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SEARCHING FOR THE BEST FITTING DETERMINISTIC MODEL FOR INNOVATIVE GROWTH ANALYSIS AND FORECASTING OF RICE PRODUCTION IN BANGLADESH

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ABSTRACT

The study tried to find out appropriate models using seven contemporary model selection criteria that could best describe the growth pattern of rice production in Bangladesh and in its foil regions (former divisions) Chittagong, Dhaka. Khulna and Rajshahi during the time period 1973/74 to 2000/01. It appeared from the study that the best fitting model for rice production in the whole country and in Dhaka was the cubic model. For Chittagong the quadratic model was the best. It means that the assumption of constant annual rate of growth in percent that lies behind the use of exponential/compound model, which was very common to use in describing growth pattern, was not true for the growth pattern of rice production in the country as a whole and also in its two regions Dhaka and Chittagong. In other words, in these regions and in the country as a whole the growth rates were different over different time points. The variation of the growth rate in the country as a whole was 1.38 to 5.76 percent, in Dhaka -1.09 to 13.01 percent and in Chittagong 0.92 to 2.06 percent during the study period. In Khulna and Rajshahi regions the exponential/compound model seemed to be appropriate. The rice production in Khulna grew at the constant rate of 2.6 percent, on the average, per year and in Rajshahi at the rate of 3.3 percent throughout the study period. Five-year forecasts were also made for each of the four regions and for the country as a whole using the best fitted models.

I. INTRODUCTION

As an agro-based developing country Bangladesh is striving hard for rapid development of its economy. The economic development of the country is basicatly based on agriculture. It is often argued that the future development of the country depends particularly on the development and proper management of the agriculture sector. The food problem i, one o1 the most critical aspects of economic development. It bears upon the rate and structure Of economic growth, rate of inflation, poverty and nutrition, and the balance of trade and government's fiscal position. The contribution of agriculture sector in GDP is 19. 11 percent. In the agriculture sector, the crop sub-sector dominates with 14.32 percent in GDP of which rice alone contributes about 53 percent. In Bangladesh although 63 percent of the labour force is directly engaged in agriculture and 78 percent of total crop is devoted to rice

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production, the country has still a chronic shortage of food-grains (BBS, 2002).

To feed the vast population of this country the government has to import food-grain from other countries through national and international agencies every year. A sizeable amount of the export earnings are spent for this purpose. This is mainly due to the low productivity in rice production. Among the rice producing countries in Asia, Bangladesh occupies one of the lowest positions in rice production per hectare (FAO, 1984). But the sluggish growth in agriculture is mainly responsible for the stagnation of the economy. Over the last three decades the agricultural value added could not keep pace with the population growth (BBS, 2002). In a country like Bangladesh-' the growth of non-agriculture sectors are dependent on the growth of agriculture sector. The raw materials needed for the growth of non-agriculture sectors largely come out from the agriculture sector. So the long term 'poor performance in agriculture sector hindered the growth of non-agriculture sectors. This resulted in the overall stagnancy of the economy.

It is necessary to enhance the growth of rice production through increasing land productivity to meet the increasing food demand for the vast population of the country as the country has serious land constraints. Significant differences in rice productivity among the different regions are also barriers to the production growth (Hossain, 1990; Hossain and Ahamed, 1989). Many steps to enhance the growth are being taken from the part of the government and non-government agencies since the independence of the country. For future planning it is necessary to evaluate the growth pattern office production that is achieved at the time in the country as a whole and also in the different regions of the country. To reveal the growth pattern and to make best forecasts of rice in Bangladesh including different regions appropriate time series models that can be able to describe the observed data successfully are necessary.

For forecasting purpose two types of time series models are widely used in practice. The first type is known as deterministic time series models and the second type is known as stochastic time series models. Among the stochastic time series models ARIMA types are very popular as they can successfully describe the observed data and can make forecast with minimum forecast error. But these types of models are very difficult to identify and also to estimate. If they are not identified correctly their forecasting performance are very poor. Moreover, they are expensive, time consuming, and very difficult to understand as the internal mechanism of the model building procedure is complex. On the other hand, deterministic type time series models, often called growth models, such as linear, quadratic, cubic, logarithmic, exponential, compound, inverse, power, and S-shaped are very quick to estimate, inexpensive and very easy to understand. Although they do not provide as much forecasting accuracy as the correctly identified and estimated stochastic time series models, in many cases they provide a simple, inexpensive, and still quite acceptable means of forecasting. It is very important to note that these models are called deterministic in that no reference is made to the sources and nature of the underlying randomness in the series (Pindyck *et. al.*, 1991). These models are widely used to estimate the growth rate of time series.

