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***YIELD AND PRICE RISK OF MAJOR CROPS IN BANGLADESH:
AN ECONOMETRIC ANALYSIS****

Quazi Shahabuddin**

ABSTRACT

In this paper, estimates of yield and price risk of different crops in some selected regions of Bangladesh have been derived. The variance-covariance matrices of random disturbances associated with both output and prices were estimated utilising aggregate time series data in four districts. The general procedure adopted was to extract the systematic portion of aggregate time series so that the residuals represented the estimates of random components from which the relevant variance-covariance matrices were subsequently computed. Ranking of crops in terms of estimated variance of output disturbances showed that jute occupied the top position, followed by wheat, *aman* rice, *aus* rice, IRRI *boro*, oilseeds and pulses. This gives some idea of relative 'yield risk' of different crops in Bangladesh. Ranking of crops in terms of estimated variance of price disturbances, on the other hand, showed that pulses occupied the top position followed by oilseeds, jute, *aman* rice, IRRI *boro* and *aus* rice. This may give some idea of relative 'price risk' of different crops in Bangladesh.

I. INTRODUCTION

To analyse farmers' decision making under risk, not only does one need quantitative information about farmers' attitudes and behaviour towards risk, but one must also evaluate the riskiness of alternative cropping patterns as well. This remains true irrespective of the specific decision model chosen for analysing their decision making behaviour. In this paper, attempt will be made to derive econometrically estimates of random disturbances associated with both output and prices of different crops in some selected areas in Bangladesh. This will throw some light on the relative riskiness (both yield as well as price risk) of different crops and/or alternative cropping patterns in Bangladesh.

*This paper is based on the author's Ph.D. dissertation.

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In Section II, the estimating procedures are discussed, and the resulting estimates of variance-covariance matrices of both output and price disturbances of different crops are presented. Based on these estimates, a comparison of yield as well as price variability of different crops in four selected districts of Bangladesh is made in Section III. Section IV summarises the main findings of this study.

II. ESTIMATION OF RANDOM DISTURBANCES ASSOCIATED WITH OUTPUT AND PRICES OF DIFFERENT CROPS IN BANGLADESH

In estimating the random disturbances associated with both output and prices, one would like to have time series of farm level data on output and prices for various crops from which one could extract the actual random disturbances over time. Unfortunately, however, we do not have the time series data on farm-level inputs, output and prices and hence we cannot compute the random disturbances in the way one could ideally have done¹. We have, therefore, been forced to devise some alternative procedures utilising the information at our disposal. Our general approach has been to try to extract the systematic component from the aggregate time series so that we are left with the estimates of the disturbance terms from which we can compute the relevant variance-covariance matrices. The statistical procedures adopted in our study and the resulting set of estimates are described below with respect to both output and price disturbances.

Estimation of Output Disturbances

Our objective, as noted above, is to extract the random component associated with output, taking into account the effect that various controllable inputs may have on output. One of the most frequently used approaches to derive econometrically the probability distribution of yields, is to simply assume that aggregate regional or district level data correctly reflect yield variations at farmer's field levels.² Our procedure thus involves the direct estimation of aggregate production functions using district level time series data on crop output, acreage and rainfall, both annual and monthly, for various crops in each of the four selected districts in Bangladesh. By fitting production functions to time series data, one can obtain not only an estimate of the mean of the frequency distribution of yields for a given set of inputs but can also examine the residuals from the fitted equations for a given range of inputs to obtain estimates of higher moments. This is essentially the approach adopted in this study.

