Journal of Rural Development 29(6): 19～43

FACTORS INFLUENCING AGRICULTURAL GROWTH IN BANGLADESH

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Keywords
growth decomposition, kinked growth model, structural change, government policy

Abstract
This study is aimed at identifying and evaluating the factors and government policy reforms which influence agricultural growth in Bangladesh. Based on the secondary data of 25 years, the study used kinked exponential growth model to estimate the growth rates of different crops for the 1980-89 and 1990-2004 sub-periods. The study revealed that total area, area under MV crop, draft animal, fertiliser, human capital, proportion of irrigated area to gross cropped area, and irrigated area were found to have significant effects on the increase in output at the aggregate level. A growth decomposition analysis confirmed that more than two-thirds of the growth in output was attributable to the conversion of area from local to

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modern varieties. Both output and output growth increased significantly in the sub-period of 1990-2004 compared to the 1980-89 sub-period. The study also confirmed that a positive structural change took place in farming practices in the 1990-2004 sub-period. The government policy reforms on farm efficiency and productivity in the 1990s might have positively contributed to this structural breakthrough. Increased research efforts to develop varieties with higher yield potentials and research on the control of resources and environment degradation could be a good policy option to promote and sustain growth in food output for some years to come.

Ⅰ. Introduction

The economy of Bangladesh is primarily dependent on agriculture. About 84 percent of the total population live in rural areas and are directly or indirectly engaged in a wide range of agricultural activities. The agricultural sector contributed about 24 percent to the country's GDP in 2002-2003 at constant 1995-96 prices. Of the agricultural GDP, the crop sub-sector contributed 71 percent, forest고 10 percent, fisheries 10 percent, and livestock 9 percent. The agricultural sector generated 63 percent of total national employment, of which crops sector's share is nearly 57 percent. Agricultural exports of primary products constituted 11 percent of the country's total exports in 2001-2002 (BBS, 2003). In the past decade, the agricultural sector contributed about three percent per annum to the annual economic growth rate (MOA, 2004).

The agricultural sector as the single largest contributor to income and employment generation is a vital element in the country's challenge to achieve food security, reduce poverty, and foster sustainable economic development. Agricultural growth as an indicator of economic development is necessary for rural poverty alleviation (RAVALLION and DATT, 1996; ODHIAMBO and NYANGITO, 2005). However, this sector's relative contribution as well as the contribution of crop sub-sector to the GDP have decreased over time. Several reasons may be responsible for this phenomenon: reduction in arable land, deterioration of land productivity, lack of proper land use planning, and lack of capital and appropriate technology.

Government can play an important role to sustain agricultural productivity and growth by reforming agricultural policy and execution of it. Some researchers contend that with abundant water resources and low crop yields, Bangladesh has a relatively greater potential for expanding food production by maintaining the momentum of the green revolution than many other developing countries (BROWN and KANE,1994). Thus, with a priori optimistic outlook, this study is designed to evaluate the impact of the government policy reforms on agricultural growth for the period 1980-2004. The specific objectives of the study are as follows:

(i) to ascertain the agricultural growth in Bangladesh;
(ii) to evaluate the future prospects of major crops;
(iii) to identify the important factors which promote the agricultural growth;
(iv) to evaluate the impact of government policy on agricultural growth; and finally
(v) to suggest appropriate policies for sustaining growth leading to food security and poverty alleviation.

This paper is organised into five sections. Section 2 describes government's activity in agriculture. Section 3 describes analytical techniques to measure agricultural productivity and growth and Section 4 discusses the results of empirical tests. Conclusions and policy implications are presented in the final section.

II. Government's Activity in Agriculture

Recently the terms 'governance' and 'good governance' are being increasingly used in development literature. Governance describes the process of decision-making and the process by which decisions are implemented. Good governance is epitomised by predictable, open and enlightened policy making (that is, transparent processes) in which a bureaucracy is imbued with a professional ethos and an executive arm of government is accountable for its actions. There should be a strong civil society participating in public affairs and all participants behaving under the rule of law. Good governance is an essential ingredient to ensure appropriate public expenditure management for rural services and to create a positive climate for private sector investment in rural areas. Farmers - whether family or corporate - are entrepreneurs, and entrepreneurs will not invest in an activity that is excessively taxed, unprotected by the rule of law, or located in a place with no roads, water or electricity. Therefore, countries with a system of governance that supports a rural investment climate have experienced substantial growth in the agricultural and rural sectors. UNESCAP (2006) mentioned that good governance has 8 major characteristics. It is participatory, consensus oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive, and follows the rule of law. It assures that corruption is minimised, the views of minorities are taken into account, and the voices of the most vulnerable in society are heard in decision-making. It is also responsive to the present and future needs of society. To generate substantial agricultural growth, Bangladesh also needs good governance. Like many other developing countries, Bangladesh needs appropriate steps from the government to strengthen its agriculture and fulfil the demands of the population. The government has therefore accorded the highest priority to this sector to enable the country to meet the demands of the people and to make this sector commercially profitable. A Poverty Reduction Strategy Paper (PRSP) has been prepared by the government in broad consultation with stakeholders and development partners including the World Bank and the International Monetary Fund. In the name of “Unlocking the Potential: National Strategy for Accelerated Poverty Reduction,” the PRSP has identified agriculture and rural development as the topmost priority sector for rapid poverty reduction. Agricultural research, technology generation and dissemination, and engagement of women in agriculture drew special attention. Regarding the alleviation of poverty, the government has been taking several steps to boost agriculture for several years. Disregarding the suggestions by a donor agency, the government has been giving indirect fertiliser subsidies to farmers for several years and the amount is increasing from year to year. Now the government is giving 25 percent fertiliser subsidy to lessen the production cost for farmers and allocated 12 billion taka (or 150 million euros) in 2005-2006, which is double the amount of 6 billion taka (or 75 million euros) in 2004-2005 (RAHMAN, 2005). It is a temporary measure of the government to encourage farmers to produce more output. The Ministry of Agriculture (MOA) is the highest central body of the government in the agriculture sector, coordinating and supervising the activities of all Agricultural Institutes and Directorates all over the country. It serves as the nation's topmost coordinating and supervising body for planning, integrating, and implementing agricultural policies and related projects. The contribution of extension services under the supervision of MOA is reflected in the increased use of chemical fertiliser, increase in recommended soil tillage, plant protection measures, use of HYV seeds, irrigation practices, seed preservation practices, etc. among farmers. The government has also established the National Agricultural Research System (NARS) consisting of ten research institutes under the umbrella of Bangladesh Agricultural Research Council (BARC). Goletti (1994) mentioned that two main features of the food grain sector in Bangladesh emerged in the 1970s and 1980s. First, a sustained growth of rice production moved the country toward declining food gaps. Second, policy removed several constraints to the operations of private markets and reduced the presence of government intervention in the sector. Other policy reform measures of the government are described below:

(i) **Liberalisation of trade in minor irrigation sector and the promotion of the private sector for the supply of minor irrigation equipment in the country:** This happened gradually in step with the removal of import restrictions on small diesel engines in 1986-87 followed by the withdrawal of duties on such imports in 1988-89. The subsidy on deep tube wells (DTW) was removed in 1992 and the government organisation BADC was removed from the procurement and distribution of minor irrigation equipment. These reform measures had a tangible effect on increasing the demand for irrigation equipment and consequently the rate of increase in the area under minor irrigation.

(ii) **Privatisation of fertiliser trade with the objective of transferring fertiliser management and distribution services exclusively to the private sector:** Imports of all fertilisers, including urea that has already been imported by the private sector, are now being undertaken by the private sector. All fertilisers are being distributed by private dealers through their network. The government has issued the revised Fertiliser Control Ordinance in 1995 in consultation with the private sector and the IFDC for quality control and regulation of fertiliser prices. This has led to the increased availability and the wider adoption of chemical fertiliser at the farm level and economic activities in rural areas have also increased manifold due to the withdrawal of government from fertiliser distribution.

(iii) **Liberalisation of trade and foreign exchange for the enhanced participation of the private sector in the trade of agricultural machinery:** The government has been continually reviewing the conditions affecting competitive trade and took actions to remove barriers.

(iv) **Liberalisation of production, processing, distribution and importing of seeds to ensure the participation of private seed dealers for the seed industry's development:** The private sector is now allowed to import any improved germplasm for research and development and to develop its own facilities for producing foundation seeds. They are also allowed to import and sell seeds except those of five notified crops (rice, wheat, sugarcane, potato, and jute). As regard to the notified crops, there are procedural formalities to be observed by the private sector before any import. The private sector has now taken up programmes for the production of hybrid rice seeds in the country.

(v) **Liberalisation of imports of agricultural machines including power tillers:** This move has had positive effects on the import of power tillers. The area under power tiller utilisation also grew by about 3.5% per annum after the introduction of the liberalisation policy.

(vi) **Structural changes were also made in food supply and management system:** Open market sale (OMS), procurement of food grains from farmers at market prices, abolition of rural rationing system, and allowing the import of food grains by the private sector were the measures so far implemented by the Government of Bangladesh.

III. Analytical Techniques for Measuring Agricultural Productivity and Growth

This study is based on secondary or time series data. Twenty five-year (1980-2004) time series data from the Bangladesh Bureau of Statistics (BBS) are used in this study. Both descriptive and inferential statistics are used to describe the status of food production and growth, and the impact of government's agricultural policy on them. Different statistical tests have been conducted where necessary. To describe and explain the agricultural production and growth in Bangladesh, both production function analysis and growth decomposition analysis have been carried out. To identify the government's influence on productivity and growth, a kinked exponential growth regression analysis has also been carried out. In the analysis, total time period is divided into two sub-periods: 1980-89 and 1990-2004. In the mid-1980s, the Government of Bangladesh reformed agricultural input markets and deregulated the import of minor irrigation equipment (HOSSAIN,1996). But Bangladesh has experienced a democratic government since 1990 and most of the policy reforms have taken place since 1990. The democratic government is assumed to be more accountable to the society and the people. That is why the period is sub-divided as above in this study.

1. Production Function Analysis

To analyse food production system and input-output relationship in Bangladesh, the following Cobb-Douglas type production function in double-log form at the aggregate level has been used:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_4 \ln X_{4it} + \beta_5 HCAP_{it} + \beta_6 PMVAR_{it} + \beta_7 PIRRI_{it} + \beta_8 t + V_{it} \quad (1)$$

where Y_{it} is crop output (thousand metric tons) for the i^{th} region in the t^{th} year ($t = 1, 2,......,T$); X_1 is area (thousand hectares); X_2 is agricultural labour force (thousand persons); X_3 is total draft animals (thousand); X_4 is the amount of fertiliser used (thousand metric tons); HCAP is the proportion of literate population above 14 years to the total population of the same age group, a proxy measure for human capital; PMVAR is the proportion of area of all modern crop varieties to gross cropped area; PIRRI is the proportion of irrigated area to gross cropped area; and t is time (year). V_i are assumed to be independently and identically distributed random errors having $N(0, \sigma^2_v)$ distribution.

The variables which have been included in the production function model are very important for agricultural production. Many economists used these types of variables in their models in different countries and observed the positive impact of them on farm productivity. Like any conventional variable, human capital (HCAP) has also been used by many economists along with other variables in their production function models to estimate the effect of education on productivity. LOCKHEED et al. (1980) surveyed many of these studies. Although they concluded that the effect of education on productivity is positive, a significant number of the studies (40%) found either a negative effect or no impact on productivity.

