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MAJOR FOOD CROPS OF BANGLADESH: PROGRESS OF THE SEED-FERTILISER REVOLUTION—AN ALTERNATIVE APPROACH

Poverty and under-development in Bangladesh are closely related to a very low level of productivity in agriculture which contributes about 55 per cent to the gross domestic product of the economy. The per acre yields of agricultural products in Bangladesh are significantly lower than those in most of the neighbouring countries which have similar geographical conditions. Even after 1965 when the yields of agricultural products were increased substantially by the "Green Revolution", the increase in the yields of agricultural products in Bangladesh has been negligible. However, with the introduction of high-yielding variety (HYV) of crops, agriculture has become more sophisticated with the increased use of modern inputs.

Since the emergence of new cereal technology in Bangladesh, the impact of technological change on production has become a major concern. Attention has focused on a number of issues suggesting that technological advance may contribute to an increased production. Again large scale adoption of HYV crops depend, among others, on the even distribution of the seed-fertiliser technology. But the seed-fertiliser technology has been unevenly distributed since it cannot yet be made available to every farmer. Because of this, many farmers, specially the small farmers and share-croppers, have not been able to take the full advantage of this new technology. Technological progress of a commodity implies a downward shift in the cost function and hence a rightward shift in the supply function, which with a downward sloping demand curve results in an increase in economic welfare through the consumption of a larger quantity at a lower cost. Thus, it is necessary to determine the extent to which economical production expansion has been achieved and to determine the extent to which new cereal technology has been developed. For this, empirical analyses of production functions of major food crops of Bangladesh are given here to allocate output changes over time to input changes and from this to infer something about technological change.

METHODOLOGY

The data used in this analysis are the total production in tons and total cultivated area in acres for major food crops, *viz.*, *aus* rice, *aman* rice, *boro* rice, wheat, gram, *masur*, *mashkalai*, potato and sweet potato of Bangladesh for the period 1947-81. The data were recorded from Statistical Digest[1] and Monthly Statistical Bulletin.[2] For each crop the following production functions were fitted:

(*i*) $Y = \alpha X^{\beta} e^{\lambda t} \mu$ ......(1)

(*ii*) $Y = \alpha X^{\beta} e^{\lambda t} e^{\delta D} \mu$ ......(2)

where Y is the total production in tons in a year; X is the total area in acres cultivated for the crop in a year; t is the time period (t =1, 2,..., 34); D is the dummy

1. Government of Bangladesh: Statistical Digest of Bangladesh, No. 7, 1970-71, Bangladesh Bureau of Statistics, Dhaka.
2. Government of Bangladesh: Monthly Statistical Bulletin of Bangladesh, 1983, Bangladesh Bureau of Statistics, Dhaka.

variable which takes values 0 and 1 representing respectively the period before and after the Green Revolution was started; α, β, λ and δ have their usual meaning and μ is a disturbance term distributed normally and independednly with mean zero and variance σ^2.

In Bangladesh Green Revolution started after 1965. Thus, to study the technological change in agricultural production before and after the green revolution, two production functions similar to (1) were fitted separately for the two periods. The functions fitted are:

$$Y_1 = \alpha_1 X_1^{\beta_1} e^{\lambda_1 t_1} \mu_1 \qquad \ldots\ldots(3)$$

$$Y_2 = \alpha_2 X_2^{\beta_2} e^{\lambda_2 t_2} \mu_2 \qquad \ldots\ldots(4)$$

where the subscripts 1 and 2 were used to represent respectively the period before and after the green revolution. In logarithmic scale and in matrix notation the models (3) and (4) can be written as:

$$Y_1 = X_1 \gamma_1 + \epsilon_1 \qquad \ldots\ldots(5)$$

$$Y_2 = X_2 \gamma_2 + \epsilon_2 \qquad \ldots\ldots(6)$$

where Y_1 and Y_2 represent the vectors of productions in logarithmic scale for the two periods; X_1 and X_2 are the coefficient matrices for the coefficients

$$\gamma_1 = \begin{bmatrix} \log_e \alpha_1 \\ \beta_1 \\ \lambda_1 \end{bmatrix} \quad \text{and} \quad \gamma_2 = \begin{bmatrix} \log_e \alpha_2 \\ \beta_2 \\ \lambda_2 \end{bmatrix}$$

respectively; ϵ_1 and ϵ_2 are two disturbance terms distributed normally and independently with mean zero and variance σ_1^2 and σ_2^2 respectively.