The functional form chosen in our estimation of aggregate production functions was of the Cobb-Douglas type, $Q = AL_j^\alpha e^{\beta T} u_j$, where Q_j represents physical output

of crop j , L_j represents acreage devoted to crop j and $e^{\beta T}$ represents the growth of complimentary inputs like labour and other purchased inputs for which no crop-wise time series data were available. With rainfall data (both annual and monthly) incorporated, different versions of our estimating equations took the following log-linear forms :

$$\log Q_j = \log A_j + \alpha \log L_j + \beta T + \gamma \log(\overline{AR}_j / \overline{AR}_j) + \log u_j, \dots \dots \dots (1)$$

$$\log Q_j = \log A_j + \alpha \log L_j + \beta T + \gamma_1 \log \overline{AR}_j + \gamma_2 (\log \overline{AR}_j)^2 + \log u_j, \dots \dots \dots (2)$$

$$\log Q_j = \log A_j + \alpha \log L_j + \beta T + \sum_{i=1}^{12} \delta_i \log (\overline{MR}_j / \overline{MR}_j) + \log u_j, \dots \dots \dots (3)$$

$$\log Q_j = \log A_j + \beta \log L_j + \beta T + \sum_{i=1}^k \delta_{1i} \log \overline{MR}_j + \sum_{i=1}^k \delta_{2i} (\log \overline{MR}_j)^2 + \log u_j, \dots \dots \dots (4)$$

Where \overline{AR}_j , \overline{MR}_j , \overline{AR}_j and \overline{MR}_j represent the annual and monthly rainfall data and their respective mean levels, T represents time-trend and k represents the crucial months identified for a particular crop on the basis of *a priori* knowledge regarding the sowing and harvesting periods of the crop.

These equations were estimated using aggregated time series on crop output, acreage and rainfall for the period, 1948-49 to 1976-77, for different crops in each of the four selected districts in Bangladesh.³ It was observed that although the co-efficients of land and those of the time trend (which captures the growth of other complimentary inputs) were usually significant, the estimated coefficients of rainfall, either in annual or monthly form were seldom statistically significant in any of the areas studied⁴. Perhaps the time period was not sufficiently long to capture the significance of the rainfall variable in explaining the variability of output for any of the crops estimated⁵.

In computing the regression residuals, \hat{u}_j , as $(\log Q_j - \log \hat{Q}_j)$, where $\log \hat{Q}_j = \log A_j + \alpha \log L_j + \beta T$, therefore, we have decided to generate two alternative sets of estimates of output disturbances in this study.

(i) Set I includes rainfall as an independent variable. Of the four versions estimated, the one with the highest R^2 was chosen for each crop in all four districts. In computing \hat{u}_j 's, of course, the fitted values of output were derived using the estimated coefficients of the controllable inputs only, so that the regression residuals reflect the random component of output fluctuations over time.

(ii) Set II excludes rainfall data. This alternative set of output disturbances were computed to check for any bias in the estimated coefficients that the omission of weather variables from the regression equation might cause.

Using these two sets of estimates of output disturbances, u_{it} s, then, the sets of variance-covariance matrices were computed for the relevant crop portfolio in each of our four selected districts in Bangladesh. Estimates of set I are presented in Table 1, those of set II are not presented because of the similarity with set I.

TABLE 1 ESTIMATED VARIANCE-COVARIANCE MATRIX OF OUTPUT DISTURBANCES FOR DIFFERENT DISTRICTS

Sylhet District					
	Local Aus	Local Aman			
Local Aus	.013	.002			
Local Aman	.002	.024			
Pabna District					
	Local Aus	Local Aman	Jute	Pulses	Oilseeds
Local Aus	.036	.015	.015	-0.05	-.005
Local Aman	.015	.035	.007	-.005	-.001
Jute	.015	.007	.039	-.004	-.005
Pulses	-.005	-.005	-.004	.006	-.001
Oilseeds	-.004	-.001	-.005	.001	-.007
Faridpur District					
	Local Aus	Local Aman	Jute	Pulses	Wheat
Local Aus	.010	-.003	.003	-.0002	-.002
Local Aman	-.003	.026	.006	-.003	-.006
Jute	.003	.006	.032	-.004	-.0001
Pulses	-.0002	-.003	-.004	-.006	-.005
Oilseeds	-.002	-0.006	-.0001	.005	.034
Mymensingh District					
	Local Aman	Jute	IRRI Boro		
Local Aman	.014	.0002	-.003		
Jute	.0002	0.037	.002		
IRRI Boro	-.003	.002	.017		

