Bangladesh J. Agric. Econ. XIII. 1 & 2 (December 1990) 25-41

A MODEL FOR ESTIMATING LINEA R TREND IN PRODUCTION, AREA AND YIELD OF AGRICULTURAL CROPS

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ABSTRACT

Growth rates in production, area and yield of agricultural crops are widely estimated for examining growth performance of the crop sector and evaluating government policies. But estimation of linear trends which provide valuable information for policy analysis received little importance. This paper developed a model for estimating linear trends in production, area and yields of agricultural crops and used the same to derive estimates of linear trends in the cereal sector. The analysis shows that linear trends in cereal production Increased in the 80's only marginaliy which is unsatisfactory in view of population growth and public investment. The poor trend resulted mainly from decreased trends in production and yield of wheat and yield of boro paddy.

1. INTRODUCTION

Growth rates in production, area and yield of agricultural crops, have been estimated extensively in Bangladesh with a view to examining growth performance of the crop sector and evaluation of government 'policies (Boyce 1987; Elahi, Husain and Rahman 1990; Parthasarathy and Chowdhury 1989; Orr and Islam 1990; Yasmin and Jaim 1990), But estimation of linear trends, which furnish information that could be highly valuable for policy analysis, received little importance. Additionally a theoretically consistent methodology is yet to be developed for estimating linear trends in agricultural crops. The main objective of this paper, therefore, was to derive a methodology for consistently estimating linear trends in agricultural crops. Then the methodology was used to estimate linear trends in the cereal sector of Bangladesh.

The paper has been organized as follows. The next section discusses the model for estimating linear trends in production, area arid yield of agricultural crops. Section III discusses growth rates in production, area and yield of cereal crops in Bangladesh. The conclusions are given in Section IV.

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The author is gratefully acknowledges the financial help provided by the Winrock International in Dhaka for writing this paper.

II. A MODEL FOR ESTIMATING LINEAR TRENDS IN PRODUCTION, AREA AND YIELD OF AGRICULTURAL CROPS

A two sector crop model is developed here to describe the procedure for estimation and computation of linear trends in production, and yield of agricultural crops. The two crops included in the model are aus and wheat which are important cereal crops in Bangladesh. Production, area and yield of aus and wheat are defined below:

Pa = Production of aus

Pw = Production of wheat

Aa = Acreage of aus

Aw = Acreage of wheat

T = Time

TP = Pa + Pw = Total production of aus and wheat

TA = Aa + Aw = Total area of aus and wheat

$Ya = \frac{Pa}{Aa}$ = Yield of aus

$Yw = \frac{Pw}{Aw}$ = Yield of wheat

$Ya+w = \frac{TP}{TA}$ = Aggregate yield of aus and wheat

The crop model is the following :

$$Pa = c_1 + d_1T + e_1 \quad \ldots (1)$$

$$Pw = c_2 + d_2T + e_2 \quad \ldots (2)$$

$$Aa = c_3 + d_3T + e_3 \quad \ldots (3)$$

$$Aw = c_4 + d_4T + e_4 \quad \ldots (4)$$

$$TP = Pa + Pw \quad \ldots (5)$$

$$TA = Aa + Aw \quad \ldots (6)$$

$$Ya = \frac{Pa}{Aa} \quad \ldots (7)$$

$$Yw = \frac{Pw}{Aw} \quad \ldots (8)$$

$$Ya+w = \frac{TP}{TA} \quad \ldots (9)$$

Equations (1) to (9) describe a two-crop linear model which contains four types of variables. Equations (1) to (4) represent stochastic equations for aus and wheat production and area. Aggregate production and area of aus and wheat are represented by identity equations (5) and (6). Yields of aus and wheat are given by indentity equations (7) to (8). Equation (9) represents aggregate yield rate.

