to each of the above equations will be consistent. These estimates, however, will be inefficient as they do not take into account the fact that the errors of different equations may be correlated with one another and in the case of profit maximisation the same α_i appears in (2) and in one of the Equations (4–8). An efficient approach, therefore, is to estimate Equations (2) and (4–8) jointly, imposing the restriction that $\alpha_i^{**} = \alpha_i^*$. Under these conditions, Zellner's seemingly unrelated regression technique becomes the natural choice. For more on the rationale of using Zellner's method, see Lau and Yotopoulos (1972), p. 15. For a comprehensive discussion of seemingly unrelated regression equations models, see, for example, Srivastava and Giles (1987).

Table 1

Joint Estimation of the Normalised Profit Function and Factor Share Equations

Variable	Parameter	Single Equation (OLS)	No Restriction	Profit Maximisation Restrictions
Profit Function				
		10.809	8.6297	2.0924*
Constant	ln A*	(10.32)	(6.929)	(0.1973)
		1.445*	0.9134*	–0.2540*
Labour	α_1*	(0.6005)	(0.4032)	(0.0431)
		–5.211	–3.3786	-0.1943
Fertiliser	α_2*	(3.311)	(2.223)	(0.1539)
Capital (Tractor		–0.130	–0.0880	–0.2392*
Services)	α_3*	(0.0981)	(.0659)	(0.0556)
		0.369	0.3200	–0.1110*
Seed	α_4*	(0.2595)	(0.1742)	(0.0218)
		1.342	1.0881	–0.00469*
Animal	α_5*	(3.419)	(2.296)	(0.0023)
		0.958*	1.045*	1.0114*
Land	β*	(0.1042)	(0.0699)	(0.0771)
		0.615*	0.2769*	0.0072
Dummy	δ_L	(0.1975)	(0.1326)	(0.1181)
Factor Share Equations				
		–0.3998*	–0.3998*	–0.2540*
Labour	α_1**	(0.0602)	(0.0602)	(0.0431)
		–0.5749*	–0.5749*	–0.1943
Fertiliser	α_2**	(0.1985)	(0.1985)	(0.1539)
Capital		–0.5150*	–0.5150*	–0.2392*
Services	α_3**	(0.0944)	(0.0944)	(0.0556)
		–0.1917*	–0.1917*	–0.1110*
Seed	α_4**	(0.0312)	(0.0312)	(0.0218)
		–0.0077*	–0.0077*	–0.00469*
Animal	α_5**	(0.0023)	(0.0023)	(0.0023)

Notes: Coefficients with * are statistically significant at the 5 percent level; the numbers in parentheses are asymptotic standard errors.

application of the ordinary least-squares (OLS) method.[15] The OLS technique provides consistent but inefficient estimators under the stochastic specification. The results of the Zellner's (1962) unrestricted efficient parametric estimates are given in Column 2. The efficiency of these estimates is enhanced further once we impose the linear restrictions implied by the profit maximisation hypothesis. The results of the restricted coefficients are consistent with the profit function assumption, i.e., profit is an increasing function of the fixed inputs and a decreasing function of the variable inputs. Moreover, the sign of the coefficient attached with the dummy variable suggests that farmers in the high rainfall-zone are economically more efficient.

The hypothesis of profit maximisation, constant returns to scale, and equal relative economic efficiency of high and low rainfall zone farms are tested by using statistical tests based on *F*-ratios. The hypothesis testing is based on the unrestricted estimation of the model. The results are provided in Table 2.

Table 2

Test of Hypotheses

Tested Hypothesis	Computed F	Critical $F_{0.05,\infty}$	Critical $F_{0.01,\infty}$
Profit Maximisation	F(5,725)= 6.1859	F(5,725) =2.21	F(5,725) =3.02
Constant Returns to Scale	F(1,725) =0.4064	F(1,725) =3.84	F(1,725) =6.63
Equal Relative Economic Efficiency of High and Low Rainfall-zone Farmers	F(1,725) =8.2844	F(1,725) =3.84	F(1,725) =6.63

