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Measurement of cost inefficiency with safety first measure of risk

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Abstract

The objectives of this paper are to incorporate a measure of risk aversion in the translog frontier cost function to estimate cost inefficiency. Risk-averse behaviour of farmers is hypothesised to reduce efficiency by leading to a situation in which the marginal value product of an input is less than price. In developing agriculture, farmers are aware of their subsistence needs and seek to minimize the probability of their incomes falling below a disaster level of income. Using such a safety first principle, a measure of risk-taking is developed and explained by socio-economic characteristics. This measure is used in the translog cost function as a fixed input and, using the frontier approach (with half normal distribution of inefficiency disturbance), a measure of cost inefficiency is obtained. This is related to socio-economic characteristics such as education, assets and holding size. A survey data of 436 farmers for the North-West Frontier Province of Pakistan is used to reach policy conclusions for reducing cost inefficiency.

1. Introduction

The measurement of efficiency in agriculture has been investigated in much detail since Farrell (1957). Most studies measure efficiency under conditions of certainty. It is well known that agricultural production is affected by uncertainty from price and yield fluctuations. Risk plays an important role in farmers' decision about the allocation of their resources. Knowledge of farmers' risk preferences is useful in the development of farm management and rural development strategies, development and transfer of technology, and policy formulation (Young, 1979; Moscardi and de Janvry, 1977). The neoclassical theory of modelling farm production behaviour with a profit maximization framework has been well-tested, but the risk-bearing of farmers is taken for granted and is not often explicitly used in the theory. This paper presents an economic analysis of the production process under the assumptions of uncertainty. Although there is a large literature on risk measurement for developing countries, no study is available in the context of Pakistan's agriculture. Consequently, the estimation of risk aversion and the measurement of efficiency including such a variable may be useful for formulating a development policy for the improvement of agriculture in Pakistan.

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The objectives of the paper are: (a) to measure inefficiency without making allowance for attitudes to risk; (b) to quantify risk aversion and establish the relationship between risk aversion and farm characteristics; (c) to incorporate the risk aversion measure in the inefficiency model, measure inefficiency in this case and compare these results with those under (a) above.

2. Data and definitions of variables

The Institute of Development Studies in Peshawar (Pakistan) conducted a sample survey in the North-West Frontier Province of Pakistan (NWFP) for 1990–91. The sample consists of all the districts of the Peshawar Division, i.e. Peshawar, Charsada and Mardan. The Peshawar division constitutes the backbone of economy in the region where agriculture has made visible progress in the last few decades, and farmers have used new inputs of production such as HYV seeds, irrigation, chemical fertilizers and new technology.

The major crops in the Province are wheat, maize, sugarcane and vegetable crops. The growers, however, are not specialised: each farmer grows at least two of the four crops per year. In our survey, the percentage area under wheat, maize, sugarcane and others were 38%, 24%, 22% and 16%, respectively. According to the provisional statistics for the whole province, 43% of the cultivated land was devoted to wheat followed by maize at 24%.

The overall cropping intensity (cropped area/net sown area) in the province was 121%. It varied with both farm size and tenure. It was the highest at 130% on tenant farms in NWFP, while lowest at 108% on owner-cum-tenant farms. Of the total farms in NWFP, 68% were owner-operated and accounted for 58% of the area, 18% were tenanted farms and accounted for 15% of the area, and the remaining 14% of the farms with 27% of the area were owner-cum-tenant-op-

Table 1
Descriptive statistics of variables used in the study (means and standard deviations)