Based on these estimated variances and covariances of output disturbances of different crops in four districts we may make the following observations :

(a) Ranking of crops in terms of estimated variances of output disturbances (average of four districts) shows that jute (.036) occupies the top position, followed by wheat (.034), aman rice (.025), aus rice (.019), IRRI boro (.017), oilseeds (.007) and pulses (.006). This may give some idea of relative 'yield risk' of different crops in Bangladesh, jute being the most risky in the set and pulses the least.

(b) A good number of covariance terms record negative values in the estimated matrices, particularly in Pabna and Faridpur districts. These mainly occur in those cases pairing with pulses and oilseeds in Pabna, and pulses and wheat in Faridpur.

(c) Between the two sets of estimated matrices (results of Set II are not shown in the text), one does not observe any significant differences either in the magnitudes of estimated variances or in the sign and magnitudes of estimated covariances in any of the areas studied. This shows that the omission of weather variables did not cause any significant bias in the estimated coefficients.

Estimation of Price Disturbances

From a statistical point of view, the estimation of price disturbances is easier than the estimation of output disturbances because the regional time series presumably do not differ appreciably from the time series of farm-gate prices. In estimating the price disturbances of different crops, using regional time series of grower's prices, we employed a variant of the Nerlovian expectation model which yields an estimating equation of the following form :

$$\log P_{it} = \lambda_0 + \lambda_1 T + \lambda_2 \log P_{it-1} + v_{it}$$

where $\log P_{it}$ and $\log P_{it-1}$ represent logarithms of the regional price of the i th crop at period t and $t-1$ respectively, T represents the time trend and v_{it} the random disturbances affecting the price of i th crop at time t .

As with output disturbances, estimates of price disturbances, \hat{v}_{it} , were derived as $(\log \hat{P}_{it} - \log P_{it} +)$ where $\log \hat{P}_{it}$ represents the fitted values. Using these point estimates, the relevant variance-covariance matrix for each district was computed.

Using a time series covering the period between 1963-64 and 1978-79, the coefficients were estimated for each crop in the four selected districts. It was observed that the coefficients of lagged price were hardly significant, the exception being the jute and motor

pulses in Pabna and Faridpur districts⁶. No evidence of the formation of farmer's price expectation, naive or otherwise, could, therefore, be established in our data set.

TABLE 2 ESTIMATED VARIANCE-COVARIANCE MATRIX OF PRICE DISTURBANCES FOR DIFFERENT DISTRICTS

Sylhet District						
	Local Aus	Local Aman				
Local Aus	.068	.077				
Local Aman	.077	.103				
Pabna District						
	Local Aus	Local Aman	Jute	Pulses (Keshari)	Pulses (Motor)	Oil-seeds
Local Aus	.070	.072	.030	.058	.042	.067
Local Aman	.072	.087	.015	.059	.030	.074
Jute	.030	.015	.099	.037	.095	.057
Pulses(Keshari)	.058	.059	.037	.129	.101	.110
Pulses(Motor)	.042	.030	.095	.101	.174	.089
Oilseeds	.067	.074	.057	.110	.089	.122
Faridpur District						
	Local Aus	Local Aman	Jute	Pulses(K)	Pulses(M)	
Local Aus	.072	.071	.030	.070	.037	
Local Aman	.071	.082	.011	.081	.025	
Jute	.030	.011	.099	.027	.097	
Pulses (K)	.070	.081	.027	.141	.095	
Pulses (M)	.037	.025	.097	.095	.066	
Mymensingh District						
	Local Aman	Jute	IRRI boro			
Local Aman	.087	.022	.701			
Jute	.022	.099	.011			
IRRI boro	.071	.011	.071			

The estimated coefficients of the time trend variable, on the other hand, were found to be highly significant in almost all cases. Our measure of price change variability as captured in the regression residuals, \hat{v}_{it} , should thus be viewed as random fluctuations around the trend values over a given time period.⁷ Based on these estimates of price disturbances, variance-covariance matrices for the relevant crop portfolio in each of our four selected districts were computed (Table 2).