2. The Growth Decomposition Model

In the case of rice production, since both local and modern varieties can be grown in all three seasons (i.e., *Aus*, *Aman* and *Boro* seasons), crop production in year t, Q_t, can be expressed by the following sum:
$Q_t = \sum_i \sum_j Q^{ij}_t$ · where i = MV (modern variety), LV (local variety) and j = seasons. Further expressing Q^{ij}_t as the product of area, A^{ij}_t and yield, Y^{ij}_t, Q_t can be written as $Q_t = \sum_i \sum_j A^{ij}_t Y^{ij}_t$
The growth rate of total rice production, ρ, can be expressed as the weighted sum of growth rates of each component:

$$\rho = \sum_{i=1}^{2} \sum_{j=1}^{3} w^{ij} (\rho^{ij}_A + \rho^{ij}_Y) \tag{2}$$

where ρ^{ij}_A and ρ^{ij}_Y are growth rates of area and yield of variety i in season j, while w^{ij} is the corresponding weight, calculated as $w^{ij} = \sum_t (Q^{ij}_t / Q_t)$. The growth rate can then be recovered from the following trend regression:

$$\ln(Q_t) = \mu + \beta t + \varepsilon_t \tag{3}$$

as $\rho = \exp(\beta)-1$. Thus, for example, growth in rice production is decomposed into 12 parts, product of the two varieties (MV and LV), three seasons (*Aus*, *Aman and Boro*), and two components (area and yield). But for other crops, the formulation of a growth decomposition model would be different from (2).

3. Kinked Exponential Growth (Single-Kink) Model

Now let k be the year in which a structural change took place. Typically, to account for such change (3) is transformed as follows:

$$\ln (Q_t) = \mu_1 D_1 + \mu_2 D_2 + (\beta_1 D_1 + \beta_2 D_2)t + \varepsilon_t \quad (4)$$

where D_1 and D_2 are the values of dummy variable D, which takes the value 1 up to year k and zero otherwise.

Since (4) is equivalent to running two separate regressions, the trend lines may not necessarily intersect at the break point k. To eliminate this discontinuity, we follow BOYCE (1986) by imposing the following linear restriction:

$$\mu_1 + \beta_1 k = \mu_2 + \beta_2 k \quad (5)$$

Restriction (5) ensures that the trend lines intersect at k. Solving (4) for μ_2, substituting the resulting expression in (4), and rearranging the terms, we get the restricted form:

$$\ln (Q_t) = \mu_1 + \beta_1(D_1 t + D_2 k) + \beta_2(D_2 t - D_2 k) + \varepsilon_t \quad (6)$$

The hypothesis that $\beta_1 = \beta_2$ is then tested; rejection would indicate that a structural break did occur in year k. As BOYCE (1986) argued, equation (6) is preferable to (4) in the absence of special circumstances. Further, (6) has the advantage of ruling out the possibility that the growth rate derived from (3) falls outside the interval (β_1, β_2) as derived from (4).

The growth rates in the two sub-periods are now given by the OLS estimates of the coefficients of the resulting composite variables. The kinked exponential growth model reduces discontinuity bias, provides better basis for growth rate comparison, reduces instability or cyclical fluctuations, and uses a full set of available information to estimate the growth rates for each sub-period in a single step.

IV. Results and Discussion

Table 1 presents output, area, and yield of different crops in Bangladesh. It reveals that total rice output produced per year is significantly higher in the sub-period of 1990-2004 (20,539,000 metric tons) than in the 1980-89 sub-period (14,481,000 metric tons), while total area of rice crops is relatively lower

TABLE 1. Summary statistics of different crops produced per year: output, area, and yield

	Total Output			Modern Varieties			Local Varieties		
	Output	Area	Yield	Output	Area	Yield	Output	Area	Yield
1980-2004									
All rice	18,116	10,345	1.75	11,453	4,535	2.46	6,663	5,810	1.17
Aus	2,369	2,141	1.15	847	448	1.89	1,522	1,693	0.94
Aman	8,959	5,717	1.57	4,238	1,883	2.19	4,721	3,834	1.25
Boro	6,787	2,487	2.63	6,368	2,203	2.81	419	284	1.49
Wheat	1,282	636	2.02						
Oilseed	381	443	0.87						
Jute	917	567	1.64						
1980-89									
All rice	14,481	10,384	1.39	6,311	2,780	2.27	8,170	7,604	1.08
Aus	3,025	2,972	1.02	924	474	1.95	2,100	2,498	0.84
Aman	7,730	5,853	1.32	2,176	1,099	1.98	5,555	4,754	1.17
Boro	3,726	1,559	2.38	3,211	1,207	2.67	514	352	1.46
Wheat	1,089	542	2.02						
Oilseed	295	349	0.86						
Jute	1,002	680	1.48						
1990-2004									
All rice	20,539	10,318	1.99	14,881	5,704	2.58	5,658	4,614	1.24
Aus	1,932	1,586	1.24	795	430	1.85	1,137	1,156	1.01
Aman	9,779	5,627	1.74	5,613	2,406	2.33	4,165	3,220	1.30
Boro	8,828	3,106	2.79	8,472	2,868	2.90	356	238	1.51
Wheat	1,410	699	2.02						
Oilseed	438	506	0.87						
Jute	861	493	1.75						

Note: Area and output are in thousands of hectares and thousands of metric tons respectively, and yields are in metric tons per hectare. Averages may not add up exactly because of rounding. Source: own computation.

in 1990-2004 than the previous years. This higher output was due to the conversion of local variety (LV) rice area into modern variety (MV) rice area and it is the major source of productivity increase in cereals. This result conforms with the study of BYERLEE (1996) and BAFFES and GAUTAM (2001). Increased yields of both the varieties were also observed in 1990-2004 and yield increase (through periodic replacement of older generation MVs by newer ones, etc.) is another source of output increase. Nevertheless, BYERLEE (1996) cautioned that future changes in productivity from either source would not likely to be as sharp or as pronounced as the impact of the green revolution. Both total output and area for *Boro* were significantly higher in the 1990-2004 sub-period than those in the previous ones. Output, area and yield of both MV *Aman* and *Bor*o showed significantly higher amounts in the 1990-2004 sub-period. But for LVs, they were in reverse except yields. For other crops, such as wheat and oilseeds, output and area were also higher in this sub-period than those in the previous ones while both output and area for jute were lower in the 1990-2004 sub-period than those in the previous sub-period. Farmers of Bangladesh are reducing the cultivation of jute day by day.