Variable	Units	Mean	SD
Family size	numbers	8.02	3.60
Age of head	years	49.03	13.34
Education	years of school	1.45	3.47
Off-farm work	hours/month	26.71	23.78
Farm assets	rupees/acre	1047.96	4664.88
Non-farm assets	rupees/acre	7495.99	8269.80
Working animals	number/acre	0.41	0.52
Credit	rupees/acre	754.52	3831.93
Fragmentation	number/acre	0.82	0.70
Extension contacts	numbers	4.44	2.54
Farm size	acres	7.20	5.93
Subsistence need	rupees/acre	2752.54	2690.15
Fertilizer price	rupees/kg	2.89	0.58
Human labour	rupees/day	25.43	6.05
Animal labour	rupees/day	52.66	9.76
Tractor	rupees/hour	58.72	10.59
Output price	rupees	37.52	43.76
Value of output	rupees/acre	3843.00	949.58
Fertilizer	kg/acre	128.27	43.73
Human labour	days/acre	23.24	5.81
Animal labour	days/acre	5.95	6.79
Tractor	hours/acre	2.90	1.18
Manure	maund/acre	71.07	39.40

maund = 80 pounds ≈ 36.3 kg.
acre ≈ 0.4047 ha.

erated. The means and standard deviations of all the variables are presented in Table 1.

3. Model of production decision and safety first principle

In developing agriculture, risk and attitudes to risk may be responsible for low agricultural production. As discussed by Roumasset (1976), risk in agriculture can broadly be divided into yield risk and price risk. Usually, price risk for both inputs and outputs is ignored as it is generally small in comparison to yield risk. In most underdeveloped countries, farmers face price guarantees for many farm products.

The main source of yield risk is from the weather and disease. Weather risk comes from floods, typhoons, droughts during the growing season, rain during the harvest and rain variability generally; crop damage risk denotes the variability in yield due to damage from pests, insects and other diseases. Yield risk is more serious in NWFP as compared to price risk, and an attempt is made to study the yield risk.

As far as the measurement of risk attitudes is concerned, the safety first approach seems appropriate for describing the behaviour of low income farmers due to the stark reality of the 'disaster' level (Roumasset, 1976). Farmers are subsistence farmers producing mainly for own consumption. Thus, the disaster need or subsistence level of their income should be taken into consideration especially where the basic need may be at risk. For this purpose, risk attitudes are introduced in a model of economic decision making as a safety first rule. This approach assumes that the individual objective is to minimize the probability of experiencing an income shortfall below some 'disaster' level.

In the safety first principle, attributable to Roy [1] (1952), it is assumed that the objective of the individual is to minimize the probability (α) (typically) of profit (π) falling below a specified disaster level (d^*):

$$\text{Minimize } \alpha \equiv \mathrm{PR}(\pi < d^*) \tag{1}$$

A model of agriculture may be constructed for the production side. This model incorporates risk in the choice of a high yielding variety crop as against a local variety. An HYV by its nature could be a risky crop. The geographical location of farmers may affect their behaviour with respect to environmental risk. Farmers who live in natural disaster areas are likely to suffer greater crop losses than farmers in the other areas, and hence ex-ante risk is much greater in the former areas. Within any given environment, these variations will be largely determined by demographic and socio-economic factors and will influence the way in which farmers respond to any given environment.

Following Shahabuddin et al. (1986) and Parikh and Bernard (1988), the efficiency condition of resource allocation using the safety first principle for an agricultural household is:

$$\mathrm{MFC}_i = P_j^{\mathrm{e}}\left(\frac{\partial Q_j^{\mathrm{e}}}{\partial X_i}\right) + \left[\frac{(d^* - \mu)}{\sigma}\right]\left(\frac{\partial \sigma}{\partial X_i}\right) \tag{2}$$

where MFC_i is the marginal factor cost of the input i, P_j^{e} and Q_j^{e} are the expected price and output for crop j, X_i is the quantity of input i used, d^* is the farm household 'disaster' income, μ is the expected income of the farm household, and σ is the standard deviation of the household's income.

If $\partial\sigma/\partial X_i > 0$, the variability in income increases when the input level is increased. A risk-averse farmer for whom $d^* < \mu$ will employ less X_i since $\mathrm{MFC}_i < P_j^{\mathrm{e}}(\cdot)$ than a risk-neutral farmer where $\mathrm{MFC}_i = P_j^{\mathrm{e}}(\cdot)$. On the other hand, a risk-taking individual for whom $d^* > \mu$ will use a greater amount of the input. If $\partial\sigma/\partial X_i < 0$, then these results are reversed. Safety first behaviour will, therefore, lead to the observed levels of input use differing from optimum levels.