Based on these estimated matrices of variance and covariance of price disturbances for different crops, we may make the following observations :

(a) Ranking of crops in terms of the estimated variances of price disturbances (average in four districts) shows that pulses ((.153) occupies the top position, followed by oilseeds (.122), Jute (.099), aman rice (.090), IRRI boro (.071) and aus rice (.070). This may give some idea of the relative 'price risk' of different crops in Bangladesh. It is significant to note that pulses and oilseeds which were ranked in the bottom in terms of output disturbances, occupy top two positions in terms of variability of price disturbances.

(b) The magnitudes of estimated variances (also covariances) of price disturbances are observed to be much higher than those of output disturbances. This is true for all crops in the four selected districts. Therefore, 'price risk' of different crops in Bangladesh is observed to be much greater than the 'yield risk' in our study.⁸

(c) Unlike output disturbances, all the estimated covariances of different crop-pairs for price disturbances record positive values in each district. Since the magnitudes of covariances associated with price disturbances are much greater than those associated with output disturbances, this means that the sign of income covariances will for the most part, be dictated by positive values of price covariances.

III. A COMPARISON OF YIELD AND PRICE VARIABILITY OF DIFFERENT CROPS IN THE SELECTED AREAS

Even though farmers are interested in the variability of crop returns (and not simply output or price variability) and ultimately in the variability of returns from a particular crop portfolio, some preliminary observation about the riskiness of output and price of various crops across different areas may be made based on these estimated variance-covariance matrices.⁹ To do so, however, it becomes necessary to rearrange the information contained in these matrices to reflect the relative variability of output and prices in different areas. This is done below in Tables 3 and 4 respectively.

TABLE 3 RELATIVE OUTPUT VARIABILITY OF DIFFERENT CROPS IN VARIOUS DISTRICTS IN BANGLADESH

Districts	Crops						
	Aus Rice	Aman Rice	Jute	Pulses	Oilseeds	Wheat	IRRI boro
Sylhet	.012 (10.96)	.077 (8.45)	—	—	—	—	—
Pabna	.034 (18.13)	.029 (16.81)	.040 (19.94)	.006 (7.61)	.006 (7.93)	—	—
Faridpur	.009 (9.66)	.026 (15.96)	.023 (15.20)	.006 (7.70)	—	.033 (17.88)	—
Mymensingh	—	.013 (10.95)	.030 (17.00)	—	—	—	.016 (12.43)

Note : The figures in the parentheses indicate coefficients of variation (in percentages) of random components of output for each crop in different districts.

(i) It is evident from Table 3 that the relative variability as captured in the coefficients of variation of two types of rice, namely *aus* and *aman* (the former harvested in summer season and the latter, in winter) is very similar in both Sylhet and Pabna districts. Only in Mymensingh does *aman* show greater variability as compared to the *aus* rice.

(ii) The output variability of the jute crop, on the other hand, is slightly higher than either *aus* or *aman* rice in Pabna. In Faridpur, the output variability of jute, though very much comparable to *aman*, is decidedly higher than that estimated for *aus* rice, its competing crop in the summer season. In Mymensingh district, again, the variability of jute is observed to be much higher than that of *aman* rice. Unfortunately, however, we do not have any estimate for the output variability of *aus* in Mymensingh, with which to make a more meaningful comparison with jute.

(iii) The output variability of pulses is the lowest of all three crops in both Pabna and Faridpur districts. This is also the case with oilseeds in Pabna district.

Wheat, the other winter crop, has, rather surprisingly, a relatively greater output variability in Faridpur district, while the estimated co-efficients for IRRI boro, a high yielding variety of rice records a lower value as compared to jute crop in Mymensingh.