First, the hypothesis of profit maximisation is examined. The tested hypothesis implies that α_i^{**}'s, in the factor demand equations and α_i^{*}'s, in the normalised profit function are equal.

$$Ho: \alpha_i^{*} = \alpha_i^{**} \qquad i = 1, 2 \ldots 5$$

The result, as shown in Table 2, rejects the hypothesis of profit maximisation at the 1 percent level of significance (99 percent level of confidence). This result implies that during the survey year the rainfed farmers were in a state of disequilibrium, i.e., the farmers were not equating the value of marginal products of variable inputs to their factor prices. A reasonable explanation of the rejection of this hypothesis is that the

[15]The profit function and factor share equations were tested for heteroscedastic errors using the Goldfeld-Quandt test. The test resulted in acceptance of the null hypothesis of homosecdastic disturbance terms.

rainfed farmers are subject to subsistence farming conditions in a risky environment where the priority is to meet the food security requirement rather than to pursue an economic efficiency (profit maximisation) objective which may undermine their food security considerations. This implies that production decisions do depend on households' consumption choices. In other words, separability may not be a reasonable assumption to model the production behaviour of the rainfed farmers facing both production as well as consumption risk.[16]

Given the significance of the profit maximisation hypothesis, the rejection of this hypothesis prompted separate tests for each equality restriction to identify the inputs for which the farmers do equate the marginal revenue product of a factor to its marginal factor cost. Except for fertiliser, the hypotheses regarding the profit maximising factor hiring rule were rejected for all other inputs at the 1 percent level of significance. These results point to a possible explanation. Except for fertiliser, the markets for other inputs, such as hired animal, seed, tractor, and labour, are imperfect in the sense that the farmers do not consider the prices for these inputs as true reflections of their contribution in the production process, as, unlike irrigated farming, the contribution of these factors is difficult to determine at planting time under rainfed conditions. Therefore, the factor hiring rule as characterised by the profit maximisation hypothesis breaks down for these variable factors of production. In the case of chemical fertiliser, however, the *barani* farmers prefer to apply chemical fertiliser after rain when they are assured of crop establishment.[17] Consequently, the fertiliser application validates the factor hiring rule as characterised by the profit maximisation hypothesis. This indicates that the rejection of the profit maximisation hypothesis is by no means a manifestation of "irrational behaviour" by the rainfed farmers; rather it is an outcome of a risk-averse strategy applied by the farmers under erratic rainfall conditions.

Second, the hypothesis of constant returns to scale is tested from the unrestricted estimation of the model. The tested hypothesis is:

$$Ho: \beta^* = 1$$

This hypothesis cannot be rejected at 1 percent level of significance. This implies that if the fixed input (land) is doubled, without changing the normalised prices for all inputs, the normalised profits will be doubled. Following Lau and Yotopoulos (1973), as constant returns to scale exists, an argument for a consolidation of small farms on the basis of economies of scale is not valid for the rainfed areas. Therefore, under rainfed conditions, a policy debate on the issue of optimum farm size becomes irrelevant.

Finally, the hypothesis of equal relative economic efficiency of the farmers from

[16]Acceptance of risk in the production process, however, implies that separability can no longer be assumed.

[17]The level of fertiliser applied also depends upon rainfall at planting time. For more on this, see Supple, *et al.* (1985), p. 51.

low and high rainfall zones is tested using unrestricted estimation of the model. The null hypothesis for this test is:

Ho: $\delta_L = 0$

The above hypothesis is rejected at 1 percent level of significance. The rejection of this hypothesis implies that the level of economic efficiency, as measured by normalised profits, differs between the high and low rainfall-zone farmers. This test confirms that farmers in the high rainfall-zone are economically more efficient.