[1] Other alternative specifications of the safety first rule have been given by Telser (1955) and Kataoka (1963). This approach has been used empirically by Moscardi and De Janvry (1977) for Mexican farmers, and by Shahabuddin, Mestelman and Feeny (1986) and Parikh and Bernard (1988) for Bangladeshi farmers. More recently, Randhir (1991) has used this approach to study the behaviour of Indian farmers.

Under the safety first approach, the risk preference of the decision maker has to be interpreted differently than in the expected utility analysis, since the risk aversion coefficient of the farm household in this framework is defined as:

$$\Psi = \frac{d^* - \mu}{\sigma} \tag{3}$$

Thus the behaviour towards risk of the farm family is determined by the household's level of disaster income relative to its expected income. In other words, the household's relative magnitude of these two variables d^* and μ determine whether the farm family is forced to gamble, when $d^* > \mu$, or allowed to trade expected returns for reduced risk, i.e. $d^* < \mu$. In the safety first principle, the maximization of the chances of survival is an important factor for the farmers as compared to maximizing their income. Different choices do not depend on differences in their attitudes towards risk, but on differences in their subsistence needs, resource factors and judgement of the riskiness among competing activities. If $\Psi > 0$, then the farm household, in its attempt to minimize the probability of disaster, is forced to gamble in its choice. It takes risk in order to maximize its chances of survival by devoting greater resources to riskier but more profitable crops. On the other hand, if $\Psi < 0$, the farm family can afford to choose a less risky crop investment with lower expected income (Shahabuddin et al., 1986; Parikh and Bernard, 1988) [2].

Computation of the risk-taking variable for each farmer requires estimates of d^*, μ and σ. In the safety first principle, d^* is assumed to be the minimum consumption needs (MNC) of the farm household, that is the income below which the farm family faces either bankruptcy or starvation or the discomfort of adjusting to a significantly lower standard of living. Following Roumasset (1976) we define the disaster level of income:

$$d^* = \text{MNC} + \text{CRD} - \text{OFFINCOME} \tag{4}$$

where CRD is the net amount of outstanding credit received from the institutional and non-institutional sources [3] and the part to be paid back during the agricultural year. Only the urgent debt is used here. Annual cash income of each household from various sources was recorded in monetary terms. This included data on income from livestock, labour supply to off-farm work, business rent on property, interest on savings etc. Income from these sources were subtracted.

Since farmers grow different crops, the net expected output is:

$$\mu = \sum_j P_j^e Q_j^e - \sum_i W_i X_i \tag{5}$$

where W_i is the price of ith variable input. Both the expected price and expected output are obtained during the field work for the survey. Specific questions were asked on the expected output, crop damage and price a particular crop is expected to fetch in the market at the time of harvest.

The standard deviation in income is required for each household, but we have only one year's data. We do, however, have the data on the previous year's output. Then we assume that the previous year's output could be used for the estimation of σ, as these data have been collected for different crops in different villages. The data on physical output and prices were available, enabling the value of output to be calculated for each farmer in each of the villages. Then the standard deviation, σ, was computed which is village-specific. We further computed the following risk coefficient:

$$\Psi_{kl} = \frac{d^*_{kl} - \mu_{kl}}{\sigma_l} \tag{6}$$

where $k = 1, 2, \ldots, M$ (farms), and $l = 1, 2, \ldots, N$ (villages).

A quantitative estimate Ψ_{kl} is derived for each farm household, and its frequency distribution is presented in Table 2. The (Ψ_{kl}) variable was

[2] A similar pattern of farmers' behaviour towards risk in subsistence agriculture has been discussed by Roumasset (1976) and Kunreuther and Wright (1979) for subsistence farming in the Philippines and Bangladesh, respectively.

[3] These are Agricultural development banks, Cooperative societies, Taccavi and other Commercial banks and non-institutional sources, i.e. landlords, relatives, friends and village money lenders.

