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# Impact of Risk on HYV Adoption in Bangladesh

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## Abstract

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The objectives of this paper are to develop a measure of risk aversion based on the safety-first principle. The risk coefficient for a large number of farmers was positive indicating the tendency towards gambling in Bangladesh agriculture. Farmers who were near subsistence income (disaster level of income) tended to choose riskier crops such as HYV rice. The risk-aversion variable was highly correlated with demographic and socioeconomic variables. Large holders of land tended to be relatively more risk-averse than small holders of land and area allocated to HYV proportionally declined with increases in holding size.

A three-equation model on HYV adoption decisions, fertilizer and hired labour was estimated with a risk-aversion variable based on the safety-first principle, and expected and significant signs were obtained with the risk-aversion variable in HYV and hired labour equations.

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## Introduction

The objective of this paper is to develop a measure of risk based on the safety principle, using data on Bangladesh farm households for the year 1982. Having developed such a measure, 'risk-taking' behaviour as against risk-averting be-

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The authors are grateful to IFPRI for permitting them to use the data collected by IFPRI/BIDS team in Bangladesh. The results of the survey will be published by IFPRI in the near future. The authors wish to thank S. Davies and referees of the journal for their useful suggestions in improving the draft.

haviour is analyzed<sup>1</sup>. Are farmers who are striving hard to survive more risk-prone compared to farmers who have a guaranteed subsistence and are relatively well off?

Any measure of farm risk will have two important variations: (a) the environment, and (b) farmers' risk attitudes based on demographic and socioeconomic factors. The developed measure of risk was examined for 16 villages and five environmental zones to reflect the variations in the farmers' risk-taking in different situations. The explanation of a derived measure of risk was sought through demographic and socioeconomic characteristics by environment and the whole sample.

The difficulty of risk measurement in any environment is compounded when one is dealing with a developing economy such as Bangladesh. Given the ambiguity of the word, we speak of 'risk-taking' or 'risk-aversion' in the context of safety-first principle, where farmers are trading expected return for reduced risk. The measure of risk-taking is used to examine its impact of HYV adoption and intensity.

In Section 1, the measures of risk based on the safety-first principle are examined and the data for defining such a measure are discussed. In Section 2, the developed measure is related to socioeconomic attitudes of farmers under different environments. In Section 3, the general model integrating HYV adoption, choices of fertilizer and hired labour inputs with the 'risk-taking' measure is suggested and estimated. In the last section, summary and conclusions are provided.

## 1. Safety-first principle

In the safety-first principle it is assumed that the individual's objective is to minimize the probability of experiencing an income shortfall below some initial level. Different formulations have been attempted and two measures of risk-taking have been used in the literature in agricultural economics (Roy, 1952; Moscardi and De Janvry, 1977). The safety-first risk formula derived by Roy (1952) was used empirically by Shahabuddin et al. (1986). Here, the agent minimizes the probability that the income falls below a specified disaster level ( $d^*$ ), i.e.

$$\text{Min } P(\pi < d^*) \quad \text{or} \quad \text{Min } F(d^*) \quad (1.1)$$

where  $P$  refers to probability, and  $F$  is the cumulative distribution function of the  $i$ th prospect. Operationally, the rule is expressed as:

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<sup>1</sup>The risk concept is based on the utility maximization model. A measure of risk aversion is the amount of money (measured by the difference between a certain pay off and an expected pay-off) that an individual will forego to avoid an uncertain outcome. In the safety-first principle, agents are indeed risk-averse. The term 'risk aversion' is used in the context of the safety-first model where a household is allowed to trade expected return for reduced risk.

$$\text{Minimize } \left( \frac{d^* - \mu}{\sigma} \right) \quad (1.2)$$

where  $\mu$  is the expected income,  $d^*$  is disaster level income, and  $\sigma$  is the standard deviation of household's income. The relative magnitudes of the variables  $d^*$  and  $\mu$  determine whether the farm family is forced to gamble ( $d^* > \mu$ ) or allowed to trade expected return for reduced risk ( $d^* < \mu$ ) in its choice<sup>2</sup>.