SUMMARY AND CONCLUSIONS

The results of this study provide an interesting insight into the production behaviour of *barani* farm-households and the nature of the production process under rainfed conditions. Given output and variable input prices and given the quantity of fixed factor, the results do not validate the profit maximisation hypothesis under rainfed farming conditions. The rejection of this hypothesis, however, should not be interpreted as a "rationality test" for the *barani* farmers. It is the contention of this paper that rainfed farming is subject to risky farming conditions where the objective function is to meet food security requirements rather to pursue an economic efficiency objective, which may undermine their food security considerations. Second, the study confirms that rainfed farming is characterised by constant returns to scale. Therefore, any policy reform that calls for consolidation of small farms based on economies of scale is invalid under rainfed conditions. Third, the paper confirms a common belief that the level of economic efficiency, as measured by normalised profits, increases as one moves from low to high rainfall zone. This study concludes that a stratification by rainfall zones is an essential step in the formulation of appropriate research design on the basis of various ecological zones.

The empirical results of this study, especially the rejection of the profit-maximisation hypothesis, should be treated with some caution as these findings warrant qualifications due to the partial nature of the model. First, because of the importance of wheat in rainfed farming, the study has ignored other crops and production activities, such as livestock, in the formulation of the profit function. It is the contention of this study that one may arrive at different conclusions if the model is based upon the "farm profit function" rather than the crop-specific profit function. Second, following the traditional farm-household econometric models, the study assumes that the production decisions can be analysed separately from the consumption decisions. A major weakness of the separability assumption is that the conditions essential for a farm-household model to be separable are quite stringent.[18] In spite of this drawback, this study has made this assumption owing to data limitations. Finally, the findings of this

[18]For more on the necessary conditions for a farm-house model to be truly separable, see Hardaker and Fleming (1993), p. 217.

study suggest that future research regarding farm-household production behaviour in the *barani* areas should tackle the issue of separability in order to bring the model closer to reality.

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Comments

Amir Mahmood's paper presents a systematic explanation of some of the important aspects of nature-dependent risky economy of the *barani* lands in Pakistan. He focuses his production behaviour analysis to test three hypotheses, viz., profit maximisation in the context of wheat production; constant returns to scales in wheat farming; and equal relative economic efficiency of the farmers. Using the Lau Yotopoulos profit function approach to data collected from 123 households of 30 villages in the area of Haripur (NWFP) and Gujar Khan (Punjab), he confirms that (i) rainfed farming is subject to risky farming conditions where the objective function is to meet food security requirements rather than to pursue an economic efficiency objective; (ii) that rainfed farming is characterised by constant returns to scale; and (iii) that economic efficiency increases while moving from low to high rainfall.

I welcome this exploratory novel effort that helps to rationalise a few aspects of the indigenous knowledge prevailing in rainfed agriculture. My major concerns, however, pertain to the complex nature of pluvial characters. Agriculture is not the mainstay of economic life in the tract under consideration and, hence, it is not appropriate to assign exclusive weightage to the crops sub-sector, especially the wheat, for analysing the imperatives of profit maximisation. Immense variation in the iso-hyetal distribution and the geo-physical resources defines the huge diversity in the *barani* agro-ecologies, and it demands a bit broader vision besides wheat, i.e., the farming systems approach. For example, in the Punjab, the Murree-Kahuta, Siwalik Piedmont, Potohar Plateau, the Salt Range, D. G. Khan, and the Tribal Areas, the Thal and Riverine belts; and in the NWFP, the Sulaiman Piedmont, Bannu Basin, Peshawar Valley, and the Swat-Chitral pockets carry area-specific distinct features. So the sampling plan has to be well-stratified. Secondly, the population and composition of stall-feds and ruminants in the rangelands, which fluctuate from high to low rainfall, cannot be under-scored as a final refuge for *barani* farmers during the lean year(s) of drought spell(s). *Barani* livestock with newly emerging silvi-pastoral and agro-pastoral models have comparatively shown a more dynamic role in the rainfed economy. Further, the debate on the use of "Costly Water" entailing from water conservation practices in the *barani* lands *vis-à-vis* irrigated plains has promoted the wisdom to shift from wheat to cash crops like orchards, vegetables, groundnuts, chickpeas, and sorghum etc. Nevertheless, the food security perspective does persist, although *barani* subsistence farming alone cannot pull on with the farm family needs without the off/non-farm support. Moreover, the institutional and policy framework in rainfed agricultural development also requires due reference because of its irrational approach and strategic inefficiency in comprehending the popular discourses on community-based initiatives.

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