Table 2
Frequency distribution of risk coefficient (Ψ_{kl}) of farm households

Range of risk	Number of farmers	(%)
−8–7	2	0.46
−7–6	5	1.15
−6–5	3	0.69
−5–4	3	0.69
−4–3	14	3.21
−3–2	112	25.69
−2–1	210	48.16
−1–0	32	7.34
0–1	13	2.98
1–2	28	6.42
2–3	14	3.21
All	436	100.00
Mean	−1.13	
SD	1.26	
Skewness	−0.88	
Kurtosis	6.12	

studied by village to see whether there were more risk-takers in any specific village. No such tendency was found. The tails of distribution of Ψ_{kl} imply that risk-takers ($\Psi_{kl} > 0$) were generally poor farmers as expected. The mean value of the risk coefficient is −1.13, and most of the farm households (80.0%) possess a negative risk coefficient. This means that their disaster level of income is lower than the expected income and large number of farmers are risk-averse. A similar frequency distribution was observed by Shahabuddin et al. (1986) and Randhir (1991).

The distribution of Ψ_{kl} shows a significant departure from normality and the distribution is skewed. When 'risk-taking' was correlated to income levels, poorer farmers showed a greater tendency to risk-taking than did rich farmers. This implies that such a measure of 'risk-taking' may be used to examine the resulting decline in inefficiency.

Correlation coefficients between σ at a village level and each of the mean input levels were calculated and in all cases are positive. Correlations are 0.35 with fertilizer, 0.15 with animal labour, 0.27 with human labour, 0.28 with tractor services and 0.14 with manures. This shows that for a risk-averse farmer with d^*, the expected value of the marginal product of a variable input will exceed its marginal factor cost by a positive marginal risk represented by $[(d^* - \mu)/\sigma]$ $(\partial\sigma/\partial X_i)$. This implies that under uncertainty the optimal input use is lower for a risk-averse farmer than in the certainty case, whilst the reverse is true for the risk-taker.

4. Determinants of risk-taking

Three classes of variables have been used to define the socio-economic characteristics of the farm household. The first category includes the demographic factors such as family size (FSZ). The second group contains the resource factors or income generating factors, i.e farm assets (AST), non-farm assets (NST), land size (HLD) and off farm income (OFF), while the third category includes the institutional factors [4].

In the first category we expect family size to have a positive impact on Ψ_{kl}. According to the safety first principle, this can be explained by the fact that larger families have higher consumption needs, and, therefore, they are more willing to take risk. In this case family size reflects the consumption needs of the family (Shahabuddin et al., 1986; Parikh and Bernard, 1988).

The second group of variables comprises the income generating factors of the farm household. The farm's income generating opportunities are represented by the land under cultivation, the level of off-farm income and non-farm assets. The hypothesis is that the wealthy farmers have more land under control, more off-farm income and more non-farm assets than poor farmers and it is the rich farmers who are risk-averse according to the safety first principle (Shahabuddin et al., 1986). As far as the third category of variables is concerned it is believed that higher education is generally positively associated with risk-taking (Moscardi and de Janvry, 1977). The risk-taking

[4] These seven variables are Family size (numbers), Education (years), Off-farm income (rupees per month), Farm assets (rupees per acre), Non-farm assets (rupees per acre), Extension visits (numbers) and Land size (acres).

variable is regressed on the socio-economic factors to see how these factors explain the constructed variable. The equation of risk-taking is specified as:

$$\Psi_k = \alpha_0 + \alpha_1 \text{ FSZ}_k + \alpha_2 \text{ EDU}_k + \alpha_3 \text{ OFF}_k + \alpha_4 \text{ AST}_k + \alpha_5 \text{ NST}_k + \alpha_6 \text{ EXT}_k + \alpha_7 \text{ HLD}_k + \epsilon_k \quad (7)$$

with $k = 1, 2, \ldots, 436$. The expected signs of the coefficients are: $\alpha_1 > 0$, $\alpha_2 > 0$, $\alpha_3 < 0$, $\alpha_4 < 0$, $\alpha_5 < 0$, $\alpha_6 < 0$, and $\alpha_7 < 0$.