### Hypotheses

Some hypotheses emerge immediately from the safety-first principle. If the disaster level of income is higher than expected income, a farmer may be forced to gamble in his choice of HYV versus local variety or in the use of inputs so that the gamble pays off and his realized income turns out to be higher than disaster-level income. Pratt (1964) and Arrow (1970) hypothesized in the context of expected utility theory that absolute risk aversion may decline rapidly in the neighbourhood of subsistence income. This hypothesis was supported by Scandizzo and Dillon (1979) in their study. Once the farmers' expected incomes are higher than the disaster level of income, risk-aversion sets in and the tendency to gamble with one's wealth or current income (when it is above disaster level) tends to diminish. This is the other plausible hypothesis which may be tested with the Bangladesh data.

The impact of risk on decision makers in their choice of HYV crop, fertilizer use and hired labour will be examined. To what extent does the marginal factor cost of variable inputs exceed or fall short of marginal value productivity on average in Bangladesh agriculture under risk?

### Data

A survey was conducted in 1981–82 by an IFPRI/BIDS team choosing 633 households comprising 465 farms across 16 villages in five environmental zones. The production, yield, area and input data were obtained for three seasons, Aus, Aman and Boro rice, and other crops. Moreover, for the year 1981, plot-wise data on yield were available, but information on inputs used was not collected during the survey. Data on crop prices by farms were not available. For two inputs, namely hired labour and fertilizers, data were recorded in value and quantity terms by farms for 1982. This permitted us to derive the prices

<sup>2</sup>In the safety-first framework, decision makers are more concerned with maximizing their chances of survival than maximizing their income. Different choices made by the farmers do not depend on their differences in attitudes towards risk but in the differences in their subsistence needs, resource endowments and perceptions of riskiness among competing activities.

by farms across 16 villages. Data on inputs and output for local and HYV crops indicate that the magnitudes were vastly different.

In the survey, farmers were asked how much output they thought they had lost due to adverse weather. This variable was recorded as perceived crop damage for each crop. Actual yield was obviously lower than expected yield in this respect. We used a weighted average of crop damage variable in the estimation of the aggregate level of expected yield. The weights were derived by using crop-by-crop yield regressions on inputs per acre and the crop damage variable. Partial regression coefficients of crop yield with respect to crop damage were used as weights to obtain an aggregate crop damage variable. Price data for all crops were not available and hence this procedure was used. The weighted crop damage variable<sup>3</sup> was defined as:

$$\text{TOTDMG2} = \frac{\sum k_i \text{DMG}_i}{\sum k_i} = \text{estimate of unexpected yield loss} \quad (1.3)$$

It is believed that regression weights will show the relative importance of the crop damage variable. It is the shadow value of yield loss, and the weighted crop damage would yield unexpected total damage for each farm.

One of the obvious limitations of obtaining expected income from cross-section data is that the year may not be a representative one for the household. However, there was no other set of data available.

### Socioeconomic variables

The survey collected data on farm assets and income as well as some information on individual household characteristics. Farm assets were aggregated into two categories: agricultural and non-agricultural. Data on credit received from both institutional and non-institutional sources were recorded. From the household characteristics, the education of the household head and the number of primary workers in the agricultural and non-agricultural activities were included. The six variables, primary workers in agriculture (PAGR), primary workers in other activities (POTH), agricultural capital (AGCP), non-agricultural capital (NAGCP), family size (FSZ) and education of the head of household (EDNHH) were denoted as socioeconomic variables.

The environmental variables, DA1 to DA5, refer to the classification of villages according to environments. Sixteen villages were classified into five groups: Red deep brown soil (DA1); Highland Ganges Project (DA2); saline soil (DA3); developed area with high infrastructure (DA4); and flood plain (low-lying) (DA5).