A very common practice to estimate the growth rate of rice production in Bangladesh is the use of exponential/compound model (Akter et. al., 2002; Barua et. al., 2000; Jabber et. a1.,1997; Hossain,1984 & 1980; and Mahmud et. a1.,1983). This model is appropriate when the annual percent growth rate is constant over time. If the growth rate is not constant but depends on time instead this model can not describe the actual picture of the growth scenario. Therefore, before performing growth analysis it is necessary to identify the growth model that best fits the time series. Here, an attempt is made to identify the best models for Bangladesh and its four regions (former divisions) Chittagong, Dhaka, Khulna and Rajshahi using seven contemporary model selection criteria such as R^2, adjusted R^2, RMSE, AIC, BIC, MAE and MAPE (Gujarati, 2003). Attempts are also made to describe the growth scenario and to make forecasts of rice production in different regions and overall Bangladesh using the best fitted models.

II. METHODOLOGY

Data and Models

The present study makes an extensive use of secondary time series data of rice production in the four regions and also in the country as a whole for the period 1973/74 to 2000/01. Four old divisions Dhaka, Chittagong, Khulna and Rajshahi of the country are considered as four regions. The data were collected from the various publications of Bangladesh Bureau of Statistics (BBS, 1982, 1990, 1999, 2000, 20001). This is the only government level institute responsible for collecting and storing necessary data required for future planning and development of the country. The models those are used to describe the behaviour of variables that vary with respect to time are termed as growth models. This type of models is needed in a specific area and in a specific problem that depends on the type of growth that. occurs in the time series data. In general, growth models are mechanism rather than empirical ones. A mechanical growth model usually arises as a result of making assumptions about the type of growth, writing down the differential or difference equations that represent these assumptions and then solving these equations. An empirical model, on the other hand, is a model chosen empirically to approximate an unknown mechanistic model. Typically the empirical model is a polynomial of some suitable order. However, in this study, nine growth models are considered for our searching purpose. Their functional forms and formulas for calculating growth rates are given in Table 1.

Table 1. The mathematical forms of the models considered and formulas of growth rates

Name of model	Mathematical form	Annual growth rate in percent	Meaning and assumptions
Linear	$Y = a + bt + \varepsilon$	$\frac{b}{Y} \times 100$	Y is the time series considered;
Quadratic	$Y = a + bt + ct^2 + \varepsilon$	$\frac{b + 2ct}{Y} \times 100$	t represents time taking integer values starting from 1;
Cubic	$Y = a + bt + ct^2 + dt^3 + \varepsilon$	$\frac{b + 2ct + 3dt^2}{Y} \times 100$	ε is the regression residual.
Logarithmic	$Y = a + b \log_e t + \varepsilon$	$\frac{b}{Yt} \times 100$	a, b, c, and d are the coefficients of the models.
Inverse	$Y = a + b / t + \varepsilon$	$\frac{-b}{Yt^2} \times 100$	
Exponential	$Y = ae^{bt\varepsilon}$	$b \times 100$	
Compound	$Y = ab^t e^{\varepsilon}$	$(b - 1) \times 100$	
S-shape	$Y = e^{a + b/t + \varepsilon}$	$\frac{-b}{t^2} \times 100$	
Power	$Y = at^b e^{\varepsilon}$	$\frac{b}{t} \times 100$	

One can easily see by looking into the above table that the nature of the different growth rates for different models are different. The growth rates for the linear, exponential and compound models are independent of time. The growth rate in the linear model is constant in its absolute value through out the time interval and the growth rates in the exponential and compound models are constant throughout the time interval in its percentage value. But the growth rates for other models are dependent on time. The only difference between the exponential and the compound model is in the value and interpretation of the b coefficients of the two models. The values of the intercept and all the diagnostic tools are the same. One can get the value of the b coefficient in the compound model simply by taking anti-log of the b coefficient in the exponential model. The cost of making particular forecasting should always be balanced against the cost of producing forecast. In this case extraneous information may not be required. Forecasts obtained in this manner can often be usefully combined with other forecasts in order to get superior overall forecasts. Having produced this sort of forecast, one is in a position to assess the variation explained in terms of its own passed or future behavior.

Model Selection Criteria

To identify the best model for a particular time series seven contemporary model selection criteria R^2, $\bar{R}^2$, RMSE, AIC, BIC, MAE and MAPE are used. The definition and related material are briefly given below.

Coefficient of determination (R^2): The coefficient of determination, proposed by Theil (1961), is the ratio of the regression sum of squares to the total sum of squares i.e. $R^2 = \frac{Regression\ sum\ squares}{Total\ sum\ squares} = \frac{RSS}{TSS}$. In interpreting R^2, it is generally considered that the more the value of R^2, the better is the fit. But there are some limitations in interpreting it in this way. One of the major objections is that R^2 can overstate the value of a regression fit since the error sum of squares ESS can be reduced simply by adding further explanatory variables, even if they are not relevant to explaining the dependent variable.

