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Considerations of Risk in the Production of High-Yielding Variety Paddy: A Generalised Stochastic Formulation for Production Function Estimation

Risk and uncertainty in production have been recognised as important constraints in the process of rapid adoption of the high-yielding variety (HYV) technology in agriculture (Hiebert, 1974; Feder, 1980). No doubt, the modern inputs like HYV seeds, chemical fertilisers, pesticides, etc., which are the main ingredients of the HYV technology increase agricultural productivity significantly but at the same time, they make agricultural production more uncertain and risky. So, when we consider the question of adoption of this new technology, it is necessary to examine the effects of these inputs not only on mean production but also on the risk of production and to do that, proper specification of risk in production function is important. The stochastic specifications of input-output relationship are examined in many ways and the most familiar and commonly used formulation for estimating production function in such cases is the log-linear Cobb-Douglas (C-D) production function. But Just and Pope (1978) have demonstrated that the popular econometric specification of the C-D production function with log-linear disturbances incorrectly imposes an *a priori* restriction on the production function in that if the marginal contribution of an input to the mean output is positive, then a positive marginal effect on the variance of output is also imposed.[1]

But all inputs do not increase risk in production; on the contrary, there may be some inputs like irrigation, pesticide, equipments, etc., which are likely to reduce risk in production. Besides, the inputs which were risky at the early stage of their application may be subsequently risk-neutral over time. So, the production function must possess sufficient flexibility such that differential effects of an input on the mean production and the variance of production are accommodated. Just and Pope (1978) have developed such a Generalised Stochastic Formulation (GSF) which shows that the marginal effects of an input on the mean output and the variance of output are independent.

In this paper, production functions have been estimated empirically for HYV paddy using the GSF as developed by Just and Pope (1978, 1979). This is a micro level study based on farm level data collected by a primary survey in 14 villages of West Bengal.

I

ECONOMETRIC FORMULATION OF THE GENERALISED STOCHASTIC PRODUCTION FUNCTION AND ITS ESTIMATION PROCEDURE

The generalised stochastic formulation of the production function developed by Just and Pope (1978) is:

$$y = f(x) + h(x)\varepsilon, \quad E(\varepsilon) = 0, \quad V(\varepsilon) = \sigma$$

where y = actual output, x = set of inputs, f(x) = mean output, h(x) = a term capturing the variability of output and it is assumed to be positive and ε = a random term.

Here, the production function has two components: *(i)* the Deterministic Component, f(x) and *(ii)* the Stochastic Component $h(x)\varepsilon$. The former specifies the effects of inputs on mean output and the latter specifies the effects of inputs on the variance of output. These two components are independent. This formulation of the function satisfies the postulate that

$$\{\partial V(y)/\partial x \gtreqless 0 \quad \text{where} \quad V(y) = E[Y - E(y)]^2\}$$

Most of the usual production functions like Cobb-Douglas, Translog, etc., can be used for the estimation of 'f' and 'h' and they will give consistent and efficient estimates. In a separate paper, Just and Pope (1979) have explained the estimation procedure of the production function, stating it in the following form:

$$y = f(x) + h^{\frac{1}{2}}(x)\varepsilon, \quad E(\varepsilon) = 0, \quad V(\varepsilon) = 1$$

where the mean output is $E(y) = f(x)$ and the variance of output is $V(y) = h(x)$ and $\partial V(y)/\partial x \gtreqless 0$.

For the purpose of empirical estimation it has been supposed that both 'f' and 'h' follow the popular Cobb-Douglas form, *i.e.*,

$$f(x) = \alpha_0 x_1^{\alpha_1} x_2^{\alpha_2} \ldots\ldots x_k^{\alpha_k}$$

$$\text{and} \quad h^{\frac{1}{2}}(x) = \beta_0 x_1^{\beta_1} x_2^{\beta_2} \ldots\ldots x_k^{\beta_k}$$

Now, the regression equation to be estimated is:

$$Y_t = \alpha_0 x_{1t}^{\alpha_1} x_{2t}^{\alpha_2} \ldots\ldots x_{kt}^{\alpha_k} + h^{\frac{1}{2}}(x_{1t}, x_{2t} \ldots\ldots x_{kt}, \beta)\, \varepsilon_t,$$

$$t = 1, 2, \ldots\ldots T$$

where ε_t is a spherical disturbance term, *i.e.*, $E(\varepsilon_t) = 0$, $E(\varepsilon_t \varepsilon_{t'}) = 0$ for $t \neq t'$ and $E(\varepsilon_t^2) = \sigma^2$ for $t = 1, 2, \ldots\ldots T$ and $h^{\frac{1}{2}}(x_{1t}, x_{2t} \ldots\ldots x_{kt}, \beta) = \beta_0 x_{1t}^{\beta_1} \ldots\ldots x_{kt}^{\beta_k}$.