Eq. (7) is estimated and the results are presented as follows (t-ratios in parentheses):

$$\begin{aligned}\hat{\Psi} = & \underset{(-5.93)}{-1.041} + \underset{(7.36)}{0.1023} \text{ FSZ} + \underset{(1.29)}{0.0149} \text{ EDU} \\ & - \underset{(-5.51)}{0.0105} \text{ OFF} - \underset{(-1.79)}{0.2121} \text{ AST} \quad (7A) \\ & - \underset{(-6.43)}{0.047 \times 10^{-5}} \text{ NST} + \underset{(0.95)}{0.0184} \text{ EXT} \\ & - \underset{(-3.90)}{0.0182} \text{ HLD} \qquad R^2 = 0.334\end{aligned}$$

The coefficients of most of the explanatory variables have the expected signs. Out of these variables, family size, off farm income, non-farm assets and land size have significant coefficients [5].

5. Estimates of inefficiency using translog cost function

Translog functions are popular in econometric literature because of their flexible functional form. Econometric testing of various assumptions can provide a parsimonious form to represent the data. Instead of estimating a direct translog production function, the dual approach is used where cost is related to input prices and output quantities. This is consistent with the assumptions that prices are exogenous and input quantities are endogenous where there is a time-lag between input use and output. Allocation of land to a given crop determines potential output of a crop at the time of sowing. Exogeneity of output follows from the area allocated to a crop determining the planned output.

The variable measuring risk-taking is used in the stochastic translog cost function estimated to measure inefficiency:

$$\begin{aligned}\ln C = & \alpha_0 + \alpha_Q \ln Q + \tfrac{1}{2}\gamma_{QQ}(\ln Q)^2 \\ & + \sum_{i=1}^{n} \alpha_i \ln P_i + \tfrac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln P_i \ln P_j \\ & + \sum_{i=1}^{n} \gamma_{Qi} \ln Q \ln P_i \\ & + \alpha_L \ln L + \tfrac{1}{2}\gamma_{LL}(\ln L)^2 \\ & + \sum_{i=1}^{n} \gamma_{Li} \ln L \ln P_i \\ & + \gamma_{LQ} \ln L \ln Q + \alpha_R \Psi + \tfrac{1}{2}\gamma_{RR}(\Psi)^2 \\ & + \sum_{i=1}^{n} \gamma_{Ri} \Psi \ln P_i + \gamma_{RQ} \Psi \ln Q + \epsilon \quad (8)\end{aligned}$$

where C is total cost, ln is a natural logarithm, Q is total value of output, P_i are prices of variable inputs, Ψ is the risk variable, and L is land. The compound disturbance term (ϵ) is:

$$\epsilon_k = V_k + U_k \quad (9)$$

where V_k is normally distributed to reflect the random factors such as weather, and U_k is a one-sided disturbance to represent the inefficiency component. Assume $U \sim |N(0, \sigma_U^2|$, while $V \sim (0, \sigma_U^2)$, and U and V are independent of each other.

The population average technical efficiency (Jondrow et al., 1982) is:

$$E[\exp(-U)] = 2 \exp(\sigma_U^2)[1 - F(\sigma_U)] \quad (10)$$

where F is the standard normal distribution function evaluated at the maximum likelihood estimates of σ_U.

The measurement of the farm level efficiency, $\exp(-U)$, requires first the estimation of the non-negative error U, i.e. decomposing ϵ into two individual components, U and V. Jondrow et al. (1982) suggested a decomposition:

$$E[\exp(-\mathrm{U})] = 2 \exp(\sigma_U^2/2)[1 - F(\sigma_U)] \quad (11)$$

[5] Shahabuddin et al. (1983) and Parikh and Bernard (1988) largely succeeded in establishing such a relationship for farm households in Bangladesh.