<sup>3</sup>As a rough check, we compared this variable with the arbitrary value share weights for rice and other crops; overall TOTDMG2 were not different for most farmers.

### Computation of disaster level income for each household

The disaster level income  $\bar{d}$  is computed using the national poverty figures for 1982 plus the credit outstanding to both institutional and non-institutional sources. The value of livestock and business assets (liquid assets) and non-farm income from trade and industry were subtracted.

The formula for disaster income for each household was based on Roumasset (1976):

$$\bar{d} = \text{MCN} + \text{UD} - \text{LA} - \text{OFI} \quad (1.4)$$

where  $\text{MCN} = 1680 [\text{FSZ} - 0.5 (\text{NWCH})]$  are the minimum consumption needs obtained from minimum calories per person converted into the Bangladesh currency unit, taka (US\$ 0.33), in which FSZ is family size and NWCH are numbers of children (family size treats all as adults), and where  $\text{UD} = \text{ICRD} + \text{NCRD}$  is urgent debt (institutional credit + non-institutional credit received),  $\text{LA} = \text{LIVT} + \text{BUST}$  are livestock and business assets in value terms (1980), and  $\text{OFI} = \text{TRDI} + \text{INDI}$  is trade income + industrial income.

### Expected income for each household and standard deviation of income for each village

The expected income defined  $\mu$  is obtained from expected value of cropped output less costs on variable inputs:

$$\mu = (\text{VOWNZ} + \text{VRINZ})(1 + \text{TOTDMG2}) - \text{SEEDQC} \\ - \text{IRRC} - \text{FERTC} - \text{BULLC} - \text{PESTC} - \text{WAGEC} \quad (1.5)$$

We use value of output on owned (VOWNZ) and rented land (VRINZ) and adjust for crop damage to obtain the expected value of output. The variable TOTDMG2 is the weighted crop damage and this yields unexpected crop damage. There is always some expected crop damage. Since we did not have output figures for the previous year, we had to use current-period output figures converted to expected value of cropped output. From these, we excluded the cost of all purchased inputs, which are seed (SEEDQC), irrigation (IRRC), fertilizer (FERTC), bullocks (BULLC), pesticides (PESTC) and wages (WAGEC). The expected income for each household does not consider the possible covariance between prices and quantities explicitly and this is because we did not have separate data on prices and quantities at a cross-sectional level for 1981 or 1982.

The standard deviation in income is required for each household, but this will be impossible to derive from one observation. Hence, it was assumed that actual yield data for the previous year (1981) could be used to obtain the variances and covariances in output values among crops. For 13 crops, yield figures were available and these were converted to values for each village. From

these we compiled the variance–covariance matrix of value of each crop and used the formulation:

$$\sigma_i^2 = c' V_i c$$

where  $c'$  is a  $(1 \times 13)$  row vector of unit elements,  $V_i$  the variance–covariance matrix for each village ( $i = 1, 2, \dots, 16$ ), and  $c$  is the  $(13 \times 1)$  column vector of unit elements.

The disaster level of income  $\bar{d}_{ij}$  and  $\mu_{ij}$  (the expected income) are household-specific while  $\sigma_i$  is village-specific. We denote by village and household sub-script the risk-aversion variable defined as:

$$R_{ij} = \frac{\bar{d}_{ij} - \mu_{ij}}{\sigma_i} \quad \text{where } i = 1, 2, \dots, 16 \quad (1.6)$$

$$j = 1, 2, \dots, 462$$

## 2. Socioeconomic attitudes and risk-taking

In this section, we discuss the results based on the relationship between socioeconomic attitudes and risk-aversion variables. Before the results are presented, various cross-tabulations were performed on the  $R_{ij}$  variable. The  $R_{ij}$  variable was studied by village to see whether there were more risk takers in any specific village. No such tendency was found, and distribution of  $R_{ij}$  appeared random.  $R_{ij}$  was classified by five different environments and it was conjectured that in relatively poorer environments farmers would tend to take more risks. No such evidence was found. Holding size and  $R_{ij}$  were closely related and small holders of land took more risk compared to large holders of land. The difference was very marked when cropped-area figures were used and the measure of risk was significantly negatively correlated with cropped area by household. The mean value of cropped area of extreme risk averters was 14.86 cropped acres (6 ha) while the mean value of extreme risk takers were 3.79 cropped acres (1.5 ha).