Adjusted coefficient of determination $(\bar{R}^2)$: An alternative to R^2, denoted by $\bar{R}^2$, which is adjusted for the degree of freedom associated with regression and total sums of squares, is defined as $\bar{R}^2 = 1-(1-R^2)\frac{n-1}{n-k}$, where n is the number of observations and k is the number of parameters to be estimated. It is to note that in some cases of particularly bad fit $\bar{R}^2$ can be negative and it does not exist when the number of observations is less than or equal to the number of parameters to be estimated. Granger and Newbold (1986), Johnston (1984) and some other econometricians recommended this alternative. The greater the value of this criterion, the more is the accuracy of the model.

Root mean square error (RMSE): The root mean square error is defined as $RMSE = \sqrt{\frac{1}{n-k}\sum_{t=1}^{n}\varepsilon_t^2}$, where, n is the sample size and k is the total number of estimable parameters. The model with minimum RMSE is assumed to describe the data series more adequately.

Akaike information criterion (AIC): Akaike's information criterion (AIC), proposed by Akaike (1973), one of the leading statisticians, provides guide lines for choosing the best possible model from a set of competing models. It is defined as AIC= $n\log(MSE)+2k$, where, n is the sample size, MSE is the mean square error and k is the total number of estimable parameters. Akaike mentioned that the model with minimum AIC is closer to the best possible choice.

Bayesian information criterion (BIC): Schwarz (1978) developed this criterion and it is known as Bayesian Information Criterion (BIC). This is defined as BIC= $n\log(MSE)+k\log n$, where, n is the sample size, MSE is the mean square error and k is the total number of estimable parameters. Schwart shows that BIC is better than AIC. The model with minimum BIC is assumed to describe the data series more adequately.

Mean absolute error (MAE): The mean absolute error is defined as $MAE=\frac{1}{n}\sum_{t=1}^{n}|\varepsilon_t|$. The model with minimum MAE is assumed to describe the data series more adequately.

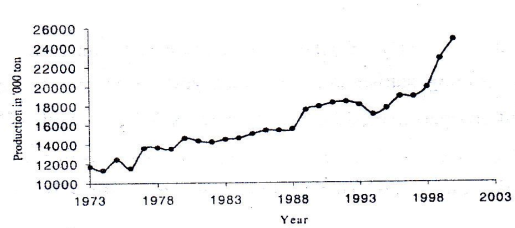
Mean absolute percent prediction error (MAPE): The mean absolute percent prediction error is defined as $MAPE=\frac{1}{n}\sum_{t=1}^{n}\frac{|\varepsilon_t|}{y_t}\times 100$. The model with minimum MAPE is assumed to describe the data series more adequately.

III. RESULTS AND DISCUSSION

Looking at the Original Series

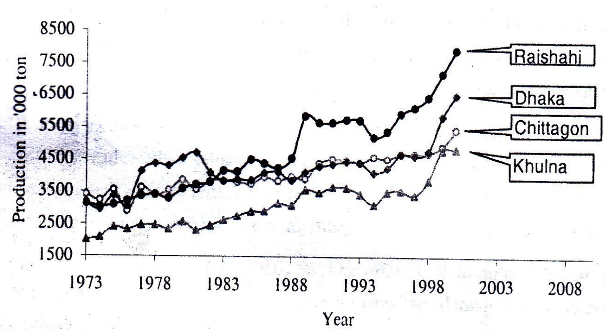
The rice production in Bangladesh had a long-term upward trend during the period 1973/74 to 2000/01. The series grew more rapidly from 1995/96 to the end of the time period after a sharp fall in 1994. In 1973/74 rice production in Bangladesh was about 12 million tons, after 28 years in 2000/01 it was about 25 million tons, which is more than two times. But this growth is not sufficient to meet the increasing food requirement of the country. Taking close look at Fig. 1 reveals that there were at least three production jumps in the series. The first was in 1977 in which rice production was increased by 2.084 million tons compared to 1976. The second jump was in 1989 in which the increase was 1.975 million tons compared to 1988. The last jump was seen in 1999 in which the production was increased by 2.931 million tons compared to 1998. Fig. 2 reveals that all the four time series for the four regions had long term upward trend. The trends for Rajshahi and Khulna were steeper than the trends for Dhaka and Chittagong.

Fig.1. Rice production in Bangladesh (1973/74-2000/01)



The production in Chittagong was highest during 1973/74 to 1975/76 and in Dhaka during 1977/78 to 1982/83. The production of Rajshahi was lower than both Chittagong and Dhaka before 1983, but it became highest from 1983/84 and maintained its first position till the end of the study period. The production of Khulna was always lower than the other three regions. During 1983/84 to 1998/99 the productions of Dhaka and Chittagong were more or less similar, but from 1999/2000 the production in Dhaka increased more rapidly. From 1994 onwards the growth of all the series except Chittagong were more rapid. In 1973/74 the highest production was obtained from Chittagong followed by Rajshahi, then Dhaka, and then Khulna. In the end of the series (2000/01) the highest production was observed in Rajshahi, followed by Dhaka, then Chittagong, and than Khulna. During 1989/90 to 1993/94 the production of Rajshahi, Chittagong and Khulna were increased considerably compared to past but in 1994 serious production fall was observed in all the regions except Chittagong.