The assumption of a common technology during each period implies that $\gamma_1 = \gamma_2$. To test the hypothesis $H_o : \gamma_1 = \gamma_2$, Chow's[3] test was performed for production functions of each crop. Under the null hypothesis $H_o : \gamma_1 = \gamma_2$ models (5) and (6) indicate that there is no structural change in production during the entire period of time. Where the difference between γ_1 and γ_2 was observed as significant, t-test was performed for testing the hypothesis

(*i*) $H_o : \log_e \alpha_1 = \log_e \alpha_2$ ......(7)

(*ii*) $H_o : \beta_1 = \beta_2$ ......(8)

(*iii*) $H_o : \lambda_1 = \lambda_2$ ......(9)

where the test statistic 't' was derived as the ratio of absolute difference of the estimates of parameters under hypothesis to the standard error of the difference of the estimates. The significant difference between γ_1 and γ_2 and between λ_1 and λ_2 may be attributed as the change in production process after the green revolution. To study the change in production due to the change in period, model (2) was fitted for each crop. For each regression Durbin-Watson statistic was computed and where significant autocorrelation and inconclusive test of autocorrelation were observed the data were transformed by the relation $V_t - rV_{t-1}$, (t = 2, 3,...,

3. G. C. Chow, "Tests of Equality between Sets of Coefficients in Two Linear Regressions", *Econometrica*, Vol. 28, No. 3, July 1960, pp. 591-605.

34). The first observation of the transformed data was found out by the relation $\gamma(1-r^2) V_1$, where V_t (t = 1, 2, ..., 34) represents the variable used in the regression at time t and Y is the estimate of the autocorrelation coefficient. Finally, the models were fitted with the transformed data and the empirical results are presented in the next section. The models were fitted with 18 and 16 observations for the crops *aus* rice, *aman* rice, *boro* rice, wheat, gram, *mashkalai* and *masur* before and after the green revolution respectively. The corresponding figures for potato and sweet potato were 9 and 16, and 4 and 16 respectively.

RESULTS AND DISCUSSION

Before performing the regression analysis the average per acre yield along with standard deviation of each crop was calculated and given in Table I. It is seen that there were significant changes in the per acre yield of every crop except *masur* after the green revolution. There were sharp increases in the yield rate of *boro* rice, wheat, potato and sweet potato in the second period under study. This significant increase in the per acre yield of different crops indicates the progress of the new seed-fertiliser technology

TABLE I. PER ACRE YIELD OF CROPS ALONG WITH STANDARD DEVIATION (s.d.) IN DIFFERENT PERIODS

Crop	Before green revolution		After green revolution		For the whole period		$t=\frac{(\bar{y}_1-\bar{y}_2)}{S.E(\bar{y}_1-\bar{y}_2)}$
	Average yield (tons) ($\bar{y}_1$)	s.d.	Average yield (tons) ($\bar{y}_2$)	s.d.	Average yield (tons)	s.d.	
Aman rice ...	0.40	0.05	0.47	0.04	0.43	0.05	4.47**
Aus rice ...	0.33	0.04	0.36	0.04	0.35	0.04	2.14*
Boro rice ...	0.43	0.05	0.79	0.10	0.60	0.20	13.50**
Wheat ...	0.23	0.02	0.46	0.19	0.34	0.18	5.07**
Gram ...	0.25	0.02	0.30	0.02	0.27	0.03	6.47**
Masur ...	0.28	0.02	0.27	0.02	0.27	0.02	1.40
Mashkalai ...	0.28	0.02	0.30	0.02	0.29	0.02	2.57*
Potato ...	2.42	0.26	3.77	0.23	3.29	0.70	13.34**
Sweet potato ...	3.04	0.20	4.39	0.26	4.12	0.60	9.56**

* Significant at 5 per cent level of significance.
** Significant at both 5 per cent and 1 per cent level of significance.

In the second phase of the study, models (1), (2), (3) and (4) were fitted for different crops and on the basis of the regression analysis Durbin-Watson 'd' statistic and 'r' were calculated. The observed results are given in Tables II and III.