The parameters to be estimated are:

(i) $\alpha_0, \alpha_1, \alpha_2, \ldots\ldots \alpha_k$
(ii) $\beta_0, \beta_1, \beta_2, \ldots\ldots \beta_k$ and *(iii)* σ, along with standard errors of the estimated coefficients.[2]

II

SOURCE OF DATA

The production functions are estimated by using primary data. The cross-section farm level data on *(i)* output of HYV paddy per acre and *(ii)* the inputs used per acre for the cultivation of HYV paddy have been collected from sample farmers by a field survey in 14 villages of Daspur Block-I in Midnapore district of West Bengal, on the basis of multi-stage stratified random sampling.[3] The data were collected for the year 1989-90 which was a normal year from the viewpoint of agricultural production. The input set considered in the study includes seed, fertiliser, pesticide and labour. While the first three inputs were measured in terms of value (in rupees), the last one was measured in terms of man-days of adult male workers. Output has been measured in terms of kilograms (see Tables I and II).

TABLE I. MEAN AND STANDARD DEVIATION OF OUTPUT OF HYV PADDY, 1989-90

Cropping season (1)	Mean output per acre (kg) (2)	Standard deviation of output (3)
Rainy	1413.28	238.73
Dry	1972.09	231.37

Source: Primary Survey.

TABLE II. MEAN VALUES OF DIFFERENT INPUTS USED PER ACRE FOR THE CULTIVATION OF HYV PADDY, 1989-90

(at 1989-90 prices)

Cropping season (1)	Seed (Rs.) (2)	Labour (man-days) (3)	Fertiliser (Rs.) (4)	Pesticide (Rs.) (5)
Rainy	136	71	350	100
Dry	164	97	679	185

Source: Primary Survey.

Daspur Block-I is predominantly an agriculture-based area where the HYV technology was first introduced in paddy cultivation during the mid-sixties and at the time of this survey cent per cent of the farmers have reported that they have the necessary knowledge regarding the use of this new technology and all of them have adopted it in paddy cultivation. HYV paddy is cultivated both in the rainy and dry seasons in this area. So, the data on the above variables were collected for the two seasons separately. For the rainy season, the data were collected from 137 sample farmers and in the dry season the number of sample farmers was 263.

III

EMPIRICAL RESULTS

In the empirical estimation of the production functions for HYV paddy, four inputs have been included and they are: x_1 = seed, x_2 = labour, x_3 = fertiliser and x_4 = pesticide.[4] Although irrigation is an important element of HYV paddy cultivation, the present study could not include it in the production function as an input because the multiplicity of irrigation systems prevalent in the area precludes a 'single measure' for irrigation input. Both the deterministic and stochastic components of the production function are estimated for the rainy season and the dry season separately and their results are analysed below.

Case 1: Estimation of Production Function for HYV Paddy in the Rainy Season

The estimates of the production function for HYV paddy in the rainy season using the GSF are presented in Table III (deterministic component) and Table IV (stochastic component).

Table III shows the estimates of the magnitudes and direction of the effects of inputs on the mean output of HYV paddy in the rainy season. It shows that the R^2 is very high, implying that the variation in mean output is well explained by the regression equation. The results also indicate that all the coefficients are positive and statistically significant. The most important factor in mean output is labour, followed by pesticide and seed respectively. Fertiliser and pesticide are the two main ingredients of the HYV technology in paddy cultivation. So, quite naturally, they have been found to have significant impact on mean output. The coefficient of pesticide is substantially higher than that of fertiliser in the rainy season. The implication of the result is that in the rainy season, the HYV plants are more susceptible to pests and disease which are controlled by pesticide. So, to increase mean production, pesticide becomes more important than fertiliser. Seed is another important component of the new technology. The amount of seed to be used per acre is more or less technically fixed. But the quality of seed differs and it is reflected in the seed cost. In the present study, the variable seed is represented in terms of cost, a higher cost implies better quality of seed. As the coefficient of seed is positive and significant, it implies that better quality of seed leads to higher mean production.