TABLE 4 RELATIVE PRICE VARIABILITY OF DIFFERENT CROPS IN VARIOUS DISTRICTS IN BANGLADESH

Districts	Crops					
	Aus Rice	Aman Rice	Jute	Pulses	Oilseeds	IRRI Boro
Sylhet	.093 (29.39)	.227 (44.85)	—	—	—	—
Pabna	.109 (31.78)	.204 (42.88)	.192 (41.46)	.190(40.96) .329(52.45)	.167 (38.47)	—
Faridpur	.113 (32.34)	.167 (38.98)	.192 (41.46)	.192(40.56) .329(52.45)	—	—
Mymensingh	—	.158 (39.97)	.192 (41.46)	—	—	.110 (31.92)

Note : The figures in parentheses indicate the coefficient of variation (in percentage) of random components of price for each crop in different districts.

(i) It is quite evident from Table 4 that the estimates of price variability of *aman* rice are larger as compared to *aus* rice in all three districts, namely Sylhet, Pabna and Faridpur where such comparisons could be made. The price variability of jute crop, on the other hand, though very much comparable to *aman* rice, is observed to be much higher, in both Pabna and Faridpur districts, than that recorded for *aus* rice, its competing crop in the summer season. This may have some implications for acreage decisions for food vis-a-vis cash crop for the farmers in Bangladesh in so far as the relative price variability of the two crops effect their allocation decisions.¹⁰

(ii) The two types of pulses, namely *khesari* and *motor* show considerable variation in estimates of their price variability, the latter type displaying greater variability in both Pabna and Faridpur districts. Also, this type is observed to show a degree of price variability which is much higher compared to all other crops in these districts. The estimate of the price variability of oilseeds in Pabna, on the other hand, is very much comparable to those obtained for all crops except, of course, *motor* pulse and *aus* rice in the district. The estimate of price variability for IRRI boro is the lowest among all three crops in Mymensingh district.

(iii) As observed earlier, the estimates of price variability of different crops are much higher than their output variability in each of the four districts studied. Also, for

each crop, the degree of variability seems to be more uniform across the four districts for price disturbances as compared to output disturbances.

Admittedly, our estimates of output variability contain some downward bias introduced by the use of aggregate (time series) data which tend to underestimate year to year variability in farmer's yields. However, this may not account for such a large differential in the estimates of variability between these two types of disturbances. It may be more plausible to conclude that for the farmers in Bangladesh, the relative riskiness of different crops as measured by their price variability is perhaps greater than those measured by their output variability.¹¹

IV. SUMMARY AND CONCLUSIONS

In this study, attempts have been made to derive estimates of some of the essential components of any decision model designed to analyse farmers' resource allocation decisions under risk. This relates to the estimation of variance-covariance matrices of random disturbances associated with both output and prices of different crops in some selected districts in Bangladesh. The general procedure adopted was to extract the systematic portion of aggregate time series so that the residuals represented the estimates of random components from which the relevant variance-covariance matrices were subsequently computed.

In estimating the output disturbances of different crops, an aggregate production function of the Cobb-Douglas type incorporating both annual and monthly rainfall data was employed. However, although the coefficients of land and time trend variable were found to be highly significant in most cases, our exercise failed to capture the significance of rainfall variables in explaining the variations of aggregate output in any of the districts studied. Ranking of crops in terms of the estimated variances of output disturbances show that jute (.036) occupies the top position, followed by wheat (.034), *aman* rice (.025), *aus* rice (.019), IRRI *boro* (.017), oilseeds (.007) and pulses (.006). This gives some idea of the relative 'yield risk' of different crops in Bangladesh.