The frequency distribution of  $R_{ij}$  is shown in Table 1. The test of normality indicates that on a sample size of 462 farms, the distribution of  $R_{ij}$  measure shows a significant departure from normality and the distribution is skewed. The classification of  $R_{ij}$  by category sharecroppers and owners should indicate that owners would be risk-takers and the mean of owner  $R_{ij}$  (+ve) should be significantly different from the mean of sharecroppers (–ve). Sharecroppers shared risk with owners, and therefore they would not take risk in the use of input decisions. This is the Stiglitz–Newbery hypothesis<sup>4</sup> (Newbery and Stig-

<sup>4</sup>The means of  $R_{ij}$  for two groups revealed that they were not significantly different from each other. There were 382 owners and 80 share croppers.

TABLE 1

Frequency distribution of safety-first measure of risk aversion

Count	Mid point of risk interval	Count	Mid point of risk interval
2	-2.75	63	0.05
0	-2.65	52	0.15
0	-2.55	44	0.25
1	-2.45	44	0.35
1	-2.35	24	0.45
0	-2.25	15	0.55
0	-2.15	14	0.65
0	-2.05	9	0.75
1	-1.95	10	0.85
1	-1.85	0	0.95
0	-1.75	3	1.05
1	-1.65	3	1.15
2	-1.55	0	1.25
1	-1.45	1	1.35
2	-1.35	0	1.45
1	-1.25	1	1.55
1	-1.15	0	1.65
2	-1.05	0	1.75
3	-0.95	1	1.85
3	-0.85		
5	-0.75		
10	-0.65		
14	-0.55		
6	-0.45		
11	-0.35		
29	-0.25		
30	-0.15		
45	-0.05		
		Total 462	

Note: There were eight very extreme cases of negative values of risk aversion and they were not included in the frequency distribution table here.  $\mu'_1 = -0.15$  is the mean,  $\mu_2 = 8.56$  is variance,  $\mu_3 = -17.16$  skewness and  $\mu_4 = 339.16$  kurtosis.

litz, 1981). This is, however, a different concept of risk-taking or risk-sharing and hence we are hesitant to confirm or reject on the basis of  $R_{ij}$ .

The tails of the distribution of  $R_{ij}$  were examined and it was found that risk-takers were generally poor farmers. Institutional credit and non-institutional credit were strongly positively related with holding size.

The variation of the risk-taking variable among households for 16 villages was explained by using the socioeconomic characteristics: education of the head of household and family size, area, non-agricultural capital, agricultural capital and non-agricultural income.



The 'risk-taking' equation will have the following form:

$$R_{ij} = \text{constant} + b_1 \text{EDNHH}_{ij} + b_2 \text{FSZ}_{ij} + b_3 \text{NAGCP}_{ij} + b_4 \text{AGCP}_{ij} + b_5 \text{NAGIN}_{ij} + b_6 A_{ij} + \epsilon_{ij} \quad (2.1)$$

With expected signs:

$$b_1 \geq 0, \quad b_2 > 0, \quad b_3 < 0, \quad b_4 \geq 0, \quad b_5 < 0, \quad b_6 < 0$$

our estimated regression was (\*, significant at 5% level, *t*-ratios in parentheses):

$$\begin{aligned} R_{ij} = & -0.1758 + 0.01704 * \text{EDNHH}_{ij} + 0.3068 * \text{FSZ}_{ij} & (2.2) \\ & (0.810) \quad (8.219) & (9.525) \\ & -0.000038 * \text{NAGCP}_{ij} + 0.000018 * \text{AGCP}_{ij} \\ & (3.643) & (2.041) \\ & -0.000044 * \text{NAGIN}_{ij} - 0.55037 * A_{ij} \\ & (3.646) & (27.069) \end{aligned}$$

$$R^2 = 0.65395, \quad F = 143.3044, \quad \text{SEE} = 1.73210, \quad n = 462$$

The equation indicates that all the coefficients have the expected signs and are significantly different from zero.