After eliminating the effect of autocorrelation the regression analyses were performed for different crops and the analytical results are presented in Tables IV and V. Table IV represents the analytical results of fitted production functions of *aman* rice. It is observed that the contribution of land on the production of *aman* rice was significant for each period and for the entire period under study. The yields of rice significantly increased over time in each period separately, but not

TABLE II. DURBIN-WATSON 'd' STATISTIC AND THE VALUE OF 'r' AFTER FITTING THE MODELS (1), (2) AND (3)

Crop	'd'			'r'		
	Number of observations (n)			Number of observations (n)		
	18	16	34	18	16	34
Aman rice ...	1.4065*	2.2401	0.4235**	0.2978	—0.3274	0.7848
Aus rice ...	1.8576	1.5194*	1.5020*	0.0464	0.2365	0.3744
Boro rice ...	2.5365*	1.5847	0.4695**	0.4840	0.1673	0.7680
Wheat ...	1.2987*	0.9410**	0.8067**	0.3468	0.5478	0.6686
Gram ...	2.1186	1.5339*	1.3848*	—0.1617	0.1976	0.2773
Masur ...	1.2632*	0.7813**	0.8501**	0.3609	0.5729	0.5655
Mashkalai ...	2.0372	0.6636**	1.4420*	—0.0729	0.6209	0.2468
	n = 9	n = 16	n = 25			
Potato ...	2.8560**	0.7930**	0.3762**	—0.6153	0.5616	0.7451
	n = 4	n = 16	n = 20			
Sweet potato ...	3.0775**	0.5857**	0.9679**	—0.8008	0.6707	0.4596

* Indicates inconclusive autocorrelation.
** Indicates significant autocorrelation.

TABLE III. DURBIN-WATSON 'd' STATISTIC AND THE VALUE OF 'r' AFTER FITTING THE MODEL (2)

Crop	'd'	'r'
Aman rice	1.5923*	0.1440
Aus rice	1.5020*	0.2450
Boro rice	0.8990**	0.5472
Wheat	0.7845**	0.6657
Gram	1.3848*	0.2773
Masur	1.5261*	0.2357
Mashkalai	1.2789*	0.2509
Potato	0.5494**	0.7375
Sweet Potato	0.7147**	0.5920

* Indicates inconclusive autocorrelation.
** Indicates significant autocorrelation.

for the entire period under study. As was observed by Chow's test, there was no change in the production process even after the green revolution. Though the average per acre yield significantly increased in the second period, the yields decreased over time as compared to the yields of the first period. The negative estimate of the parameter δ also supports the fact. Over time technological progress was observed but it had no significant impact on *aman* rice production after the green revolution. Similar findings are observed in the case of production of *aus* rice (Table V) also.

TABLE IV. ANALYTICAL RESULTS FOR AMAN RICE

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistics
n = 18						
α_1 ...	1.25436	—	—			
β_1 ...	0.94757	0.02577	36.77**	763.49**	0.9903	
λ_1 ...	0.01456	0.00664	2.19*			
n = 16						
α_2 ...	1.01228	—	—			
β_2 ...	0.93341	0.01482	62.98**	2530.62**	0.9974	
λ_2 ...	0.01302	0.00367	3.55**			
n = 34						
α ...	4.56815	—	—			
β ...	0.94150	0.01466	64.22**	2264.31**	0.9932	1.44
λ ...	0.01181	0.00770	1.53			
α ...	0.85608	—	—			
β ...	0.95941	0.04095	23.43**	186.21**	0.9990	
λ ...	0.01316	0.00338	3.89**			
δ ...	−0.07401	0.06391	1.16			

* Significant. ** Highly significant.

TABLE V. ANALYTICAL RESULTS FOR AUS RICE

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 18						
α_1 ...	0.00005	—	—			
β_1 ...	1.55423	0.38427	4.04**	45.88**	0.8595	
λ_1 ...	0.00890	0.00753	1.18			
n = 16						
α_2 ...	1.55330	—	—			
β_2 ...	0.92472	0.04196	22.04**	290.59**	0.9781	
λ_2 ...	0.00148	0.00959	0.15			
n = 34 ...						
α ...	1.79505	—	—			
β ...	0.91165	0.02393	38.10**	732.68**	0.9793	0.63
λ ...	0.00863	0.00296	2.91**			
α ...	0.03589	—	—			
β ...	1.12907	0.26531	4.25**	75.69**	0.9866	
λ ...	0.01173	0.00432	2.71*			
δ ...	−0.14799	0.07735	1.91			

* Significant. ** Highly significant.

TABLE VI. ANALYTICAL RESULTS FOR BORO RICE

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 18						
α_1 ...	0.61669	—	—			
β_1 ...	0.94655	0.01140	83.03**	4148.67**	0.9965	
λ_1 ...	0.03332	0.01167	2.86*			
n = 16						
α_2 ...	0.05563	—	—			
β_2 ...	1.18736	0.06030	19.68**	261.67**	0.9757	
λ_2 ...	—0.00079	0.00580	0.14			
n = 34						
α ...	0.58652	—	—			
β ...	0.94878	0.02044	46.42**	1087.59**	0.9859	25.29**
λ ...	0.03718	0.00824	4.51**			
α ...	0.57875	—	—			
β ...	0.95668	0.01022	93.64**	3106.92**	0.9968	
λ ...	0.02954	0.00308	9.74**			
δ ...	0.11595	0.05276	2.20*			

* Significant. ** Highly significant.