Fig. 2. Rice production in different regions



Selecting the Best Model

Bangladesh: All the models considered for this study, given in Table 1, are estimated for the time series of rice production in Bangladesh during 1973/74 to 2000/01 and shown in Table 2. The parameters those are significant at 1 percent level are marked by double star and single star is used to show the coefficients those are significant at 5 percent level. The analysis shows that all the coefficients of all the models are highly significant (at 1-percent level) except the quadratic model. In this model the linear part i.e. the coefficient b is insignificant and the quadratic part i.e. the coefficient c is significant at 5 percent level. Since all the coefficients are highly significant for the cubic model, it seems that the assumption of constant annual rate of growth in percent that lies behind the use of compound/exponential model is not true for the growth pattern of rice production in Bangladesh.

Table 2. Parameter estimates of the models of rice production in Bangladesh

Model	Parameter Estimates			
	a	b	c	d
Linear	10785.33**	368.23**		
Logarithmic	8387.67**	3191.00**		
Inverse	17446.83**	-9426.72**		
Quadratic	11934.86**	138.33	7.93*	
Cubic	10297.48**	761.83**	-44.89**	1.21**
Power	9657.83**	0.204**		
S	9.76**	-0.626**		
Exponential	11396.84**	0.0227**		
Compound	11396.84**	1.0229**		

The significant quadratic term of the quadratic model is also supports it. At this stage we can say that the growth rate of rice production in Bangladesh during the study period was not constant as an exponential/compound model assumes but before taking the decision we have to examine the model selection criteria discussed in the methodology section. All the model selection criteria that have been used in this study to identify the best fitted model for forecasting purpose and also for explaining the growth pattern are calculated and given in Table 3. In interpreting the criteria we consider that the more the value of R^2 or $\bar{R}^2$, the better is the fitness of the model. On the other hand, the smaller is the value of RMSE, AIC, BIC, MAE, or MAPE, the better is the fitness of the model. It is obvious that a better model yields smaller forecasting error. From the results of model selection criteria, given in Table 3, it appears that the value of R^2 (0.929) and $\bar{R}^2$ (0.920) for the cubic model are the highest in comparison of other models. Moreover except AIC (173.71) the values of BIC (171.50), MAE (697.60), and MAPE (4.18) are the smallest in comparison with other models. The compound/exponential model yields the lowest AIC (172.89).

Table 3. Criteria of model selection for the rice production in Bangladesh

Model	R^2	$\bar{R}^2$	RMSE	AIC	BIC	MAE	MAPE
Linear	0.883	0.878	1123.74	174.84	173.73	815.14	4.79
Logarithmic	0.699	0.687	1802.82	186.33	185.23	1224.27	7.57
Inverse	0.335	0.310	2677.92	195.96	194.85	2096.00	13.15
Quadratic	0.904	0.897	1036.56	174.87	173.21	761.38	4.51
Cubic	0.929	0.920	910.20	173.71	171.50	697.60	4.18*
Power	0.785	0.776	1644.39	184.10	182.99	1078.27	6.42
S	0.408	0.385	2599.62	195.23	194.13	2006.31	12.27
Exponential	0.920	0.917	1037.47	172.89	171.79	754.34	4.40
Compound	0.920	0.917	1037.47	172.89	171.79	754.34	4.40

So, for describing the growth pattern of rice production in Bangladesh and making forecast with minimum forecasting error the cubic model is appeared to be the best. Although RMSE and MAE are noticeably large we can not ignore the exponential/compound model. For estimating the growth rate of rice production the second best model may be considered as compound or exponential model. A caparison between the growth rates obtained from exponential/compound and cubic models will be made in the growth analysis section.

Chittagong: All the models considered for this study, given in Table 1, are estimated for the time series of rice production in Chittagong during 1973/74 to 2000/01 and shown in Table 4. The parameters those are significant at 1- percent level are marked by double star and single star is used to show the coefficients those are significant at 5 percent level. The analysis shows that all the coefficients of all the models are highly significant (at 1-percent level) except the quadratic and the cubic models. The regression coefficients of the quadratic model are significant at 5% level but the coefficients of the cubic model are insignificant. It seems difficult at this stage to select the best model but looking at the diagnostic tools will be helpful. The diagnostic tools that have been used in this study to identify the best fitted model for forecasting purpose and also for explaining the growth pattern are calculated and given in Table 5.