Some crucial factors of production are presented in Table 2. It shows that agricultural labour force is increasing day by day due to the lack of employment opportunities in other sectors. The number of labour force in the 1990-2004 sub-period was 36,141,000 while it was 18,185,000 per year in the previous sub-period. The number of draft animals also was significantly higher in the sub-period of 1990-2004 (33,277,000) than in the 1980-89 sub-period (22,578,000). Annual fertiliser application and irrigated area were significantly higher in the 1990-2004 sub-period, they were 2,656,000 metric tons and 3,802 hectares, respectively, while they were 1,124,000 metric tons and 2,016,000 hectares respectively in the previous 1980-1989 sub-period. The agricultural sector policy reform measures by the government might have had a positive impact on the increase in these vital inputs in the 90s and afterwards.

Table 3 shows the estimates for the parameters of production functions for rice, wheat, oilseed, jute, and "all crops" (four crops taken together). Table 3 reveals that area has a significantly positive impact on the increase in the output of all crops considered here and agricultural labour force has a negative impact on the output of rice, wheat, oilseed, and "all crops."

Overutilisation of labour force might have had negative influence on crops. It is well known that high concentration of labour force is increasing in the agricultural sector day by day due to insufficient employment opportunities in other sectors. Draft animal is found to have a significant impact on the increase in the outputs of rice and "all crops." Fertiliser is found to have a positive impact on the increase in oilseed only. For wheat and jute, fertiliser is found to be highly collinear with labour force. That is why fertiliser is excluded from the model of wheat and jute. Human capital (HCAP) has a significant impact on wheat output. Area under modern variety (MV) has a positive impact on the rice output. PMVAR has been excluded from all models for its high co-linearity with other explanatory variables. Proportion of irrigated area to gross cropped area (PIRRI) has also a positive impact on the increase in rice and wheat outputs while total irrigated area was found to have a positive impact on "all crops." Like many other economists such as COELLI et al. (1998), we have included time (year) in the model along with other different

TABLE 2. Average resource use in agriculture annually

Resources	Years			Difference between 1980-89 and 1990-2004 (t-values)
	1980-2004	1980-89	1990-2004	
Agricultural labour force (thousand)	28,958 (9,589)	18,185 (5,146)	36,141 (1,552)	12.79**
Draft animal (thousand)	28,998 (6,457)	22,578 (1,874)	33,277 (4,488)	7.09**
Fertiliser (thousand metric tons)	2,043 (840)	1,124 (326)	2,656 (370)	10.62**
Irrigated area (thousand hectares)	3,088 (1,038)	2,016 (356)	3,802 (632)	8.08**
HCAP (proportion)	0.40 (0.09)	0.32 (0.02)	0.46 (0.07)	6.12**
PMVAR (proportion, for rice only)	0.44 (0.16)	0.27 (0.06)	0.55 (0.08)	9.54**
PIRRI (proportion)	0.22 (0.07)	0.15 (0.02)	0.27 (0.04)	8.44**

Figures in the parentheses indicate standard deviation. The double asterisk (**) indicates significance at 0.01 probability level. Source: own computation.

TABLE 3. Estimates for parameters of different crop models in Bangladesh

Variables	Parameters	Rice	Wheat	Oilseed	Jute	All crops
Intercept	β_0	-12.804 (6.524)	2.374 (8.572)	-1.368 (3.154)	2.258 (7.066)	-15.134** (5.312)
Area	β_1	1.021** (0.311)	1.196** (0.199)	0.780** (0.037)	0.911** (0.085)	0.561* (0.220)
Labour force	β_2	-0.341** (0.108)	-0.413** (0.093)	-0.204* (0.076)	0.039 (0.079)	-0.362** (0.095)
Draft animal	β_3	1.725* (0.746)	0.551 (1.060)	0.288 (0.442)	-0.320 (0.931)	2.078** (0.573)
Fertiliser	β_4	0.018 (0.107)	-	0.156* (0.064)	-	-0.116 (0.086)
HCAP	β_5	-0.314 (0.280)	1.225* (0.590)	-0.102 (0.184)	-0.015 (0.474)	-0.107 (0.238)
MV area	β_6	0.540* (0.212)	-	-	-	-
PMVAR	β_7	-	-	-	-	-
PIRRI	β_8	3.445* (1.364)	5.572* (2.436)	-	-	-
Irrigated area	β_9	-	-	0.129 (0.260)	-	1.199** (0.363)
Year	β_{10}	-0.069** (0.025)	-0.066 (0.033)	-0.005 (0.017)	0.018 (0.028)	-0.070** (0.021)
F-value		119.93**	47.22**	489.13**	32.23**	161.53**
Adjusted R^2		0.98	0.94	0.99	0.87	0.98
DW statistic		2.04	2.00	1.21	2.31	2.17

The single and double asterisks (* and **) indicate significance at 0.05 and 0.01 probability levels, respectively. DW statistic means Durbin Watson statistics, and the figures in the parentheses are standard errors of respective coefficients. Source: own estimation.

variables. The year variable measured the technical change. The coefficient of year is negative and significant for rice and "all crops." This means that the technical change which has taken place for the last 25 years was negative. This could happen due to the lack of new addition of advanced technology and due to the overall degradation of resources and environment. The problem of multicollinearity might have contributed to this negative impact. The estimated F-values suggest that all the models are well fitted to the data. Durbin-Watson (DW) statistics ensure that there is no autocorrelation in the data for all models.