The time derivatives of equations (1) to (9) which are linear trends are as follows:

$$\frac{dPa}{dT} = d_1 \; ; \frac{dPw}{dT} = d_2 \; ;$$

$$\frac{dAa}{dT} = d_3 \; ; \frac{dAw}{dT} = d_4 \; ;$$

$$\frac{dTP}{dT} = \frac{dPa}{dT} + \frac{dPw}{dT} = d_1 + d_2$$

$$\frac{dTA}{dT} = \frac{dAa}{dT} + \frac{dAw}{dT} = d_3 + d_4$$

$$\frac{dYa}{dT} = \frac{1}{Aa^2} (Aa.d_1 - Pa.d_3)$$

$$\frac{dYw}{dT} = \frac{1}{Aw^2} (Aw.d_2 - Pw.d_4)$$

$$\frac{dYa+w}{dT} = \frac{1}{TA_2} \; [TA\,(d_1+d_2) - TP(d_3+d_4)]$$

We have nine derivatives from nine equations. To find values of these derivatives, equations (1) to (4) can be consistently estimated by OLS method which will provide estimates of d_1, d_2, d_3 and d_4. But trends in yield of individual crops of production, area and yield of crop aggregates can not be estimated by the OLS method. This is because there is an identity relationship between these variables and production and area of individual crops. Estimation of an identity equation violates the assumption of the econometric methods which assume that there is a disturbance term in each equation (Elahi, Hussain and Rahman 1990; Johnston 1984; Maddala 1977). But an identity equation does not contain any disturbance term. However, trends in yield of individual crops or production, area and yield of crop aggregates can be computed from estimated trends in production and area of individual crops (Chaing 1984).

The estimated equations are the following:

$$\hat{Pa} = \hat{c}_1 + \hat{d}_1 T$$

$$\hat{Pw} = \hat{c}_2 + \hat{d}_2 T$$

$$\hat{Aa} = \hat{c}_3 + \hat{d}_3 T$$

$$\hat{Aw} = \hat{c}_4 + \hat{d}_4 T$$

The calculated values of other equations are :

$$\hat{TP} = \hat{Pa} + \hat{Pw} = (\hat{c}_1 + \hat{c}_2) + (\hat{d}_1 + \hat{d}_2)T$$

$$\hat{TA} = \hat{Aa} + \hat{Aw} = (\hat{c}_3 + \hat{c}_4) + (\hat{d}_3 + \hat{d}_4)T$$

$$\hat{Ya} = \frac{\hat{Pa}}{\hat{Aa}} \; ; \; \hat{Yw} = \frac{\hat{Pw}}{\hat{Aw}}$$

$$\hat{Ya+w} = \frac{\hat{TP}}{\hat{TA}}$$

The calculated trends are as follows:

$$\frac{dTP}{dT} = \hat{d}_1 + \hat{d}_2 \; ; \; \frac{dTA}{dT} = \hat{d}_3 + \hat{d}_4$$

$$\frac{dYa}{dT} = \frac{1}{\hat{A}^2_a}(\hat{Aa}.\hat{d}_1 - \hat{Pa}.\hat{d}_3)$$

$$\frac{dYw}{dT} = \frac{1}{\hat{A}^2_w}(\hat{Aw}.\hat{d}_2 - \hat{Pw}.\hat{d}_4)$$

$$\frac{dYa+w}{dT} = \frac{1}{\hat{TA}^2}\left[\hat{TA}(\hat{d}_1 + \hat{d}_2) - \hat{TP}(\hat{d}_3 + \hat{d}_4)\right]$$

The procedure for estimating and computing linear trends in agricultural crops is summarized as follows. Linear trends in production and area of individual

crops can be estimated consistently by the OLS method. Linear trends in aggregate production and area are obtained by summing trends in production and area of individual crops. Linear trends in yields are wighted difference between trends in production and areas.

III. ESTIMATES OF LINEAR TRENDS IN THE CEREAL SECTOR OF BANGLADESH

The model developed in the previous section was used to derive estimates of linear trends in the cereal sector of Bangladesh. In addition to testing the model, the objective of the analysis was to contribute to the recent debate that growth performance of the cereal sector slowed down in the 80's (Elahi, Husain and Rahman 1990 ; Parthasarathy and Chowdhury 1989 ; Orr and Islam 1990). These studies, however, examined growth rates only ; consequently magnitude of changes could not be ascertained. The linear trend analysis permits the estimation of dimensions of changes, in addition to the directions of changes.