In estimating price disturbances of different crops using regional time series of grower's prices, a variant of the Nerlovian expectation model was used. No evidence of formation of farmer's price expectation, naive or otherwise, could be established in our data set, except in the case of jute and pulses. The estimated coefficients of the time trend variable, however, was found to be highly significant in almost all cases, implying that our estimates of price disturbances should be viewed as random fluctuations around the trend values over this period. Again, ranking of crops in terms of estimated variances of price disturbances show that pulses (.153) occupies the top position, followed by oilseeds (.122),

jute (.099), *aman* rice (.090), IRRI boro (.071) and *aus* rice (.070). This may give some idea of the relative 'price risk' of different crops in Bangladesh. It is significant to note that pulses and oilseeds which were ranked in the lowest two categories in terms of 'yield risk' now occupy the top two positions when ranking is done in terms of 'price risk'.

It is quite evident that the 'price risk' of different crops are greater than their 'yield risk' in the four districts studied. However, the relative riskiness of different crops should be studied not in terms of variances of output disturbances or price disturbances alone, but in terms of disturbances affecting farmers' income. This may be derived by suitably combining the estimated variance-covariance matrices of output and price disturbances of different crops in each area. How these matrices should be combined in turn would depend upon the extent of interdependencies between these two types of disturbances. This is a matter which is expected to be taken up in a subsequent study.

Notes :

1. In fact, there is no such ideal procedure but there exists several procedures depending on the type of data (economic, agronomic, experimental etc) available. Roumasset (1976) provides an excellent review of such procedures for estimating risk, and also suggests a new procedure which, however, is quite data-demanding.
2. Some of the weaknesses associated with this approach are :
 - (a) Aggregate regional data tend to underestimate year to year variability in farmers fields.
 - (b) Farm household's perceived variability of output (subjective probability distribution of yields) may be quite different from the one captured in the regression residuals representing an objective probability distribution on yields.
3. For the detailed set of estimated regression equations for various crops in four districts, see Shahabuddin (1982). Sources of data used in the study include Agricultural Production Levels (1947-72) and Yearbook of Agricultural Statistics (1976-77) published by the Bangladesh Bureau of Statistics, Govt. of Bangladesh. In this context, it may be noted that the reliability of such data upto 1963/64 has been seriously questioned and were later revised. However, such revised time series were not available to the author while estimating the model, nor was he aware of such deficiencies in the published data at the time.
4. This was also confirmed by a Factor Analysis where no evidence of any significant interrelationship among crop output and acreage on one hand, and the rainfall data, either in annual or monthly form, on the other, were found in our data set.
5. Also, perhaps high level of aggregation in the time series data used and/or lack of heterogeneity in the data base was partly responsible for this. For example, crops could have been distinguished by their varieties and/or rainfed crops could have been separated from the irrigated ones to improve the reliability of the estimates and also to make the analysis more meaningful in investigating the 'yield risk' of different crops in Bangladesh.

6. As no district-wise breakdown of time series of prices were available for jute, the regressions were run for Bangladesh as a whole, though covering a longer time period. Time series data on growers' prices for various crops (except jute) in each district were collected from the Agricultural Marketing Directorate, Govt. of Bangladesh. All-Bangladesh figures for jute were collected from the Jute Marketing Directorate, Govt. of Bangladesh.
7. Admittedly, price change variability represents a crude measure of price uncertainty and a more sophisticated analysis might contain an explicit model of formations of price expectations based on the stochastic properties of the time series. See Klein (1978).
8. This underscores the greater need for adopting buffer stock policies and/or other appropriate price stabilization schemes to mitigate the impact of variability in agricultural prices facing the farmers in Bangladesh.
9. This is because their actual acreage choice among different crops would depend, among others, on the relationship between expected return and the variability of returns to alternative crop portfolio.
10. Also, this provides some rationale for incorporating proper 'risk variables' in the acreage determination and/or supply response models for these crops in Bangladesh.
11. As emphasized earlier, what is important for analysing acreage decisions of the farm households under uncertainty is neither output nor price variability separately but the variability of farmer's income from different crops or more significantly, of alternative crop portfolios relative to their expected incomes.

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