The estimated growth rates of different crops are given in Table 4, and the estimated growth rates for the period of 1980-2004 are shown in the upper panel of the table. To allow for a structural break due to the policy reforms of the government, growth rates were re-estimated for the sub-periods 1980-89 and 1990-2004 by using a kinked exponential growth regression following BOYCE (1986). A kinked exponential growth regression ensures continuity in the growth path at the time the structural break (kink) occurs, allowing for the path dependency on the growth rate. The growth rates of the two sub-periods are reported in the middle and lower panels of Table 4. BOYCE (1986) mentioned that the ‘discontinuity bias’ and the sensitivity of growth rate estimates to instability are reduced by the kinked exponential methods.

Total rice production grew at an annual rate of 2.74 percent in the last two decades (shown in the top panel of Table 4). It is similar to the result of ROSEGRANT and PINGALI (1994). ROSEGRANT and PINGALI (1994) reported that the rice output growth rate of Asia increased from 2.60 percent per annum during the pre-green revolution period (1958-66) to 3.30 percent during the post-green revolution period (1966-82). Seasonal estimates showed that *Boro* rice production has grown 6.93 percent annually while *Aman* production has grown at a lower rate (1.51 percent) and *Aus* production has declined (2.96 percent) in the years 1980-2004. The growth in gross area allocated to rice production has been virtually zero (0.10 percent). That is, almost all growths in rice production were made due to an increase in average yields. At the seasonal level, area allocated to *Boro* rice has increased by 5.44 percent, causing a decrease in *Aus* area by 4.59 percent and *Aman* area by 0.39 percent. Similar results were observed by BAFFES and GAUTAM (2001) while studying Bangladesh rice crops for the years 1973-99. The growth rate of MV areas for *Boro* and *Aman* increased at the expense of their respective LV areas. The differences of local and modern variety yields highlight some important features. MV yields grew at an average of 1.01 percent, while LV yields grew at an average of 1.11 percent for the entire 1980-2004 period. *Aus* MV yield declined at the rate of 0.29 percent while *Aman* and *Boro* yields grew at the rates of 1.01 and 0.80 percent, respectively. The growths in LV yields for *Aus*, *Aman*, and *Boro* were 1.51, 0.80, and 0.50 percent, respectively.

TABLE 4. Estimates for compound growth rates of different crops in Bangladesh

	Total output			Modern varieties			Local varieties		
	Output	Area	Yield	Output	Area	Yield	Output	Area	Yield
1980-2004									
All rice	2.74	0.10	2.74	6.61	5.55	1.01	−2.86	−3.82	1.11
Aus	−2.96	−4.59	1.71	−0.39	−0.09	−0.29	−4.59	−6.01	1.51
Aman	1.51	−0.39	1.92	6.61	5.55	1.01	−2.27	−3.05	0.80
Boro	6.93	5.44	1.41	7.89	7.04	0.80	−2.76	−3.25	0.50
Wheat	2.43	2.12	0.30						
Oilseed	2.53	2.12	0.40						
Jute	−0.89	−2.08	1.21						
All crops	2.53	0.10	2.43						
1980-89									
All rice	2.12**	−0.29	2.43**	8.22**	8.00**	0.20	−2.27**	−3.27**	1.01
Aus	−3.25**	−3.73**	0.50	−4.11**	−1.69*	−2.47**	−2.76**	−3.92**	1.21
Aman	1.61	−0.69*	2.33**	8.98**	7.79**	1.11	−1.98**	−2.86**	0.90
Boro	8.55**	8.00**	0.50	10.74**	11.63**	−0.79**	−4.50**	−3.44**	−1.19*
Wheat	−0.19	2.53**	−2.63**						
Oilseed	8.00**	8.87**	−0.69						
Jute	−0.49	−2.18	1.71**						
All crops	1.92**	0.04	1.92**						
1990-2004									
All rice	3.15**	0.30*	2.84**	5.76**	4.19**	1.51**	−3.05**	−4.21**	1.11**
Aus	−2.86**	−5.16**	2.43**	1.61**	0.70	0.90**	−5.54**	−7.13**	1.71**
Aman	1.51**	−0.29	1.71**	5.34**	4.39**	1.01	−2.47**	−3.15**	0.70
Boro	6.18**	4.08**	1.92**	6.50**	4.60**	1.71**	−1.69**	−3.15**	1.41**
Wheat	3.87**	1.92**	1.92**						
Oilseed	−0.39	−1.39	1.11**						
Jute	−1.19	−2.08**	1.01**						
All crops	2.94**	0.20	2.74**						

Growth rates have been estimated using regressions (3) (upper panel) and (6) (middle and lower panels). The asterisks in the middle and lower panels denote rejection of the hypothesis of equality for the growth rates of 1980-89 and 1990-2004 periods. The single and double asterisks (* and **) indicate significance at 0.01 and 0.05 probability levels, respectively.

Source: own estimation.

The output of wheat, oilseed, and "all crops" grew at the rates of 2.43, 2.53, and 2.53 percent, respectively, while the output of jute declined at the rate of 0.89 percent for the entire 1980-2004 period. The area under wheat and oilseed grew at the rate of 2.12 percent while the area under "all crops" remained almost unchanged (0.10 percent), but the area under jute declined at the rate of 2.08 percent. The yield rates of wheat, oilseed, jute, and "all crops" grew at the rates of 0.30, 0.40, 1.21, and 2.43 percent, respectively.