Following Elahi, Husain and Rahman, Parthasarathy and Chowdury and Orr and Islam, data on the cereal sector were analysed for the period 1975-76 to 1986-87. Trends were estimated for two periods : the period 1975-76 to 1986-87 is called the entire period (EP) while the period 1980-81 to 1986-87 is called the recent (RP). The recent period represents the 80's. The objective of such analysis was to compare trends in the shorter period of the 80's with the trends in the longer post-independance period.

Trends were estimated for production, area and yield of four major cereal crops of Bangladesh, viz. aus, aman, boro and wheat. Analysis was done for both local and modern varieties of each crops. Trends in production, area and yield were estimated for eighteen variables : aus local (AL), aus HYV (AH), aus total (AT=AL+AH), aman local (AML), aman HYV (AMH), aman total (AMT=AML+AMH), boro local (BL), boro HYV (BH), boro total (BT=BL+BH)· wheat local (WL), wheat HYV (WH), wheat total (WT=WL+WH). Paddy local (PL=AL+AML+BL), Paddy HYV (PH=AH+AMH+BH). Paddy total (PT=AT+AMT+BT). Cereal local (CL=PL+WL). cereal HYV (CH=PH+WH), and cereal total (CT=PT+WT).

Results of the analysis are given in Table 1 which are discussed here. Details of estimation are provided in the appendix.

Production

Trend in total cereal production increased by about ten thousand M. T. in the 80's. This occurred mainly due to increased trend in the paddy production. Trend in paddy production increased from 227 thousand M. T. in the EP to 274 thousand M. T. in the RP. Trend in wheat production decreased 45 thousand M. T. to 7 thousand M. T. in the 80's.

Among the paddy crops, negative trends in aus production continued in the RP. On the other hand, trends in boro production did not change whereas trends in aman production increased significantly. Total aus production decreased about 58 thousand M. T. annually along the trend line in the 80's while trend in boro production remained constant at 195 thousand M. T. Trend in aman production increased from 53 thousand M. T. in the EP to 137 thousand M. T. in the RP.

It is important to note that increased trend in cereal production was due to increased trend in local variety. Trends in local cereal production were negative in both periods however, magnitude of trend was much lower in the RP meaning that the trend increased in the recent period. Trends in local cereal production were respectively -105 and -40 thousand M. T. In the EP and RP. Trends in local paddy production were not much different from those of local cereal production, because local wheat production constituted an insignificant proportion of total wheat production. Trend in HYV cereal production decreased.

Among the paddy crops, trends in local aus and local boro production were negative in both periods, but magnitudes were higher in the 80's, meaning that trends decreased. Trend in local aman turned from negative in the EP to positive in the RP.

Trend in HYV aus production decreased while it increased in HYV boro production. These was no change in trend in production of HYV aman.

Area

Trend in total cereal area decreased significantly. It was 101 thousand acres in the EP which decreased to 58 thosand acres in the RP. This was

Table 1. Linear Trends in Production, Area and Yield of Major Cereal Crops in Bangladesh.

	Production (1)		Area (2)		Yield (3)	
	1975-76 to 1986- 87	1980-81 to 1986-87	1975-76 to 1986-87	1980-81 to 1986-87	1975-76 to 1986-87	1980-81 to 1986-87
Cereal Total	271.22	281.18	100.54	57.87	8.18	9.13
—Cereal local	—105.02	—40.06	—344.69	—302.07	2.08	4.66
—Cereal HYV	375.26	321.21	445.23	359.90	—3.99	0.001
Paddy Total	226.55	274.26	57.80	55.60	7.70	9.44
—Paddy local	—104.26	—40.42	—341.57	—302.08	2.06	4 65
—Paddy HYV	330.81	314.68	399.37	357.68	—6.59	—1.55
Wheat Total	44.67	6.92	42.74	2.22	10.65	3.67
—Wheat local	—0.76	0.36	—3.12	0.07	3.25	6.98
—Wheat HYV	45.43	6.56	45.86	2.15	8.32	3.55
Aus Total	—21.76	—57.85	—92.31	—127.50	1.95	—0.83
—Aus local	—28.58	—36.64	—129.79	—143.64	2.06	1.73
Aus HYV	6.82	—21.21	37.48	16.14	—22.27	—7.00
Aman Total	53.20	137.25	8.07	—19.14	3.36	9.98
—Aman local	—53.76	29.68	—161.90	—134.68	1.77	7.68
—Aman HYV	106.96	107.57	169.97	115.54	14.85	6,05
Boro Total	195.11	194.86	142.04	202.24	20.99	0.14
—Boro local	—21.92	—33.46	—49.88	—23.76	6.44	—21.88
—Boro HYV	217.03	228.32	191.92	226.00	6.39	—5.77