The yields of *boro* rice significantly increased over time during the first period of investigation (Table VI). But in the second period the yields decreased over time. Again it is seen from Table I that the average rate of yields was much higher in the second period as compared to the first period. The Chow's test indicated that there was a significant change in the production process. The parameters $\log_e \alpha_i$, β_i and λ_i ($i = 1, 2$) differed significantly in the two periods as is observed by the t-test where the t-values are 2.63, 3.92 and 2.62 respectively for the three parameters. As is observed by the estimates of δ, there were substantial increases in the yields of *boro* rice after the green revolution. This study reveals that new cereal technology had a significant impact in the production process of *boro* rice.

Table VII indicates that the production of wheat increased significantly over time, specially after the green revolution. The per acre average yield doubled (Table I) in the second period. However, the production process of the two periods did not differ significantly. The estimate of δ also signifies a substantial gain in the yield rate of wheat after the green revolution was started. From the analysis it reveals that the seed-fertiliser technology had a significant impact in the production process of wheat.

Table VIII represents that the production process of gram differed significantly in the two periods. After the green revolution the yields decreased significantly over time. However, the average rate of yield (Table I) in the second period was significantly higher as compared to the first period. The parameters β_i and λ_i ($i = 1, 2$) differed significantly in the two periods as is observed by the t-test where the t-values are 7.33 and 4.87 respectively. Here also a significant impact of the seed-fertiliser technology was observed in producing gram.

TABLE VII. ANALYTICAL RESULTS FOR WHEAT

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 18						
α_1 ...	1.41552	—	—			
β_1 ...	0.87512	0.03568	24.53**	313.46**	0.9766	
λ_1 ...	0.01196	0.00755	1.58			
n = 16						
α_2 ...	2.46185	—	—			
β_2 ...	0.89018	0.03474	25.62**	328.32**	0.9804	
λ_2 ...	0.09235	0.01681	5.49**			
n = 34						
α	2.16478	—	—			
β ...	0.90889	0.02449	37.17**	744.21**	0.9796	0.33
λ ...	0.05279	0.00600	8.80**			
α ...	2.15454	—	—			
β ...	0.90620	0.02159	41.97**	643.59**	0.9847	
λ ...	0.04755	0.00582	8.17**			
δ ...	0.18665	0.08763	2.13*			

* Significant. ** Highly significant.

TABLE VIII. ANALYTICAL RESULTS FOR GRAM

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 18						
α_1 ...	0.00135	—	—			
β_1 ...	1.42095	0.10705	13.27**	297.66**	0.9754	
λ_1 ...	0.01729	0.00400	4.32**			
n = 16						
α_2 ...	0.00885	—	—			
β_2 ...	1.30224	0.16166	8.05**	52.67**	0.8902	
λ_2 ...	—0.00858	0.00349	2.46*			
n = 34						
α ...	2.15285	—	—			
β ...	0.88833	0.01996	44.50**	1101.03**	0.9861	27.11**
λ ...	0.00497	0.00367	1.35			
α ...	0.15344	—	—			
β ...	1.04294	0.18754	7.58**	148.43**	0.9879	
λ ...	—0.00189	0.00438	0.43			
δ ...	0.21354	0.06948	3.07**			

* Significant. ** Highly significant.

TABLE IX. ANALYTICAL RESULTS FOR MASUR

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 18						
α_1	... 2.11816	—	—			
β_1	... 0.86541	0.02506	34.53**	885.99**	0.9916	
λ_1	... —0.00738	0.00593	1.24			
n = 16						
α_2	... 2.67058	—	—			
β_2	... 0.88129	0.01030	85.56**	4566.98**	0.9986	
λ_2	... —0.01870	0.00588	3.18**			
n = 34						
α	... 2.67794	—	—			
β	... 0.87692	0.01340	65.45**	2513.93**	0.9939	0.551
λ	... —0.00692	0.00246	2.84*			
α	... 2.55769	—	—			
β	... 0.83422	0.02667	31.28**	491.41**	0.9960	
λ	... —0.00948	0.00271	3.50**			
δ	... 0.07029	0.04852	1.45			

* Significant. ** Highly significant.