It appears from the table that the values $\overline{R}^2$ and RMSE are in favour of the quadratic model but AIC, BIC, and MAE are in favour of the compound/exponential model. Here, again, we are in a conflicting situation in choosing one from the two models quadratic and compound/exponential. However, we will have to take a decision in spite of these difficulties.

Table 4. Parameter estimates of the models of rice production in Chittagong

Model	Parameter Estimates			
	a	b	c	d
Linear	3090.83**	66.87**		
Logarithmic	2681.76**	568.67**		
Inverse	4282.53**	-1582.52**		
Quadratic	3280.96**	28.85*	1.31*	
Cubic	3220.23**	51.98	-0.648	0.045
Power	2845.36**	0.143**		
S	8.36**	-0.403**		
Exponential	3167.55**	0.016**		
Compound	3167.55**	1.017**		

The differences in AIC, BIC, and MAE are very small between the two conflicting models. The significance of the quadratic term of the quadratic model with maximum $\overline{R}^2$ is a relatively stronger evidence of choosing the quadratic model against the compound/exponential model. Moreover, since RMSE of the quadratic model is lower than the

RMSE of the exponential/compound model, we may place the quadratic model in 1st position of our choice. So, for describing the growth pattern of rice production in Chittagong and making forecast with minimum forecasting error the quadratic model is chosen as the best. The second best model may be considered as exponential/compound model to estimate the growth rate of rice production in Chittagong region. Growth rates are calculated using both quadratic and exponential/compound models and they will be discussed and compared in the growth analysis section.

Table 5. Criteria of model selection for the rice production in Chittagong

Model	R^2	$\bar{R}^2$	RMSE	AIC	BIC	MAE	MAPE
Linear	0.890	0.885	197.42	132.54	131.44	144.03	3.71
Logarithmic	0.678	0.666	337.33	145.57	144.47	258.77	6.60
Inverse	0.289	0.261	501.26	155.20	154.10	418.20	10.50
Quadratic	0.907	0.900	184.39	132.88	131.22	138.06	3.54
Cubic	0.909	0.897	187.13	135.24	133.03	138.12	3.55
Power	0.703	0.691	313.73	143.81	142.70	243.55	6.14
S	0.309	0.282	491.62	154.73	153.63	405.51	10.01
Exponential	0.889	0.882	186.60	131.17	130.07	137.11	3.54
Compound	0.889	0.882	186.60	131.17	130.07	137.11	3.54

Dhaka: The models considered for this study are estimated for the time series of rice production in Dhaka during 1973/74 to 2000/01 and shown in Table 6. The analysis shows that all the coefficients of all the models are highly significant (at 1-percent level) except the quadratic model.

Table 6. Parameter estimates of the models of rice production in Dhaka

Model	Parameter Estimates			
	a	b	c	d
Linear	3309.28**	64.87**		
Logarithmic	2786.78**	603.47**		
Inverse	4542.32**	-2084.41**		
Quadratic	3592.68**	8.19	1.95	
Cubic	2355.04**	479.48**	-37.97**	0.918**
Power	2922.89**	0.149**		
S	8.416**	-0.536**		
Exponential	3363.22**	0.015**		
Compound	3363.22**	1.015**		

The regression coefficients of the quadratic model are insignificant. Since all the coefficients of the cubic model are highly significant, it seems that the assumption of constant annual rate of growth in percent that lies behind the use of compound/exponential model is not true for the growth pattern of rice production in Dhaka.

The diagnostic tools may reveal the picture more clearly. The tools that have been used in this study to identify the best fitted model for forecasting purpose and also for explaining the growth pattern are calculated and given in Table 7. It appears from the table that the value of R^2 (0.83) and R^2 (o.81) are the highest for cubic model in comparison with other models.

Further all the values of model selection criteria AIC (148.31), BIC (146.10), MAE (258.39), MAPE (G.31) and RMSE (320.24) for the cubic model are the smallest in comparison with other models. The important point here to note is that the values of R^2 and R^2 are very low for the exponential/compound model and other tools are sufficiently large compared to the cubic model.

Table 7. Criteria of model selection for the rice production in Dhaka

Model	R^2	R^2	RMSE	AIC	BIC	MAE	MAPE
Linear	0,530	0.512	511.83	155.71	154.61	399.45	9.19
Logarithmic	0.480	0.463	536.68	156.86	155.75	393.81	8.98
Inverse	0.317	0.291	617.05	160.26	159.15	413.36	9.71
Quadratic	0.555	0.5 19	507.87	157.52	155.86	382.76	9.03
Cubic	0.830	0.809	320.24	148.31	146.10	258.39	6.31
Power	0.561	0.543	531.05	156.61	155.50	377.00	8.52
S	0.401	0.377	606.56	159.84	158.74	400.34	9.24
Exponential	0.555	0.538	505.84	155.42	154.32	382.09	8.80
Compound	0.555	0.538	505.84	155.42	154.32	382.09	8.80

So, the exponential/compound model will not be appropriate to describe the growth pattern of time series of rice production in Dhaka. The performances of other models are also very poor. Consequently, the only model that may be used for describing the growth pattern of rice production in Dhaka and making forecast with minimum forecasting error is the cubic model.

