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*MEASUREMENT OF CROP RISK IN FOUR SELECTED DISTRICTS IN BANGLADESH**

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ABSTRACT

The paper attempts to measure the income risk of major crops in four selected Districts in Bangladesh. This was done by suitably combining the estimated variance-covariance matrices of random disturbances associated with both crop outputs and prices. Ranking of crops in terms of estimated income variances showed that jute occupied the top position followed by pulses, *aman* rice, oilseeds, *aus* rice and IRRI *boro.* This may give some idea of relative riskiness of various crops in Bangladesh.

I. INTRODUCTION

In a recent issue of this journal, Shahabuddin (1983) derived some estimates for yield and price risk of major crops in Bangladesh. These estimates were based on the variance-covariance matrices of random disturbances associated with both output and prices. However, it is widely recognised that the riskiness of a crop and/or crop portfolio should be analysed not in terms of output and price disturbances alone, but in terms of their combined disturbances affecting farmer's income.' So, what is needed, in order to assess the total risk of a crop and/or crop portfolio is to integrate the two sources of risk in 2n appropriate fashion through combination of variance-covariance matrices of output and price disturbances. How they should be combined in turn will depend upon the nature and extent of correlation between them. In this paper, an attempt will be made, to estimate along these lines, the (income) risk associated with various crop activities in Bangladesh. This will give a better idea of the relative riskiness of major- crops in some selected areas in Bangladesh.

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

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II. METHODOLOGY AND EMPIRICAL RESULTS

Shahabuddin (1982, 1983) discussed in detail the econometric procedures for estimating the random disturbances associated with both output and prices.[2] Based on these estimates of output and price disturbances, the corresponding estimates of variance-covariance matrices of crop portfolios in each of the four selected Districts were subsequently derived. In order to generate the estimates of variance-covariance matrices of joint disturbances affecting farmer's income, it will now be necessary to combine these two sets of matrices in an appropriate way. And the way one can combine these two sets of matrices (of putput and price disturbances) would depend, as we shall shortly see, on the nature and extent of interrelationship between these two types of disturbances. For example, if the output and price disturbances are assumed to be stochastically independent of each other, then the resulting set of combined matrices will be different from those derived if interdependencies exist between them. The statistical procedures for computing the alternate set of variance-covariance matrices of income disturbances, and the resulting computed set of matrices are presented below.

Variance-Covariance Matrices of Disturbances Affecting Farmer's Income under the Assumption of Stochastic Independence between Output and Price Disturbances

Given the statistical properties of the products of two independent random variables (Goodman 1960), the variance and covariance of the product of output and price disturbances are given by

$$\sigma^2_{u_i v_i} = var(u_i)var(v_i) + var(u_i)E(v_i)^2 + var(v_i)E(u_i)^2 \qquad (1)$$

$$\sigma_{ij} = cov(u_i u_j)E(v_i)E(v_j) + cov(v_i v_j)E(u_i)E(u_j) + cov(u_i u_j)cov(v_i v_j) \qquad (2)$$

where $\sigma^2_{u_i v_i}$ represents the variance of product of output and price disturbances, i.e., the disturbances affecting farmer's income from crop i, and σ_{ij} represents the covariance of product of output and price disturbance, i.e., disturbances affecting farmer's income from crop i and crop j.

Using these expressions for variance and covariances, and the set of matrices of output and price disturbances estimated earlier (see, Shahabuddin 1983), the variance-covariance matrices of disturbances affecting farmer's income were computed for different crops in each of our four selected Districts. The estimated set of matrices are presented in Table 1.

TABLE 1 ESTIMATED VARIANCE-COVARIANCE MATRIX OF INCOME DISTURBANCES FOR SELECTED DISTRICTS

Sylhet District

	Local Aus	Local Aman
Local Aus	.120	.135
Local Aman	.135	.263

Pabna District

	Local Aus	Local Aman	Jute	Khesari	Motor	Oilseeds
Local Aus	.156	.163	.054	.086	.039	.139
Local Aman	.163	.256	.024	.120	.017	.104
Jute	.054	.024	.252	.009	.211	.056
Khesari	.086	.120	.009	.245	.090	.127
Motor	.039	.017	.211	.090	.331	.093
Oilseeds	.139	.104	.056	.127	.093	.187