TABLE X. ANALYTICAL RESULTS FOR MASHKALAI

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 18						
α_1	... 0.18509	—	—			
β_1	... 1.03855	0.23605	4.40**	9.39**	0.5560	
λ_1	... —0.00138	0.00406	0.34			
n = 16						
α_2	... 3.03244	—	—			
β_2	... 0.88476	0.00864	102.43**	6920.20**	0.9991	
λ_2	... —0.01879	0.00556	13.31**			
n = 34						
α	... 1.45926	—	—			
β	... 0.88989	0.02720	32.72**	577.13**	0.9738	4.45*
λ	... 0.00146	0.00205	0.71			
α	... 1.57815	—	—			
β	... 0.87975	0.02794	31.49**	377.27**	0.9741	
λ	... —0.00484	0.00337	1.44			
δ	... 0.13943	0.06247	2.23*			

* Significant. ** Highly significant.

TABLE XI. ANALYTICAL RESULTS FOR POTATO

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 9						
α_1	... 0.47362	—	—			
β_1	... 1.09134	0.00938	116.35**	11974.18**	0.9997	
λ_1	... —0.00022	0.00704	0.031			
n = 16						
α_2	... 2.67571	—	—			
β_2	... 1.08263	0.00698	155.16**	14569.70**	0.9995	
λ_2	... —0.00331	0.00371	0.81			
n = 25						
α	... 4.53187	—	—			
β	... 1.03902	0.02149	48.35**	1269.61**	0.9914	21.83**
λ	... 0.01381	0.00973	1.44			
α	... 4.40631	—	—			
β	... 1.03958	0.02071	50.20**	908.78*	0.9923	
λ	... 0.00801	0.01010	0.79			
δ	... 0.12559	0.09062	1.39			

* Significant. ** Highly significant.

TABLE XII. ANALYTICAL RESULTS FOR SWEET POTATO

Parameters	Estimates	S.E.	t	F	R^2	Chow's test statistic
n = 4						
α_1	... 0.56065	—	—			
β_1	... 1.08892	0.00645	168.82**	28031.26**	0.9999	
λ_1	... 0.03272	0.01685	1.94			
n = 16						
α_2	... 3.50188	—	—			
β_2	... 1.10064	0.01102	99.88**	6359.77**	0.9990	
λ_2	... —0.01303	0.00797	1.63			
n = 20						
α	... 2.47665	—	—			
β	... 1.06608	0.01999	53.33**	1512.55**	0.9944	10.21**
λ	... 0.00931	0.00541	1.72			
α	... 2.79773	—	—			
β	... 1.07998	0.01324	81.57**	2561.81**	0.9979	
λ	... 0.00152	0.00560	0.27			
δ	... 0.16575	0.06062	2.73*			

* Significant. ** Highly significant.

Table IX indicates that the production of *masur* significantly decreased over time, specially after the green revolution. The average rate of yield also decreased in the second period. The green revolution had no impact on the production of *masur*.

Over time the production of *mashkalai* (Table X) decreased and it decreased significantly in the second period. Of course, the average rate of yield was slightly higher in the second period as compared to the first period. The estimate of δ also signifies a significant increase of yield in the second period. The parameter $\lambda_i(i = 1, 2)$ of the two periods differed significantly as is observed by the t-test where the t-value is 2.53. This analysis also supports the impact of the green revolution.

Time had no significant contribution in the production of potato and sweet potato (Tables XI and XII) in any of the periods under study. But the average rate of yields of these crops increased significantly in the second period. The estimate of δ also signifies an increase in the yield of the crops in the second period and this increase was significant for sweet potato. The parameters $\log_e \alpha_i$ in the production process of potato and $\lambda_i(i = 1, 2)$ in the production process of sweet potato differed significantly in the two periods as is observed by the t-test where the t-values are 2.92 and 2.45 respectively. It indicates that the green revolution had a significant impact on the production of potato and sweet potato.

CONCLUSION

The present analysis reveals that the production of major food crops except *masur* significantly increased after the green revolution. Remarkable changes in the average per acre yields of *boro* rice, wheat, potato and sweet potato were observed in the second period. Again the yields of *aus* rice, *boro* rice and wheat significantly increased over time throughout the period of investigation. There were structural changes in the production process of *boro* rice, gram, *mashkalai,* potato and sweet potato. Except *masur*, the production of all other crops increased significantly with the progress of the new seed-fertiliser technology. But the impact of new technology was not equal in accelerating the yield rate of all crops. The impact of the new seed-fertiliser revolution on the production of *boro* rice, wheat, potato and sweet potato was better.

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