(1) Production in thousand metric ton.
(2) Area in thousand acre.
(3) Yield in Kilogram per acre.

mainly due to decrease in the trend in wheat area as trend in paddy area virtually remained constant. Trend in wheat area decreased from 43 thousand acres to 2 thousand acres.

Among the paddy crops, trends in aus area were negative in both periods, but the magnitude of trend was higher in the RP. Trend in aman area became

negative in the RP while trend in boro area increased from 142 thousand acres in the EP to 202 thousand acres in the RP.

Estimates of trends in area of local and HYV cereal reveal some important information. Trend in local cereal area increased while that in HYV decreased in the 80's. Trends in area under local cereal were negative in both periods, but magnitude was lower in the RP. Trend in area under HYV cereal decreased from 445 thousand acres in the EP to 360 thousand acres in the RP.

Local wheat area had little contribution to local cereal area because more than 95% area was under HYV wheat cultivation. Thus trends in local cereal were virtually trends in local paddy. Trends in area under both HYV wheat and HYV paddy decreased.

Trends in area under both local and HYV aus decreased in the RP while those under both local and HYV boro increased. On the other hand, trend in area under HYV aman decreased whereas it increased under local aman although trends were negative in both periods.

Yield

Trend in per acre cereal yield showed slight improvement in the 80's. It increased from 8.18 kg in the EP to 9.13 kg in the RP. The increased trend in cereal yield resulted from increased trend in paddy yield, because trend in wheat yield decreased significantly.

Among the paddy crops, there was a remarkable decrease in trend of yield rate of boro paddy in the 80's. Trend in boro yield per acre was 20.99 kg. in the EP which decreased to 0.14 kg in the RP. Trend in aus yield also decreased. But trend in aman yield increased significantly.

Trend in per acre yield of local cereal production more than doubled in the 80's. It was 2.08 kg in the EP which increased to 4.66 kg in the RP. This increased trend was mainly due to increased trend in yield rate of local paddy, because local wheat constituted a negligible proportion of local cereal production. Trend in yield of HYV cereal was just positive in the 80's. This was also due to increased trend in yield of HYV paddy, because trend in HYV wheat decreased in the RP.

Highly noticeable changes took place in trends in yields of different paddy crops. Dramatic changes occurred in boro yield. Trends in yields of both

local and HYV boro became highly negative in the 80's. Trends in yields of local and HYV boro were respectively 6.44 kg and 6.39 kg in the EP which became -21.88 kg and -5.77 in the RP. Trend in local aus yield decreased marginally but it improved in case of HYV aus.

Trend in yield of local aman increased significantly. It was 1.77 kg in the EP which increased to 7.68 kg in the RP. The trend in HYV aman, however, decreased.

Summary

The main points of the analysis are summarized below :

First, trend in cereal production increased by ten thousand M. T. in the 80's. This was due to increased trend in local amen production. The trend irn boro production, which was the main focus of government policy, did not change. The trend in local variety of paddy increased signilicatly while that in HY V paddy decreased.

Second, trend in cereal acreage decreased significantly in the 80's resulting mainly from decreased trend in wheat acreage as virtually no change occurred in trend in paddy area. Trend in both aus and aman area decreased, while trend in boro area increased. It may be noted that trend in local paddy area improved while it deteriorated in case of mordern varieties.