Khulna: Table 8 shows the estimated regression coefficients of various models considered in this study for Khulna region. It appears from the table that all the coefficients of all the models except cubic and quadratic models are highly significant. In these two models all the coefficients except the intercepts are insignificant. Table 9 shows the results of model selection criteria of various models. As observed from the table that the value of R^2 (0.867) and R^2(0.883) are the highest in case of exponential/compound growth model as compared with other models. The values of RMSE (280.89), AIC (141.12) and BIC (141.01) are also the lowest for the exponential/compound model compared to the other models.

Table 8. Parameter estimates of the models of rice production in Khulna

Model	Parameter Estimates			
	a	b	c	d
Linear	1889.13**	81.76**		
Logarithmic	1363.66**	705.67**		
Inverse	3367.96**	-2091.29**		
Quadratic	2124.65**	34.66	1.62	
Cubic	1908.94**	116.79	-5.33	0.160
Power	1685.56**	0.237**		
S	8.11**	-0.739**		
Exponential	2042.46**	0.026**		
Compound	2042.46**	1.027**		

The criteria MAE (200.20) and MAPE (6.10) are the smallest for the cubic model. Therefore, the best model that can describe the series adequately is exponential/compound growth model in Khulna region. It indicates that in Khulna region the assumption of constant annual growth in percent holds true.

Table 9. Criteria of model selection for the rice production in Khulna

Model	R^2	$\bar{R}^2$	RMSE	AIC	BIC	MAE	MAPE
Linear	0.843	0.837	296.03	142.40	141.29	218.77	6.73
Logarithmic	0.662	0.649	434.26	151.71	150.61	314.00	10.41
Inverse	0.320	0.293	615.80	161.21	159.10	475.82	15.87
Quadratic	0.860	0.849	284.81	143.45	141.80	208.77	6.39
Cubic	0.868	0.852	281.87	145.20	142.99	200.20	6.10
Power	0.754	0.745	398.12	149.60	148.50	270.49	8.55
S	0.402	0.379	599.20	159.54	158.44	449.42	14.45
Exponential	0.887	0.883	280.89	141.12	140.01	206.26	6.26
Compound	0.887	0.883	280.89	141.12	140.01	206.26	6.26

The second best model could be the cubic model. But all the regression coefficients are statistically insignificant. So to estimate the growth rate, exponential model should be preferred in Khulna region.

Rajshahi : Table 10 shows the regression coefficients of the models considered in this study for Rajshahi region. The analysis shows that all the coefficients of all the models are highly significant except the quadratic model and the cubic models.

Table 10. Parameter estimates of the models of rice production in Rajshahi

Model	Parameter Estimates			
	a	b	c	d
Linear	2496.10**	154.72**		
Logarithmic	1555.47**	1313.20**		
Inverse	5254.03**	-3668.50**		
Quadratic	2936.57**	66.62	3.04*	
Cubic	2813.26**	113.58	-0.940	0.091
Power	2266.34**	0.289**		
S	8.54**	-0.837**		
Exponential	2837.22**	0.033**		
Compound	2837.22**	1.034**		

The part of the quadratic model is insignificant but the quadratic part is significant at 5 percent level. The regression coefficients of the cubic model are insignificant. Table 11 shows the values of model selection criteria for different models. It appears from the table that the value of R^2 (0.94) and $\bar{R}^2$ (0.94) of compound and exponential models are the highest compared to other models. The values of RMSE (368.18), AIC (147.70), BIC (146.59) are also the smallest for this model compared to other models. But MAE (261.22) and MAPE (224.99) are the smallest for the quadratic model. Since the quadratic part of the quadratic model is significant and MAE and MAPE are the smallest for this model and all other criteria favour the exponential/compound model we are in a very conflicting situation in selecting the best model. However, on the basis of majority we may select the exponential/compound model as the best fitting model for Rajshahi region. The quadratic model may be considered as the second best model for this region.