The negative sign with respect to *A* confirms the hypothesis that larger cropped area puts farm households less at risk and reduces the likelihood that they will gamble in order to minimize the probability that they will suffer disaster.

When we divided the sample into the five environments described earlier and ran the regressions using the same set of explanatory variables, the error term did not satisfy normality for each of the sub-samples.

### 3. Model integrating risk in input decisions

In this section, a simple model of inputs and output integrating risk aversion is presented. Our flow model is shown in Fig. 1. The chart indicates that farmers' risk attitudes presumably affect the adoption of HYV decision and area allocated to HYV adoption. This is the first-stage decision. HYV area allocation is not only affected by the risk, but also by potential or expected value of output, availability of irrigation and institutional and non-institutional credit. The infrastructure index (the lower it is, the better the infrastructure) was compiled by the IFPRI and was used in the equation but it seems that this effect is captured in the credit and potential output indicator. The potential (expected) output is derived by using  $(1 + \text{crop damage proportions})$  times the actual output. The perception of crop damage of each household has also influ-

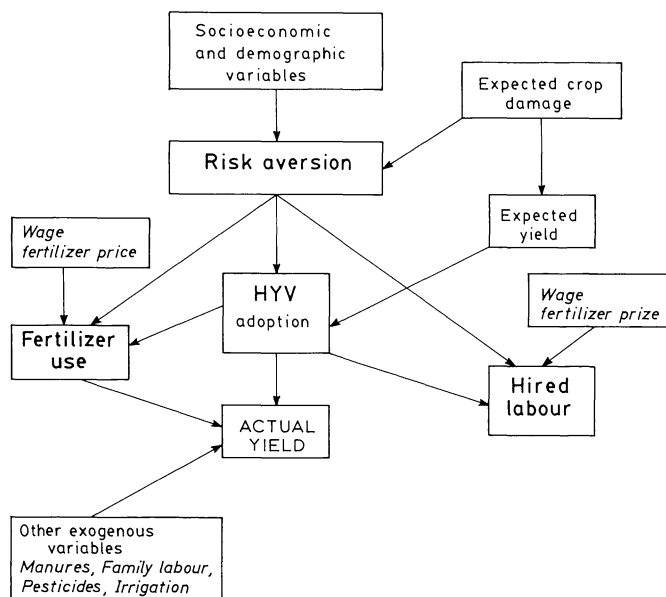


Fig. 1. Chart of a simple model of inputs and outputs integrating risk aversion.

enced the measure of risk aversion based on safety-first principle, especially the expected net income.

The use of fertilizer intensity and hired labour intensity is expected to be influenced by risk-aversion attitudes and HYV cropped area, family labour, infrastructure, availability of manures, wage rate and fertilizer price. It is plausible that risk aversion may not have a direct impact on the choice of these inputs but it could come through the first-stage decision on HYV area allocation and the potential value of crop output. Manures, family labour and infrastructure are structural inputs.

A three-equation model is estimated using three-stage least squares with constraints. The coefficient of wage rate in the fertilizer demand equation is equated to the coefficient of fertilizer price in the hired labour equation<sup>5</sup>. We did not include the farms where HYV was not adopted. The inclusion of these farms would require simultaneous tobit estimation. In addition, the output equation is not estimated in a simultaneous equation context and when this was attempted, most of the regression coefficients were insignificant in the output equation.