Finally, trend in per acre cereal yield exhibited small improvement which resulted from increased trend in paddy yield. Trends in boro yield, both local and modern varieties, showed notable decrease in the 80's. It is important to note that trend in yield of local variety of paddy increased significantly.

IV. CONCLUSIONS

Growth rates in production, area and yield of agricultural crops are widely estimated for examining growth performance of the crop sector and evaluating government policies. But estimation of linear trends which provide valuable information for policy analysis received little importance. In this paper, a model was developed for estimating linear trends in production, area and yield of agricultural crops which was used to derive estimates of linear trends in cereal crops in Bangladesh.

The analysis reveals information which is of great concern to policy makers. Trend in total cereal production increased marginally which is unsatisfactory in view of population growth, public investment and the emphasis placed by the government on the development of the cereal sector. The more disturbing message of the analysis is the reasons for poor trends in cereal production. First, increased trend in cereal production resulted entirely from increased trend in local aman production. Trends in wheat and aus production declined while trends in boro and HYV aman production did not change. Second, trends in cereal area decreased significantly because of decreased trends in wheat, aus and aman areas. But trends in both local and HYV boro increased. Finally, trend in yield of cereal production improved marginally in the 80's, because of remarkable increase in trend in yield of local aman production. Trends in yield of wheat, aus and boro decreased significantly. Particularly, decreased trends in both local and HYV boro production are alarming.

To achieve self-sufficiency in foodgrains by 1990, the government singled out boro as the major field of expansion. The government has been successful in expanding the boro area, which however, took place at the expense of other grains. But dramatic reduction in trend in yield rate of boro frustrated the goal of increased trend in cereal production.

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APPENDIX

ESTIMATION OF LINEAR TRENDS

Time period

The objective of the analysis was to investigate whether trends in the cereal sector decreased in the 80's. To achieve this objective, data were analysed for the period 1975-76 to 1986-87. The reason is that the early part of the 70's was characterized by depressed conditions due to disruption of the economy and 1975-76 could be thought to be marked by a new phase of growth after recovery (Parthasarathy and Chowdhury). The data after 1986-87 were affected by unprecedented floods. The data were analysed for two time periods : 1975-76 to 1986-87 and 1980-81 to 1986-87.

Estimation of Linear Trends

To estimate linear trends in production and area, linear equations were estimated with OLS method. But time series data on production and acreage often show high degree of fluctuations. Sudden large variations in crop production and area may be caused by extremely good or bad weather conditions. These sudden extreme variations in time series do not represent trend. Maddala (1977) called them statistical outliers. Sometimes changes in government policies change the trend in production and acreage. Additionally trend is dependent critically upon the choice of the time period. The OLS method which minimizes squared deviations from the trend line to estimate parameters puts greater emphasis on large deviations. If data series show extremely large or small observations or change in trend then estimated trend line may not represent the true trend line. The problems are reflected in high standard error of trend coefficient, low value of R^2 and presence of autocorrelation.

Thus, the impact of outliners and change in trend should be taken into account to accurately estimate trend coefficient. The dummy variables are widely used to measure the impact of statistical outliers or change in data series (Boyce 1987; Hossain 1989; Johnston 1984; Maddala 1977).

In this study, dummy variables were used for the following series and years :

Series	Equations for 1975-76 to 1986-87	Equations for 1980-81 to 1986-87
AAMH	1977-78 to 1978-79	—
ABL	1976-77	1980-81 to 1981-82
AWL	1975-76 to 1976-77	1984-85
AWH	1975-76 to 1978-79	1984-85
PAH	1980-81 to 1981-82	—
PAMH	1976-77 to 1978-79	—
PBL	1976-77	—
PWL	1975-76	—
PWH	1975-76 to 1978-79	1984-85

Linear equations were estimated with OLS method for the following variables : AAL, AAH, AAML, AAMH, ABL, ABH, AWL, AWH, PAL, PAH, PAML, PAMH, PBL, PBH, PBWL and PWH.

Linear trends of other variables were computed applying the formulas developed in section II. The results of estimation are reported in Appendix Tables I. to IV.