Table 11. Criteria of model selection for the rice production in Rajshahi

Model	R^2	$\bar{R}^2$	RMSE	AIC	BIC	MAE	MAPE
Linear	0.909	0.905	410.91	150.37	149.26	301.34	6.22
Logarithmic	0.690	0.678	757.51	165.25	164.14	593.79	13.28
Inverse	0.296	0.269	1141.38	175.22	174.11	957.55	21.46
Quadratic	0.927	0.921	374.88	150.14	148.48	257.93	4.90
Cubic	0.928	0.919	380.45	152.50	150.29	263.68	5.10
Power	0.771	0.762	660.02	161.90	160.79	510.64	10.74
S	0.356	0.331	1108.00	174.49	173.39	913.34	19.54
Exponential	0.944	0.942	368.18	147.70	146.59	261.22	4.99
Compound	0.944	0.942	368.18	147.70	146.59	261.22	4.99

The above discussion about the fitness of various models to the time series of rice production in different regions and in the country as a whole reveals that not any particular but different models are appropriate for different regions in describing the growth pattern. It also reveals that the selection of the best model for a particular region can sometimes be very confusing. However, the discussion recommends a best model for a particular region as given in Table 12.

Table 12. Best estimated models for rice productions of different regions

Region	The name of the best model	The functional form of the model
Bangladesh	Cubic	$\hat{Y} = 10297.48 + 761.83t - 44.89t^2 + 1.21t^3$
Chittagong	Quadratic	$\hat{Y} = 3280.96 + 28.85t + 1.31t^2$
Dhaka	Cubic	$\hat{Y} = 2355.04 + 479.48t - 37.97ct^2 + 0.918t^3$
Khulna	Exponential	$\hat{Y} = 2042.46e^{0.026t}$
Rajshahi	Exponential	$\hat{Y} = 2837.22e^{0.033t}$

Growth Analysis

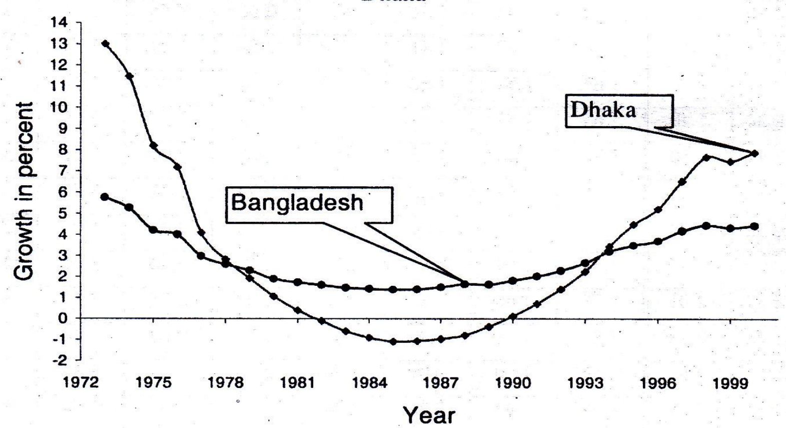
The model selection section identifies a best model for each region but the discussion also reveals that the most important three models for describing the growth pattern of rice production in Bangladesh are exponential, quadratic and cubic. The growth rates calculated using these three models for each region during the study period are given in Table 13. It appears from the table that the exponential growth rate of rice production in Bangladesh during the study period was 2.27 percent. It means that the production grew on the average at this constant rate per year throughout the study period. This is the inherent assumption of the exponential/compound growth model. But the best fitting model for rice production of Bangladesh is the cubic model, which assumes that the growth of the series was not constant throughout the study period; instead it was dependent on time with a quadratic nature of variation. Taking a close look at the annual cubic growth rates of rice production in Bangladesh given in Table 13 and also at Fig. 3 will reveal a different picture of the growth scenario.