For the sub-periods 1980-89 and 1990-2004, the annual growth rates in total rice production were estimated at 2.12 and 3.15 percent, while the rice area grew at −0.29 and 0.30 percent, respectively. The annual yield in total rice grew at the rate of 2.43 percent in 1980-89 and 2.84 percent in 1990-2004. The output, area, and yield of MV rice grew at the respective rates of 8.22, 8.00, and 0.20 percent in the sub-period of 1980-89 and 5.76, 4.19, and 1.51 percent in the 1990-2004 sub-period. It is obvious from Table 4 that growths in total rice output, area, and yield and the yield of MV rice were significantly higher in the 1990-2004 compared to the 1980-89 sub-period. Both growths in LV output and area declined in both the sub-periods. The output, area, and yield of wheat grew at the rates of −0.19, 2.53, and −2.63 percent respectively in 1980-89 while they increased by 3.87, 1.92, and 1.92 percent respectively in the 1990-2004 sub-period. Although the growth rate in oilseed output increased during 1980-89, it declined in the 1990-2004 sub-period. But the output, area, and yield of "all crops" grew at higher rates in the 1990-2004 sub-period than in the previous sub-period. The overall results confirmed that a positive structural change (kinked) took place in farming practices in the sub-period 1990-2004 rather than in the sub-period 1980-89. This structural breakthrough might have taken place due to the positive impact of policy reforms by the government on farm efficiency and productivity in the 1990s. BAFFESS and GAUTAM (2001) also mentioned the positive impact of policy reforms by the Bangladesh Government on farm efficiency and productivity in the post-1987.

The upper panel of Table 5 reports the weighted contribution of area and yield to the overall rice output growth by seasons and varieties for the entire 1980-2004 period. *Boro* contributed 95 percent to the output growth, *Aman* contributed 27 percent while *Aus* contributed −14 percent to the output growth. Further decomposition reveals that MV *Aman* and *Boro* yields contributed respectively 9 and 10 percent to the overall rice output growth while Aus yield marginally reduced it (by 1 percent). MV *Aman* and *Boro* area contributed respectively 47 and 91 percent while LV *Aus*, *Aman*, and *Boro* areas contributed respectively −18, −29, and −3 percent to the total rice output growth.

TABLE 5. Growth rates decomposition of different crops in Bangladesh

	Total output			Modern varieties			Local varieties		
	Output	Area	Yield	Output	Area	Yield	Output	Area	Yield
1980-2004									
All rice	100	5	95	152	128	24	−38	−52	14
Aus	−14	−22	8	−1	0	−1	−14	−18	4
Aman	27	−7	34	56	47	9	−21	−29	8
Boro	95	75	20	101	91	10	-2	-3	1
Wheat	100	87	13						
Oilseed	100	84	16						
Jute	-100	−235	135						
1980-89									
All rice	100	−14	114	168	164	4	−60	−87	27
Aus	−32	−37	5	−12	-5	−7	−19	−27	8
Aman	40	−18	58	64	56	8	−36	−52	16
Boro	103	97	6	112	120	−8	−7	−5	-2
Wheat	−100	1,331	−1,431						
Oilseed	100	109	−9						
Jute	−100	−444	344						
1990-2004									
All rice	100	10	90	132	97	35	−26	−36	10
Aus	−8	−15	7	2	1	1	-9	−12	3
Aman	22	−4	26	46	38	8	−16	−20	4
Boro	84	56	28	84	61	23	−1	−2	1
Wheat	100	50	50						
Oilseed	−100	−356	284						
Jute	−100	−174	84						

Figures represent the weighted contributions to overall growth in percentage terms as described in equation (2). The boldface figures represent the 12 components of the overall growth rate for rice and they add up to 100 subject to rounding and stochastic error.
Source: own estimation.

On the other hand, the yields of LV *Aus*, *Aman*, and *Boro* contributed respectively 4, 8, and 1 percent. MV and LV yields together contributed less than one-third to the overall rice output growth. The major portion of growth was the result of conversion from LV area to MV *Aman* and *Boro* areas.

The area and the yield of wheat contributed 87 and 13 percent respectively to the overall wheat output growth while the area and the yield of oilseed contributed 84 and 16 percent respectively to the overall oilseed output growth. The contribution of MV Aman yield to rice output growth remained unchanged (8 percent) in both the sub-periods 1980-89 and 1990-2004, while the contribution of the yield of MV *Boro* was 23 percent in the 1990-2004 but it was −8 percent to rice output growth in the 1980-89 sub-period. The contribution of MV yield to rice output growth was significantly higher in the 1990-2004 period than in the 1980-89 period. But the contribution of MV area to the overall rice output was lower in the 1990-2004 period than in the 1980-89 period. This could happen due to the relative inflexibility of land area. HAYAMI and OTSUKA (1994) argued that with limits on cultivable area, rapid population growth, stagnating yields, and potential resource degradation, the future does not appear to be promising; and in that case, a pre-emptive action is required to promote and sustain the growth in food output. Wheat output increased in the 1990-2004 period while oilseed output decreased.

The decomposition findings have important policy implications for the simple reason that each of the growth components has a limited potential for expansion. For example, the land potential has already been exhausted. Thus, the conversion from local to modern varieties is limited by the total area allocated to rice and other crops. When this potential is exhausted, assuming that current yield trends continue, the growth in crop production will decline after some years. Coupled with a growing population whereby some arable lands would be reduced to accommodate this population, this will imply a decline in per capita production.

Ⅴ. Conclusions and Policy Implications

Both partial and functional analyses suggest that total output per year of "all crops" is significantly higher in the 1990-2004 period than in the 1980-89 sub-period. Total area, area under MV crop, draft animal, fertiliser, human capital, proportion of irrigated area to gross cropped area, and irrigated area were found to have significant effects on the increase in output at the aggregate level. The area allocated to crop production was virtually unchanged during the last 25 years. Almost the entire growth in crop production in Bangladesh can be attributed to an increase in average yields. A growth decomposition analysis confirmed that more than two-thirds of the growth in output was attributable to the conversion of area from local to modern varieties. Overall results confirmed that a positive structural change (kinked) took place in farming practices during 1990-2004 compared to the 1980-89 sub-period. The positive impact of policy reforms by the government on farm efficiency and productivity in the 1990s might have contributed to this structural breakthrough. However, the future prospect for growth in crop production is not promising for Bangladesh as the potentials for most of the growth promoting factors are likely to be exhausted in the near future. As a policy option, a preemptive action by the government is necessary to promote and sustain the growth in food output for some years in future.