TABLE III. THIRD-STAGE ESTIMATES OF THE DETERMINISTIC COMPONENT OF THE PRODUCTION FUNCTION IN THE RAINY AND DRY SEASONS

Inputs		Coefficients of inputs in mean output	
		Rainy season	Dry season
(1)		(2)	(3)
x_1	α_1 =	0.37* (0.13)	0.11 (0.07)
x_2	α_2 =	0.79* (0.09)	0.83* (0.08)
x_3	α_3 =	0.17* (0.07)	0.41* (0.07)
x_4	α_4 =	0.52* (0.08)	0.48* (0.07)
Constant terms	α_0 =	33.56* (7.71)	31.45* (4.54)
		$R^2 = 0.99$	$R^2 = 0.99$
		n = 137	n = 263

Figures in parentheses are standard errors.
* Significant at 5 per cent level.

The coefficient of labour is positive and highly significant in influencing mean output. This result suggests that as the cultivation of HYV paddy becomes highly labour intensive (Harriss, 1972; Ruttan, 1977), proper cultivation is possible only when sufficient labour is employed. This is particularly so when the use of labour-substituting machineries and equipments is limited.

Table IV shows the relative contributions of the sample inputs to the variability of output in the rainy season. The very low R^2 indicates that the inputs considered here do not explain the variability of output to any significant extent. It is also evident from the result that the 'goodness of fit' of the regression equation to the observed data is poor. This may be due to the fact that there is some inadequacy in the specification of the regression equation in the sense that the factors which are really contributing to output variability, such as rainfall, nature of irrigation, weather condition, physical environment, timing of input use, etc., were not included in the regression equation.

TABLE IV. SECOND-STAGE ESTIMATES OF THE STOCHASTIC COMPONENT OF THE PRODUCTION FUNCTION IN THE RAINY AND DRY SEASONS

Inputs (1)		Coefficients of inputs in mean output	
		Rainy season (2)	Dry season (3)
x_1	β_1 =	-1.18 (0.94)	-0.82 (0.56)
x_2	β_2 =	1.34* (0.72)	-1.15* (0.65)
x_3	β_3 =	-0.54 (0.56)	-0.09 (0.56)
x_4	β_4 =	0.44 (0.62)	1.40* (0.59)
Constant	β_0 =	2.18 (1.56)	2.93* (1.15)
		$R^2 = 0.05$ F = 1.68 n = 137	$R^2 = 0.03$ F = 1.95 n = 263

Figures in parentheses are standard errors.
* Significant at 5 per cent level.

The results in Table IV also show that only the coefficient of labour is significant while those of other inputs are insignificant. It is a very important result that fertiliser has no risk-raising effect on production and it supports the finding of Antle and Crissman (1990).[5] According to their explanation, in the short run, the farmers may be inefficient in using the modern inputs like fertiliser but over time as learning takes place, the farmer's efficiency, both technical and allocative, will improve and as a result, the input which was risky at the early stage, may be ultimately risk-neutral or risk-reducing. But here on the basis of the present result, we can not draw the inference that the farmers in this study have accumulated sufficient efficiency in using this input because this result is based on cross-section data which can not capture the time-series effects on efficiency. It is a cross-section study which examines the effect of fertiliser use on production across farms at a particular point of time when the state of knowledge and the efficiency of the farmers are more or less given. It may be stated further that there is inter-farm variation in fertiliser use,[6] although the farmers may be using it around some optimal dose and this variation, other things remaining the same, could have been a source of variability in output. But that did not happen possibly because the farmers are almost equally efficient in countering such effects. To strengthen this argument, it can be mentioned here that the data on which the present study is based were collected from an area where HYV paddy is being cultivated for more than two decades and after such a long experience, it is very likely that the farmers will be more or less equally efficient in using the input. A similar explanation can be offered for pesticide also.

The coefficient of seed is negative but insignificant in explaining the variability of output. That means, better quality of seed has a risk-reducing effect on production but the effect is evidently weak. Only labour has been found to have a risk-raising effect on production and the effect is significant. This result can be explained in the following way: The rainy season is the main cropping season of paddy in India and paddy being a labour intensive crop, the local demand for labour remains very high in the rainy season. The demand is further increased with the cultivation of HYV paddy. As a result, the farmer's dependence on 'hired labour' increases and then not only the uncertainty in timely availability of labour increases but also the possibility of unskilled labourers getting employed in large numbers increases. As a result, uncertainty in production increases with increase in labour employment.