Table 3
Maximum likelihood estimates of translog cost frontier

Parameter	Coefficient	t-ratio
α_0	4.7738	6.94 *
α_l	−1.2328	−2.36 *
α_F	0.6018	0.25
α_H	2.6755	1.27
α_A	3.9582	1.55
α_M	−0.1903	−0.24
α_V	2.1475	2.99 *
γ_{LL}	0.0769	1.78
γ_{LF}	0.0232	0.18
γ_{LH}	−0.0201	−2.26 *
γ_{LA}	0.0506	0.33
γ_{LM}	−0.4051	−0.98
γ_{LV}	0.0710	1.56
γ_{FF}	0.4459	0.77
γ_{FH}	−0.3318	−0.74
γ_{FA}	−0.4095	−0.61
γ_{FM}	0.0586	0.46
γ_{FV}	−0.0856	−0.44
γ_{HH}	0.4758	0.83
γ_{HA}	0.0335	0.69
γ_{HM}	−0.1002	−0.62
γ_{HV}	−0.1352	−0.99
γ_{AA}	0.6474	0.85
γ_{AM}	−0.0537	−0.25
γ_{AV}	−0.3557	−1.73
γ_{MM}	0.1877	2.51 *
γ_{MV}	0.0898	1.36
γ_{VV}	−0.3943	−4.53 *
$\lambda = \sigma_U / \sigma_V$	1.4933	6.71 *
$\sigma = \sqrt{\sigma_U^2 + \sigma_V^2}$	0.1622	11.85 *
Log Likelihood	303.81	

* Significant at 5% level.
The subscripts L, F, H, A, M and V stand for land, price of fertilizer, human labour, animal labour, manure and value of output, respectively.

where $\lambda = \sigma_U / \sigma_V$ and $\sigma^2 = \sigma_U^2 + \sigma_V^2$, and f is the standard normal density function evaluated at $(\epsilon\lambda/\sigma)$.

Maximum-likelihood methods (ML) were used to estimate (8) with and without a constructed risk aversion variable (see Tables 3 and 4). In Table 3, the risk aversion variable is not used and the value of $\hat{\lambda}$ is 1.493. In Table 4, the unrestricted translog cost function has too many parameters to obtain precise estimates and a number of them are individually insignificant and hence a parsimonious form was obtained through backward and forward stepwise regression routines. The restricted model is not rejected against the unrestricted model by the likelihood ratio test and the coefficient of risk variable is statistically significant. The value of $\hat{\lambda} = 1.476$ which implies that the one-sided error term U dominates the symmetric error V. The discrepancy between the observed cost and the frontier (minimum) cost is primarily due to inefficiency. We estimated farm-specific inefficiencies (Table 5). When risk aversion is considered in a translog cost function, it is expected to lead to a decline in cost inefficiency in comparison to the cost inefficiency derived in a model without risk. Our estimates of inefficiency fell from a mean level inefficiency of 11.5% (without risk) to 9.8% (with risk) [6]. Variation is also visible in individual farm inefficiencies. The inefficiency index shows a decline when it is compared with measure of inefficiency without a risk factor. A histogram corresponding to the frequency distribution is presented in Fig. 1. There is a decline in inefficiency as larger number of farms fall between 10% and 20% inefficiency group with risk than without risk.

The measured inefficiency index (INI) from (11) was regressed on family size, age of the farm household head, education, fragmentation, extension visits and holding size. The signs of most regression coefficients are as expected. Subsistence requirements and credit variables are not used as they form the basis of the risk-taking variable, which is used as a fixed input in the estimation of the translog cost function.

Our results (see Table 6) indicate that education and extension visits contribute to a decrease in inefficiency while the farmers spending more time away from the farm contributes to inefficiency. Most of the other coefficients are insignificant but the signs of the coefficients of all asset

[6] Statistical tests of differences in means cannot be conducted because two samples are not independent. The test on the coefficient of Ψ in the maximum likelihood procedure and the dominance of restricted model with risk as against model without risk establishes the significance of risk factor.