Appendix Table I. Estimates of Linear Trends in Production of Cereal Crops for the Period 1975-76 to 1986-87

(Coefficients in '000 MT)

Variable	Regression Coefficients		$\bar{R}^2$	D. W.
	Trend	Dummy		
PAL	-28.58**	—	0.43	2.52^N
	(- 2.75)			
PAH	6.28	135.6*	0.53	2.81^N
	(1.61)	(3.45)		
PAML	-53.76	—	0.20	1.45^N
	(- 1.58)			
PAMH	106.96*	-699.20*	0.93	2.93^N
	(6.27)	(5.14)		
PBL	-21,92*	-214.77*	0.59	2.29^N
	(3.91)	(- 3.07)		
PBH	217.03*	—	0.91	1.72
	(7.78)			
PWL	0.76**	21.05*	0.82	1.27^I
	(-2.24)	(4.96)		
PWH	45.43**	-497.51*	0.88	2.14^N
	(2.16)	(-3.23)		

Figures in the parentheses indicate t-values.
* indicates significant at 1%
**indicates significant at 5%
N indicates no autocorrelation
I indicates test is inconclusive.

Appendix Table II. Estimates of Linear Trends in Production of Cereal Crops for the Period 1980-81 to 1986-87

(Coefficients in '000 MT.)

Variable	Regression Coefficients		$\bar{R}^2$	D. W.
	Trend	Dummy		
PAL	-36.64	—	0.32	2.19N
	(-1.54)			
PAH	-21.21	—	0.43	2.29N
	(-1.94)			
PAML	29.68	—	0.10	2.48N
	(0.75)			
PAMH	107.57*	—	0.69	2.55N
	(3.36)			
PBL	-33.64*	—	0.80	2.66N
	(-4.46)			
PBH	228.32*	—	0.86	2.32N
	(5.49)			
PWH	6.56	362.35*	0.70	2.15N
	(0.40)	(3.48)		

Figures in the parentheses indicate t-values

* indicates significant at 1%

N indicates no autocorrelation.

Appendix Table III. Estimates of Linear Trends in Area of Cereal Crops for the Period 1975-76 to 1986-87

(Coefficients in '000 acres)

Veriable	Regression Coefficients		$\bar{R}^2$	D. W.
	Trend	Dummy		
AAL	-129.76*	—	0.86	1.39N
	(-7.88)			
AAH	37.48*	—	0.85	1.88N
	(7.40)			
AAML	-161.90*	—	0.37	1.55N
	(-5.25)			
AAMH	-169.97*	-988.22*	0.95	1.47I
	(9.53)	(-5.98)		
ABL	-49.88*	-334.39*	0.94	1.49I
	(-12.81)	(-6.88)		
ABH	191.92*	—	0.92	1.50N
	(11.07)			
AWL	-3.12	57.88*	0.86	2.23N
	(-2.27)	(4.54)		
AWH	45.86**	-667.20*	0.91	2.74N
	(2.17)	(-4.30)		

Figures in the parentheses indicate t-values

* indicates significant at 1%

** indicates significant at 5%

N indicates no autocorrelation

I indicates test is insigniticant.

Appendix Table IV. Estimates of Linear Trend in Area of Cereal Crops for the Period 1980-81 to 1986-87

(Coefficients in '000 Acres)

Variable	Regression Coefficient		$\bar{R}^2$	D. W.
	Trend	Dummy		
AAL	-143.64*	—	0.77	1.17^{I}
	(-4.06)			
AAH	16.14	—	0.29	1.87^{N}
	(1.43)			
AAML	-134.68**	—	0.59	2.59^{N}
	(-2.66)			
AAMH	115.54*	—	0.91	2.40^{N}
	(6.97)			
ABL	-23.76*	105.73*	0.97	3.10^{N}
	(-4 39)	(4.42)		
ABH	226.00*	—	0.93	2.27^{N}
	(8.02)			
AWL	0,07	—	0.002	3.27^{N}
	(0.11)			
AWH	2.15	309.83*	0,62	1.26^{I}
	(0.13)	(3.33)		

Figures in the parentheses indicate t-values

* indicates significant at 1%

** indicates significant at 5%

N indicates no autocorrelation

I indicates test is inconclusive,