Faridpur District

	Local Aus	Local Aman	Jute	Khesari	Motor
Local Aus	.126	.129	.035	.102	.035
Local Aman	.129	.209	.008	.131	.009
Jute	.035	.008	.205	.014	.223
Khesari	.102	.131	.014	.228	.087
Motor	.035	.009	.223	.087	.335

Mymensingh District

	Local Aman	Jute	IRRI Boro
Local Aman	.176	.017	.124
Jute	.017	.238	.008
IRRI Boro	.124	.004	.130

The following observations can be made based on these income variances and covariances of different crops in four districts.

(a) Ranking of crops in terms of estimated income variances (average of four areas) show that pulses (.285) occupy the top position followed by jute (.238), *aman* rice (.226), oilseeds (.187), *aus* rice (.134) and IRRI *Boro* (.131). This gives some idea of relative riskiness of different crops in Bangladesh.

(b) The estimated income covariances for all pairs of crops in each area have positive values. This is what we expected in view of the fact that all our estimates of price covariances are both positive and greater in magnitudes than those of output covariances some of which, as we observed earlier, transpired to have negative values. The fact that our estimates of income covariances are all positive implies that the marginal income riskiness of production for all crops is also positive.

Variance-Covariance Matrcies of Disturbances affecting Farmer's Income Incorporating Interdependencies between Output and Price Disturbances

Our second set of variance-covariance matrices of disturbances affecting farmer's income do not assume any stochastic independence between output and price disturbances, but are based on the calculated covariances between these two types of disturbances. Following the statistical properties of the product of two dependent random variables (Goodman 1960), the expressions for variance and covariance in this case are given by :

$$\sigma^2_{u_i v_i} = var(u_i)var(v_i) + var(u_i)E(v_i)^2 + var(v_i)E(u_i)^2 + 2cov(u_i v_i)E(u_i)E(v_i) + cov(u_i v_i)^2 \quad (3)$$

$$\sigma_{ij} = E(u_i v_i u_j v_j) - cov(u_i v_i)cov(u_j v_j) - cov(u_i v_i)E(u_j)E(v_j) - cov(u_j v_j)E(u_i)E(v_i) - E(v_i)E(u_i)E(u_j)E(v_j) \quad (4)$$

It is clear from the above expressions for $\sigma^2_{u_i v_i}$ and σ_{ij} that to compute these variance and covariances we need, in addition to the estimates of variance-covariance matrices of output and price disturbances, the covarianc matrices *between* output and price disturbances as well. These matrices were estimated and are presented below for the four Districts in Table 2. And finally, based on these matrices, in addition to those estimated earlier involving output and price disturbances separately, the variance-covariance matrices of disturbances affecting farmer's income taking into consideration the interrelationship between output and price disturbances were estimated for various crops in each District and presented in Table 3.

TABLE 2 ESTIMATED COVARIANCE MATRIX ETWEEN OUTPUT AND PRICE DISTURBANCES FOR SELECTED DISTRICTS

Sylhet District

	Local Aus	Local Aman
Local Aus	.027	.083
Local Aman	-.074	-.004

Pabna District

	Local Aus	Local Aman	Jute	Khesari	Motor	Oilseeds
Local Aus	-.001	-.013	.053	-.019	.038	.005
Local Aman	.014	.008	.026	.018	.021	.020
Jute	-.015	-.024	.016	-.029	.004	-.022
Pulses	-.016	-.018	-.030	-.012	-.033	-.022
Oilseeds	.001	.001	.0001	.002	.0004	-.022

Faridpur District

	Local Aus	Local Aman	Jute	Khesari	Motor
Local Aus	-.003	-.003	-.009	-.007	-.017
Local Aman	-.010	-.015	.015	-.005	.021
Jute	-.021	-.026	-.010	-.024	-.021
Pulses	-.006	-.007	.009	.002	.016
Oilseeds	-.002	-.006	-.010	-.019	-.023

Mymensingh District

	Local Aman	Jute	IRRI Boro
Local Aman	.0003	-.001	-.001
Jute	-.011	.028	-.011
IRRI Boro	-.013	-.004	.-012