Table 4
Maximum likelihood estimation of translog cost frontier with risk

Unrestricted model			Restricted model		
Parameter	Coefficient	t-ratio	Parameter	Coefficient	t-ratio
α_0	5.817	0.85	α_0	2.7234	1.60
α_L	−1.284	−2.42 *	α_L	−1.0299	−4.46 *
α_F	0.822	0.36	α_F	0.1918	3.76 *
α_H	2.361	1.16	α_H	1.0469	8.83 *
α_A	4.816	1.86	α_A	0.2470	3.63 *
α_M	−0.220	−0.28	α_M	0.5307	2.86 *
α_V	2.079	2.84	α_V	1.1735	2.61 *
α_R	−0.049	−0.20	α_R	−0.0193	−3.09 *
γ_{LL}	0.087	2.00 *	γ_{LL}	0.0958	3.01 *
γ_{LF}	0.004	0.03	γ_{LH}	−0.2999	−4.01 *
γ_{LH}	−0.205	−2.24 *	γ_{MM}	0.1349	2.30 *
γ_{LA}	0.101	0.64	γ_{VV}	−0.1183	−2.02 *
γ_{LM}	−0.045	−1.07	$\lambda = \sigma_U/\sigma_V$	1.6013	7.96 *
γ_{LV}	0.079	1.72	$\sigma = \sqrt{\sigma_U^2 + \sigma_V^2}$	0.1665	13.62 *
γ_{LR}	0.003	0.20	Log Likelihood [a]	300.64	
			Unrestricted model (continued)		
γ_{FF}	0.514	0.87	γ_{FH}	−0.347	−0.79
γ_{FA}	−0.237	−0.35	γ_{FM}	0.009	0.07
γ_{FV}	−0.062	−0.30	γ_{FR}	0.012	0.22
γ_{HH}	0.468	0.83	γ_{HA}	0.264	0.54
γ_{HM}	−0.128	−0.81	γ_{HV}	−0.133	−0.95
γ_{HR}	−0.017	−0.34	γ_{AA}	0.764	1.08
γ_{AM}	−0.020	−0.10	γ_{AV}	−0.391	−1.90
γ_{AR}	−0.011	−0.16	γ_{MM}	0.159	2.10 *
γ_{MV}	0.066	0.92	γ_{MR}	0.012	0.59
γ_{VV}	−0.396	−4.40 *	γ_{VR}	0.003	0.11
γ_{RR}	−0.003	−0.44	$\lambda = \sigma_U/\sigma_V$	1.476	6.90 *
$\sigma = \sqrt{\sigma_U^2 + \sigma_V^2}$	0.158	12.12 *	Log Likelihood	300.64	

* Significant at 5% level.
[a] This test accepts the restricted model.
The subscripts L, F, H, A, M, V and R stand for land, price of fertilizer, human labour, animal labour, manure, value of output and risk, respectively.

variables in the explanation of inefficiencies are negative as expected.

6. Conclusions

In developing agriculture, the behaviour of farmers in the presence of uncertainty plays a significant role in determining the efficient level of operations. The concept of efficiency is not independent of the attitudes towards risk and the policy makers can not ignore the role of risk-averse behaviour in measuring inefficiency. The cautious and most risk-averse farmers may tend to use less than optimum level of inputs which may result in a loss of efficiency. It is, therefore, likely that inefficiency is exaggerated when farmers aim not to fall below the disaster level of income while maximising their income. Hence, from a policy point of view, the measures which can reduce risk and change farmers' behaviour could lead to improvement in farming efficiency. Perhaps, the schemes which can reduce the effects of floods and drought may lead to greater efficiency as these measures would enhance the prospects of survival.