The following policy options can be outlined to increase the productivity growth:

(a) Policy should be taken to develop new high-yielding varieties by genetic engineering and biotechnological research.

(b) In Bangladesh, environmental or ecological conditions have been deteriorating because of household waste, and urban and industrial pollution. The depletion of organic matter in the soil, the indiscriminate application of fertiliser, and the build-up of toxicity through the improper use of pesticides, the excessive withdrawal of water, and relentless wetland depletion are major reasons for agricultural land degradation and the loss of biodiversity. An appropriate land management strategy guided by proper institutional support could bring the environment better off. Policy should be taken to maintain environment-friendly cultural practices in agriculture.

Appendix A. Detailed results of exponential growth rate model estimations

Variable	Parameter	Total output			Modern varieties			Local varieties		
		Output	Area	Yield	Output	Area	Yield	Output	Area	Yield
For aggregate rice:										
Intercept	μ	7.268**	9.180**	-1.911**	3.352**	3.413**	-0.060	11.408**	12.252**	-0.845**
		(0.159)	(0.075)	(0.125)	(0.215)	(0.205)	(0.153)	(0.204)	(0.112)	(0.156)
Time	β	0.027**	0.001	0.027**	0.064**	0.054**	0.010**	-0.029**	-0.039**	0.011**
		(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
Adj-R^2		0.91	0.03	0.94	0.97	0.96	0.61	0.87	0.98	0.63
F-value		251.53**	0.78	382.20**	758.14**	581.94**	39.20**	166.43**	1051.75**	41.46**
For Aus rice:										
Intercept	μ	10.518**	11.973**	-1.455**	7.121**	6.236**	0.884**	11.576**	13.050**	-1.474**
		(0.283)	(0.197)	(0.188)	(0.378)	(0.270)	(0.208)	(0.330)	(0.231)	(0.203)
Time	β	-0.030**	-0.047**	0.017**	-0.004	-0.001	-0.003	-0.047**	-0.062**	0.015**
		(0.003)	(0.002)	(0.002)	(0.004)	(0.003)	(0.002)	(0.004)	(0.003)	(0.002)
Adj-R^2		0.80	0.95	0.75	0.03	-0.032	0.02	0.88	0.96	0.66
F-value		97.17**	491.72**	72.06**	1.07	0.26	1.47	172.07**	615.100**	48.01**
For Aman rice:										
Intercept	μ	7.698**	9.028**	-1.330**	2.326**	2.491**	-0.164**	10.562**	11.056**	-0.495**
		(0.273)	(0.102)	(0.227)	(0.472)	(0.302)	(0.328)	(0.238)	(0.120)	(0.178)
Time	β	0.015**	-0.004**	0.019**	-0.064**	0.054**	0.010**	-0.023**	-0.031**	0.008**
		(0.003)	(0.001)	(0.002)	(0.005)	(0.003)	(0.004)	(0.003)	(0.001)	(0.002)
Adj-R^2		0.51	0.35	0.71	0.87	0.92	0.23	0.77	0.96	0.39
F-value		26.11**	13.74**	61.05**	157.87**	272.49**	8.20**	79.77**	556.00**	16.06**
For Boro rice:										
Intercept	μ	2.503**	2.860**	-0.356**	1.582**	1.318**	0.264	8.550**	8.645**	-0.095
		(0.236)	(0.237)	(0.117)	(0.287)	(0.341)	(0.140)	(0.265)	(0.132)	(0.219)
Time	β	0.067**	0.053**	0.014**	0.076**	0.068**	0.008**	-0.028**	-0.033**	0.005**
		(0.003)	(0.003)	(0.001)	(0.003)	(0.004)	(0.002)	(0.003)	(0.001)	(0.002)
Adj-R^2		0.97	0.95	0.84	0.96	0.93	0.55	0.79	0.97	0.14
F-value		694.64**	428.10**	128.16**	605.05**	339.93**	30.25**	92.46**	525.41**	5.05*

Source: Own estimation.

Appendix B. Detailed results of exponential growth rate model estimations of wheat, oilseed, jute and all crops

Variable	Parameter	Wheat			Oilseed			Jute			All crops		
		Output	Area	Yield	Output	Area	Yield	Output	Area	Yield	Output	Area	Yield
Intercept	μ	4.925** (0.388)	4.498** (0.228)	0.427 (0.261)	3.619** (0.480)	4.167** (0.621)	-0.548** (0.160)	7.657** (0.392)	8.281** (0.403)	-0.624** (0.146)	7.578** (0.135)	9.271** (0.057)	-1.694** (0.116)
Time	β	0.024** (0.004)	0.021** (0.002)	0.003 (0.003)	0.025** (0.005)	0.021** (0.007)	0.004* (0.002)	-0.009 (0.004)	-0.021** (0.004)	0.012** (0.002)	0.025** (0.001)	0.001 (0.001)	0.024** (0.001)
Adj-R^2		0.57	0.75	0.001	0.48	0.26	0.18	0.14	0.49	0.71	0.93	0.13	0.94
F-value		32.47**	73.14**	1.02	22.91**	9.32**	6.33*	4.74*	23.90**	58.78**	303.81**	4.59*	365.46**

Source: Own estimation.