TABLE 3 ESTIMATED VARIANCE-COVARIANCE MATRIX OF INCOME DISTURBANCE FOR SELECTED DISTRICTS

Sylhet District

	Local Aus	Local Aman
Local Aus	.218	.182
Local Aman	.182	.277

Pabna District

	Local Aus	Local Aman	Jute	Khesari	Motor	Oilseeds
Local Aus	.133	.137	.099	.049	.052	.114
Local Aman	.137	.265	.009	.118	.013	.181
Jute	.099	.009	.347	-.049	.200	.048
Khesari	.049	.118	-.049	.185	.068	.108
Motor	.052	.013	.200	.068	.179	.075
Oilseeds	.114	.181	.048	.108	.075	.179

Faridpur District

	Local Aus	Local Aman	Jute	Khesari	Motor
Local Aus	.117	.116	.004	.090	.008
Local Aman	.116	.149	-.004	.125	.016
Jute	.004	-.004	.238	-.006	.245
Khesari	.090	.125	-.006	.232	.124
Motor	.008	.016	.245	.124	.425

Mymensingh District

	Local Aman	Jute	IRRI Boro
Local Aman	.203	.002	.108
Jute	.002	.362	-.015
IRRI Boro	.108	-.105	.091

It is quite evident from these estimates of covariances between output and price disturbances that although the magnitudes of these estimates are rather small in most cases, for the most part they have negative signs which conforms to a *priori* expectations for *own* covariances (i.e., covariance between output and price disturbances of a particular crop). For *cross* covariances (i.e., covariances between output disturbance of one crop and price disturbance of another crop), however, no such definite statement can be made since their signs, for any pair of crops, will depend on the substitutability/complementarity reltionship both on the supply and demand sides.

Based on these estimates of variances and covariances of disturbances affecting farmer's income in four Districts, we may make the following observations :

(a) Ranking of crops in terms of estimated income variances (average of four areas) shows that jute (.316) now occupies the top position, followed by pulses (.256), *aman* rice (.216), oilseeds (.177), *aus* rice (.156) and IRRI *boro* (.091). This, therefore, implies that the relative riskiness of different crops does not change except for jute and pulses which switch positions, under the alternative set of assumptions concerning the interrelationship among output and price disturbances.

(b) Even with incorporation of interdependencies between output and price disturbances, only four out of twenty seven estimates of income covariances in our study record negative values for different crop-pairs in four areas. This is mainly because, as observed earlier, although most of the etimated covariances between output and price disturbances are negative, their magintudes are too small to affect the sign of estimates of income covariances in any but four cases.

(c) A comparison between the two sets of matrices—with and without the assumption of stochastic independence between output and price disturbances-shows that although the latter set of matrices record higher values for the estimates of variance and covariances, this differential may not be significant enough to result in substantial differences in the computation of risk factors and/or risk coefficients based on these matrices. In fact, our exercise of testing the significance of correlation coefficients of output and price disturbances for every pair of crops in each District shows that most of these estimated coefficients are not significantly differert from zero even at the 5% level. This explains why the variance-covariance matrices estimated incorporating the interdependencies between output and price disturbances do not differ appreciably from those estimated under the assumption of stochastic independence between these two types of disturbances.

III. A COMPARISON OF INCOME VARIABILITY OF DIFFERENT CROPS IN FOUR SELECTED DISTRICTS IN BANGLADESH

We now examine below the relative riskiness of different crops in terms of their relative income variability computed under both sets of assumptions.[3] To do so, however, it becomes necessary to rearrange the information contained in these matrices to reflect the income variability of different crops as done in Table 4 and Table 5. The following observations may be made based on these estimates.

(i) It is evident from Table 4 that the variability of *aman* rice is much greater than that of *aus* rice in all three Districts where such comparison could be made. The degree of divergence, however, varies from District to District.

(ii) The income variability of jute crop in Pabna District is very close to that of *aman* rice and therefore, is high relative to *aus* rice, its competing crop in the summer season. In Faridpur and Mymensingh Districts, however, the variability of jute income is greater than that of *aman* rice, although is less pronounced in case of Faridpur. This incidentally makes jute income variability in Faridpur relative to *aus* rice comparable to that obtained in Pabna.