Table 5
Frequency distribution of farm-specific cost inefficiencies using a stochastic translog cost frontier

Inefficiency index (%)	Without risk			With risk		
	Number of farmers		(%)	Number of farmers		(%)
1–5	36		8.2	33		7.5
5–10	191		43.8	218		50.0
10–15	117		26.8	123		28.3
15–20	45		10.3	39		8.9
20–25	28		6.4	17		3.9
26–30	8		1.8	5		1.2
31–35	7		1.6	0		0.0
36–42	4		0.9	1		0.2
All	436		100.0	436		100.0
Mean		11.5			9.8	
SD		6.6			5.0	
Minimum		3.0			2.4	
Maximum		41.5			33.7	

In this study, a safety first measure of 'risk-taking' is used in the translog cost function. The 'risk-taking' variable is treated as a fixed input in the translog cost function and interactions with normalised input prices are considered. However, the inefficiency measured through the frontier approach does not interact with the 'risk-taking' variable. This remains a major limitation of the safety first measure in the context of frontier approach as we do not study the behaviour of

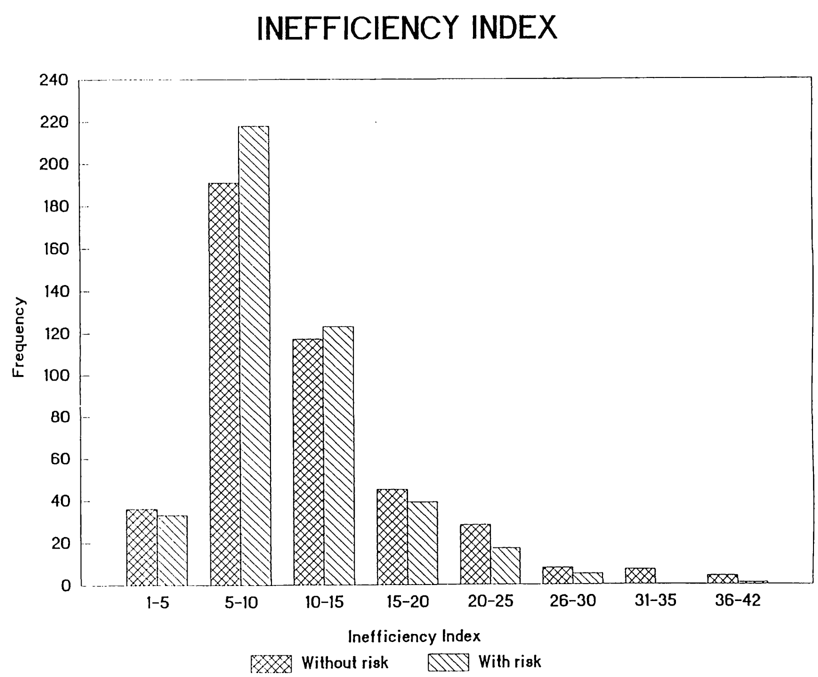

Fig. 1.

Table 6
Relationship of cost inefficiency with farm characteristics

Variable	Without risk		With risk	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	0.126	6.80 *	0.1065	7.59 *
Family size	−0.0011	−1.34	−0.0004	−0.52
Age	0.00030	1.45	0.0001	1.11
Education	−0.0030	−3.91 *	−0.0013	−2.16 *
Off-farm work	0.78×10^{-4}	0.61	0.0002	2.60 *
Farm assets	-0.2075×10^{-6}	−0.32	-0.48×10^{-6}	−1.37
Non-farm assets	-0.514×10^{-6}	−1.72	-0.75×10^{-6}	−1.17
Working animals	−0.0153	−2.29 *	−0.0004	−0.06
Credit	-0.16×10^{-5}	−2.08 *	NI	
Fragmentation	0.0049	1.10	0.0045	1.40
Extension visits	−0.0063	−5.01 *	−0.0034	−3.68 *
Holding size	0.0015	2.84 *	0.0001	0.61
Subsistence	0.32×10^{-5}	2.17 *	NI	
R^2/SEE	0.214	0.061	0.132	0.050
F(12,423)(10,425)	10.87	5.32		
Log Likelihood	604.627		689.94	
White				
HET	43.78		67.08	
χ^2(90,65).05	69.126		86	

* Significant at 5% level. NI, Not included in the model.

farmers in their input decisions, but only of costs which supposedly embody all the choices of farmers in ex-post realizations.

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