Appendix C. Kinked exponential growth models for rice crops

Variable	Parameter	Total output			Modern varieties			Local varieties		
		Output	Area	Yield	Output	Area	Yield	Output	Area	Yield
For aggregate rice:										
Intercept	μ_1	9.464**	9.259**	0.204**	8.321**	7.508**	0.813**	9.119**	9.100**	0.019
		(0.038)	(0.018)	(0.031)	(0.047)	(0.031)	(0.035)	(0.050)	(0.026)	(0.039)
d_1t+d_2k	β_1	0.021**	-0.003	0.024**	0.079**	0.077**	0.002	-0.023**	-0.033**	0.010
		(0.005)	(0.002)	(0.004)	(0.006)	(0.004)	(0.005)	(0.007)	(0.003)	(0.005)
d_2t-d_2k	β_2	0.031	0.003*	0.028**	0.056**	0.041**	0.015**	-0.031**	-0.043**	0.011**
		(0.003)	(0.001)	(0.002)	(0.004)	(0.002)	(0.003)	(0.004)	(0.002)	(0.003)
Adj-R^2		0.92	0.07	0.94	0.98	0.99	0.66	0.87	0.98	0.61
F-value		131.71**	1.89	187.39**	469.85**	770.14**	24.47**	82.70**	600.24**	19.90**
For Aus rice:										
Intercept	μ_1	8.152**	8.167**	-0.016	7.014**	6.213**	0.801**	7.760**	8.007**	-0.247**
		(0.070)	(0.046)	(0.041)	(0.067)	(0.061)	(0.035)	(0.075)	(0.042)	(0.050)
d_1t+d_2k	β_1	-0.033**	-0.038**	0.005	-0.042**	-0.017*	-0.025**	-0.028**	-0.040**	0.012
		(0.009)	(0.006)	(0.005)	(0.009)	(0.008)	(0.005)	(0.010)	(0.006)	(0.007)
d_2t-d_2k	β_2	-0.029**	-0.053**	0.024**	0.016**	0.007	0.009**	-0.057**	-0.074**	0.017**
		(0.006)	(0.004)	(0.003)	(0.005)	(0.005)	(0.003)	(0.006)	(0.003)	(0.004)
Adj-R^2		0.79	0.96	0.79	0.46	0.10	0.53	0.89	0.98	0.65
F-value		46.79**	266.84**	47.166**	11.17**	2.29	14.41**	99.69**	549.10**	23.49**
For Aman rice:										
Intercept	μ_1	8.887**	8.718**	-0.016	7.266**	6.633**	0.801**	8.723**	8.617**	-0.247**
		(0.068)	(0.025)	(0.041)	(0.111)	(0.065)	(0.035)	(0.053)	(0.030)	(0.050)
d_1t+d_2k	β_1	0.016	-0.007*	0.005	0.086**	0.075**	-0.025**	-0.020*	-0.029**	0.012
		(0.009)	(0.003)	(0.005)	(0.015)	(0.009)	(0.005)	(0.008)	(0.004)	(0.007)
d_2t-d_2k	β_2	0.015**	-0.003	0.024**	0.052**	0.043**	0.009**	-0.025**	-0.032**	0.017**
		(0.003)	(0.002)	(0.003)	(0.009)	(0.005)	(0.003)	(0.005)	(0.002)	(0.004)
Adj-R^2		0.49	0.34	0.79	0.88	0.94	0.53	0.76	0.96	0.65
F-value		12.49**	7.06**	47.17**	85.91**	174.19**	14.41**	38.57**	267.91**	23.49**
For Boro rice:										
Intercept	μ_1	7.744**	6.913**	0.831**	7.464**	6.444**	1.020**	6.484**	6.056**	0.428**
		(0.053)	(0.042)	(0.024)	(0.056)	(0.044)	(0.021)	(0.057)	(0.033)	(0.046)
d_1t+d_2k	β_1	0.082**	0.077**	0.005	0.102**	0.110**	-0.008**	-0.046**	-0.035**	-0.012
		(0.007)	(0.006)	(0.003)	(0.007)	(0.006)	(0.003)	(0.008)	(0.004)	(0.006)
d_2t-d_2k	β_2	0.060**	0.040**	0.019**	0.063**	0.045**	0.017**	-0.017**	-0.032**	0.014**
		(0.004)	(0.003)	(0.002)	(0.004)	(0.004)	(0.002)	(0.005)	(0.003)	(0.004)
Adj-R^2		0.97	0.97	0.89	0.98	0.98	0.83	0.84	0.96	0.36
F-value		404.29**	402.91**	94.73**	479.18**	628.29**	61.11**	61.61**	253.55**	7.82**

Source: Own estimation.

Appendix D. Kinked exponential growth models for wheat, oilseed, jute and all crops

Variable	Parameter	Wheat			Oilseed			Jute			All crops		
		Output	Area	Yield	Output	Area	Yield	Output	Area	Yield	Output	Area	Yield
Intercept	μ_1	6.973** (0.086)	6.143** (0.056)	0.830** (0.041)	5.270** (0.078)	5.402** (0.107)	1.020** (0.021)	6.900** (0.097)	6.595** (0.100)	0.305** (0.035)	9.624** (0.032)	9.382** (0.014)	0.242** (0.027)
d_1t+d_2k	β_1	-0.002 (0.011)	0.025** (0.007)	-0.026** (0.005)	0.077** (0.010)	0.085** (0.014)	-0.008** (0.003)	-0.005 (0.013)	-0.022 (0.013)	0.017** (0.005)	0.019** (0.004)	0.000 (0.002)	0.019** (0.004)
d_2t-d_2k	β_2	0.038** (0.007)	0.019** (0.005)	0.019** (0.003)	-0.004 (0.006)	-0.014 (0.009)	0.017** (0.002)	-0.012 (0.008)	-0.021* (0.008)	0.010** (0.003)	0.029** (0.003)	0.002 (0.001)	0.027** (0.002)
Adj-R^2		0.64	0.74	0.59	0.77	0.62	0.83	0.10	0.47	0.71	0.93	0.10	0.94
F-value		22.53**	35.60**	18.35**	40.72**	20.93**	7.93**	2.35	11.43**	30.26**	163.98**	2.36	196.58**

Source: Own estimation.

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