(iii) The greater price variability of 'motor' pulse relative to the 'khesari' pulse is also reflected in the estimates of relative income variability in both Pabna and Faridpur.

The income variability of oilseeds in Pabna is greater than the variability of *aus* rice but lower than the variability of all three other crops grown in this District. The same is true for IRRI *boro* in Mymensingh where the estimate of income variability of this crop is low as compared to both *aman* and *aus* rice.

(iv) A look at the estimates recorded in Table 5 makes it readily evident that the picture of relative riskiness of different crops across four Districts as measured by their income variability depicted above remains very much the same when one considers the estimates which incorporate the interdepedencies between output and price distrubances. This is not surprising in view of the lack of significant evidence of correlation between these two types of disturbances among the crops grown in our selected districts.

TABL 4 RLATIVE INCOME VARIABILITY OF DIFFERENT CROPS IN FOUR DISTRICTS IN BANGLADESH[a]

Districts	Crops					
	Local Aus	Local Aman	Jute	Pulses	Oilseeds	IRRI Boro
Sylhet	.108 (31.57)	.239 (45.89)	—	—	—	—
Pabna	.158 (37.69)	.261 (47.81)	.264 (47.76)	.204[b] (42.07) .411[c] (58.34)	.180 (39.84)	—
Faridpur	.134 (35.10)	.204 (42.57)	.227 (44.52)	.201[b] (41.76) .340[c] (53.18)	—	—
Mymensingh	—	.176 (39.76)	.237 (45.35)	—	—	.131 (34.61)

a. Aassuming that output and price disturbances are stochastically independent.

b. Khesari pulse c. Motor pulse

Figures in parentheses represent the coefficients of variation (percentage) in random disturbances affecting farmer's income,

TABLE 5 RELATIVE INCOME VARIABILITY OF DIFFERENT CROPS IN FOUR DISTRICTS IN BANGLADESH[b]

Districts	Crops					
	Local Aus	Local Aman	Jute	Pulses	Oilseed	IRRI Boro
Sylhet	.199 (41.66)	.230 (44.93)	—	—	—	—
Pabna	.118 (32.76)	.278 (47.87)	.344 (53.93)	.185[b] (40.35) .219[c] (43.52)	.117 (39.31)	—
Faridpur	.116 (32.78)	.149 (36.90)	.245 (46.47)	.235[b] (45.03) .425[c] (58.60)	—	—
ymensingh	—	.193 (41.70)	.327 (52.30)	—	—	.088 (28.75)

a. Taking into consideration interdependencies that may exist between output and price disturbances.
b. Khesari pulse
c. Motor pulse

Figures in parentheses represent the coefficients of variation (in percentages) of random disturbances affecting farmer's income,

IV. CONCLUSIONS

In this paper, we estimated some of the basic components of any decision model designed to analyse farmer decision making behaviour under uncertainty. This relates to the estimation of variance-covariance matrices of random disturbances affecting farmers' income. This was achieved by suitably combining the estimated variance-covariance matrices of random disturbances associated with both crop outputs and prices. We derived two sets of such matrices-one that assumed stochastic independence between output and price disturbances, and the other that incorporated the interdependencies that may exist between them. Our empirical work, however, failed to establish any significant differences between these two sets of matrices, presumably because of lack of any significant correlation between output and price disturbances. Ranking of crops in terms of estimated income variances showed that jute (.316) occupied the top position followed by pulses (.256), *aman* rice (.216), oilseeds (.177), *aus* rice (.156) and IRRI *boro* (.091). This may give some idea of relative riskiness of various crops in Bangladesh.

Notes :

1. This, however, does not obviate the need to estimate yield and price risk separately. To distinguish between these two major sources of total (income) crop risk may be desirable for many purposes.

2. In estimating random disturbances associated with both output and prices, the general procedure adopted was to extract the systematic portion of aggregate (district level) time series so that the residuals represented the estimates of random components from which the relevant variance-covariance matrices were subsequaently computed.

3. It should be emphasized that it is not even the relative income variability of different crops that affect farmers' resource allocation decisions under uncertainty. What is important for analysing farmer behaviour under uncertainty is the variability of income from alternative crop portfolio relative to their expected incomes (also, the disaster level of income especially in the context of safety-first models).

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