The results based on 368 HYV farms with their fertilizer and hired labour intensity are presented in Table 2. The Wald test yields a value of  $\chi^2$  about 1.026 while the likelihood ratio  $\chi^2$  test has a value of 1.9749. Both of these

<sup>5</sup>This was attempted to obtain labour and fertilizer as substitutes, in both the equations.

TABLE 2

System estimation with risk and cross-equation constraints

	HYVA equation	FQA equation	HLA equation
Constant ( <i>t</i> -ratio)	0.03517 (1.371)	78.3985 (6.586)	13.1375 (6.228)
CRDI <sub>ij</sub> ( <i>t</i> -ratio)	0.000124 (2.201)		
CRDNI <sub>ij</sub> ( <i>t</i> -ratio)	0.000176 (3.801)		
IRGA <sub>ij</sub> ( <i>t</i> -ratio)	0.16779 (5.046)		
EVVADJ <sub>ij</sub> ( <i>t</i> -ratio)	0.000059 (9.709)	-0.002943 (1.781)	0.001338 (2.526)
<i>R</i> <sub>ij</sub> ( <i>t</i> -ratio)	0.01734 (4.559)	-1.15220 (1.582)	0.44162 (1.958)
DINF <sub>ij</sub> ( <i>t</i> -ratio)		-3.7080 (7.143)	
FLA <sub>ij</sub> ( <i>t</i> -ratio)		-0.25550 (2.946)	-0.32079 (11.621)
MNRA <sub>ij</sub> ( <i>t</i> -ratio)		0.14105 (3.392)	0.01054 (0.787)
WAGE <sub>ij</sub> ( <i>t</i> -ratio)		0.29579* (3.708)	-0.01905 (0.737)
FPRICE <sub>ij</sub> ( <i>t</i> -ratio)		-15.8007 (4.987)	0.29579* (3.708)
HYVA <sub>ij</sub> ( <i>t</i> -ratio)		224.735 (11.136)	38.3348 (5.459)
LAND ( <i>t</i> -ratio)			0.004273 (1.743)

Wald  $\chi^2 = 1.026$ , LR  $\chi^2 = 1.9749$ ,  $\chi^2_{0.05}$  (1 degree of freedom) = 3.841.

\*Identical coefficients because they were constrained.

confirm that our restriction that the coefficient of wage rate in fertilizer equation is identical to the coefficient of fertilizer price in the hired labour equation is not rejected by the tests. The estimates suggest that credit, risk aversion, availability of irrigation and potential output all positively influence the allocation of area to HYV crop. The fertilizer intensity is significantly related to infrastructure, family labour, manures, fertilizer price and HYV area intensity.

In the hired labour equation, cropped area, potential output, HYV area intensity and risk aversion – all explain a significant proportion of variation in hired labour use on sample farms.

## Summary and Conclusions

In this paper, an estimate of risk aversion variable using the safety-first principle is obtained from farm-level household data. The coefficients for a large number of farmers was positive, indicating the tendency towards gambling in Bangladesh agriculture. This meant that farmers who were near the subsistence income (disaster level of income) tended to go for riskier crops such as HYV. The HYV adoption intensity was significantly related to risk and both the use of hired labour and fertilizer intensity were significantly related to HYV intensity. Risk thus played a very important role in the explanations of input decisions.

The risk coefficients were highly correlated with both demographic and socioeconomic variables. A multiple linear regression provided a good fit and it was found that large holders of land tended to be more risk-averse compared to small holders of land. Efforts to correlate the estimates of risk preference and the socioeconomic and structural characteristics of farm household in peasant agriculture have had both mixed results, i.e. success and failure stories. The results in this paper are contrary to the results of Binswanger (1980) and Walker (1981).

The other contribution of the paper is to develop a three-equation model in which a measure of risk is incorporated. We find that risk plays a significant role in the adoption of HYV and the use of hired labour in equation-by-equation estimation. The estimated three-equation model reflects that the use of both fertilizers and hired labour is influenced by HYV decisions on which risk has a significant role.

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