Case 2: Estimation of Production Function for HYV Paddy in the Dry Season

The estimates of the deterministic and stochastic components of the production function for HYV paddy in the dry season using the GSF are also presented in Tables III and IV. Table III shows the relative effects of the inputs on mean output in the dry season. As before, the coefficients of labour, fertiliser and pesticide are positive and highly significant. It is interesting to note that the coefficient of fertiliser in mean output is much higher in the dry season than in the rainy season. The implication of the result is that the use of fertiliser becomes more effective in the dry season due to better physical environment and more controlled supply of water. For the same reason, the relative importance of pesticide slightly declines in the dry season as compared to the rainy season. The coefficient of seed indicates that seed choice has an insignificant effect on mean output in the dry season. It is evident from Table II that the mean value of seed is higher in the dry season as compared to the rainy season. That means, the farmers are using better quality of seed in the dry season, but it fails to make any significant effect on mean output. This result can be explained by the fact that most of the farmers are uniformly using better quality of seed in the dry season. That is why, the standard deviation of seed variable is comparatively low in the dry season.[7] As the variability in seed is low, its effect on mean output is insignificant.

The results in Table IV show that in the dry season also, the inputs considered here do not explain output variability to a significant extent as indicated by R^2. The 'goodness of fit' of the regression equation to the observed data is also poor for the same reasons as explained earlier. But as the physical environment and the weather conditions are better in the dry season, the F-statistic improves.

The results also indicate that in the dry season also, both seed and fertiliser have no significant effect on the variability of output. But labour has been found to have a risk-reducing effect on production. This is due to the fact that in the dry season, the intensity of cultivation (particularly of paddy) is low. So, the aggregate demand for labour does not become high. As a result, the uncertainty in labour supply declines. Not only that, as employment of labour increases, the agricultural operations are properly done. As a result, the risk in production declines with increase in labour employment.

Another important result of the dry season is that the coefficient of pesticide is positive and significant in the variability of output. Pesticide is generally supposed to reduce risk in production by controlling pests and disease. But here we have got a reverse result. Pesticide is a chemical input and it has some optimum dose of application. At the same time, a favourable climatic condition may be necessary for its effectiveness. So, the present result indicates that this input could not be used properly in the dry season.

IV

SUMMING UP

Production functions were estimated empirically for HYV paddy using the GSF as developed by Just and Pope (1978) and it has been found that in the context of the study area the marginal effects of inputs on mean output and variance of output are independent, *i.e.*, an input which has positive marginal effect on mean production does not necessarily have similar effect on the risk of production.

The inputs like fertiliser, pesticide and labour have significant impact on mean output of HYV paddy both in the rainy and dry seasons. Fertiliser becomes more effective in raising mean output specially in the dry season due to better physical environment and suitable weather conditions. The quality of seed has important effect on mean output particularly in the rainy season when the plants are more susceptible to pests and disease.

The uncertainty in the production of HYV paddy is not significantly explained by the inputs considered here. Apart from the sample inputs, there are many other factors like weather condition, nature of irrigation, soil condition, farmer's efficiency, etc., which appear to be more important in explaining output variability.

Fertiliser has been found to have no significant effect on production risk both in the rainy and dry seasons. But pesticide has been found to be risky in the dry season, although its effect on production risk in the rainy season is insignificant. The better quality of seed has a risk-reducing effect on production in both the seasons. But the effect is weak.

Labour has a risk-reducing effect on production under normal situation but if there is uncertainty in labour supply or unskilled labour is employed in large numbers, production risk will rise with increase in labour employment.

Mean output is higher and variance of output is lower in the dry season than in the rainy season because the physical environment and the weather conditions in the dry season are more appropriate for the cultivation of HYV paddy.

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NOTES

1. They have also added that the other functional forms like Transcendental, Translog, CES (Constant Elasticity of Substitution) and Generalised Power Function will have the same limitation if they are used with log-linear disturbances.
2. This heteroscedastic non-linear regression is estimated by using the three-step procedure, as formulated by Just and Pope (1979).
3. The Survey Project was financed by the University Grants Commission (India).
4. As the production functions have been estimated by non-linear regression (NLS), the test for possible multicollinearity among the inputs is not necessary here.
5. Antle and Crissman (1990) have concluded on the basis of their empirical results using pooled time-series and cross-section data in the context of the Philippine agriculture that nitrogen fertiliser does not necessarily increase risk in production, on the contrary, it may reduce risk under favourable conditions.
6. The standard deviations of fertiliser in the rainy and dry seasons are respectively 97 and 115.
7. The standard deviations of seed variable in the rainy and dry seasons are 24 and 17 respectively.

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