Table 13. Quadratic, cubic and exponential annual growth rates in percent

Year	Bangladesh		Chittagong		Dhaka		Khulna		Rajshahi	
	Quad.	Cubic	Quad.	Cubic	Quad.	Cubic	Quad.	Cubic	Quad.	Cubic
1973	1.32	5.76	0.92	1.49	0.39	13.01	1.88	5.28	2.30	3.54
1974	1.50	5.26	1.05	1.54	0.54	11.46	1.96	4.65	2.58	3.64
1975	1.49	4.21	1.03	1.38	0.59	8.20	1.84	3.70	2.73	3.55
1976	1.75	4.00	1.35	1.68	0.78	7.19	2.04	3.51	2.82	3.42
1977	1.60	2.97	1.16	1.35	0.67	4.08	2.05	3.05	2.87	3.29
1978	1.71	2.59	1.31	1.44	0.72	2.81	2.19	2.84	3.01	3.27
1979	1.84	2.30	1.33	1.39	0.82	1.92	2.44	2.80	3.30	3.44
1980	1.81	1.89	1.29	1.30	0.86	1.06	2.35	2.41	3.19	3.21
1981	1.96	1.73	1.46	1.43	0.92	0.40	2.74	2.57	3.25	3.18
1982	2.09	1.60	1.43	1.37	1.15	-0.11	2.72	2.36	3.34	3.20
1983	2.16	1.47	1.50	1.40	1.32	-0.59	2.66	2.18	3.21	3.03
1984	2.25	1.42	1.58	1.47	1.41	-0.90	2.66	2.09	3.38	3.15
1985	2.29	1.38	1.67	1.54	1.52	-1.09	2.64	2.04	3.22	2.99
1986	2.34	1.40	1.65	1.52	1.53	-1.07	2.73	2.11	3.45	3.20
1987	2.44	1.50	1.76	1.63	1.62	-0.97	2.62	2.04	3.71	3.45
1988	2.52	1.64	1.77	1.64	1.82	-0.79	2.78	2.22	3.59	3.36
1989	2.33	1.62	1.87	1.76	1.80	-0.38	2.50	2.07	2.90	2.74
1990	2.37	1.80	1.73	1.64	1.82	0.11	2.65	2.30	3.11	2.97
1991	2.41	2.01	1.73	1.68	1.88	0.70	2.61	2.38	3.22	3.12
1992	2.48	2.28	1.81	1.78	1.93	1.40	2.72	2.61	3.28	3.23
1993	2.61	2.65	1.89	1.90	2.04	2.24	2.98	3.03	3.39	3.39
1994	2.86	3.19	1.88	1.93	2.28	3.44	3.39	3.67	3.84	3.92
1995	2.84	3.49	1.96	2.06	2.30	4.47	3.11	3.58	3.83	3.99
1996	2.75	3.70	1.95	2.10	2.17	5.20	3.15	3.85	3.58	3.80
1997	2.84	4.17	2.01	2.22	2.28	6.51	3.39	4.41	3.57	3.87
1998	2.78	4.44	2.06	2.32	2.29	7.66	3.06	4.22	3.48	3.87
1999	2.49	4.32	2.02	2.34	1.94	7.46	2.54	3.72	3.22	3.65
2000	2.36	4.43	1.88	2.23	1.80	7.88	2.59	4.02	2.99	3.47
	Exponential 2.27		Exponential 1.60		Exponential 1.50		Exponential 2.60		Exponential 3.30	

It appears from the table that there lies a variation (1.38 to 5.76) in growth rates throughout the study period. In 1973/74 the production grew at the rate of 5.76 percent (the year 1972/73 was considered as base) but in the next year it declined to 5.26 percent and maintained declining up to 1.38 percent in the year 1985/86. In the next year (1986/87) the growth increased to 1.40 percent and maintained increasing up to 4.43 percent in the end of the study period. It can be said that in seventies (1973/74 to 1979/80) the growth rate was declining, in eighties (1980/81 to 1989/90) it was its lowest position, and in nineties (1990/91 to 2000/01) it was increasing. The exponential/compound growth rate was only 2.27 percent but during the last four years the actual growth rate was more than 4 percent. The low exponential/compound growth rate (2.27 percent) was due to the incorrect averaging of low growth rates in eighties with the high growth rates of seventies and nineties.

Fig. 3. Annual growth of rice production in Bangladesh and Dhaka



The quadratic model assumes that the growth rate is linearly related to time. Although this model is not appropriate for rice production in Bangladesh during the study period, it indicates that there was positive relationship between growth rate and time as all the coefficients of the model are positive.

For Dhaka region the growth rate of rice production was 1.5 percent for the period 1973/74 to 2000-01 when growth rate of rice production is estimated using an exponential model (Table 13). But the exponential growth model is not appropriate for the time series of rice production in Dhaka region. The best fitting model for this region is the cubic model. It means that the assumption of constant annual rate of growth in exponential/compound model was not true for Dhaka region. The growth rates were estimated using the cubic model and given in Table 13. From the table it appears that rice production growth rate was 13.01 percent for Dhaka region at the beginning of the study period. From then the growth rate was decreasing drastically up to 1985/86. During the period 1981/82 to 1989/90 production growth rate was negative. After the year 1985/86 the growth rate started to increase and kept increasing till the end of the study period. The pattern of growth variation in Dhaka region was similar to the growth variation in overall Bangladesh. It was declining in seventies (1973/74 to 1979/80), in eighties (1980/81 to 1989/90) it was negative, and in nineties (1990/91 to 2000/01) it was increasing. It also appears from the table that there was a wide variation in growth rates (-1.09 percent to 13.01 percent) of rice production for Dhaka region in different points of time. The scenario of the growth pattern should be well understood by looking at Fig. 3. At the end of the study period i.e. in 2000/01 the actual growth was 7.88 percent but the exponential model shows that the growth rate was only 1.5 percent. During the period 1996/97 to 2000/01 rice production increased rapidly and maintained the growth of more than 5 percent. Between the year 1999-2000 to 2000-2001 production growth rate was 7.88 percent in Dhaka region.

In model selection section we have seen that the selection of the model that can best describe the growth scenario of rice production in Chittagong region was very difficult. According to R^2 the best model was the cubic model, according to $\bar{R}^2$ and RMSE the best model was the quadratic model, according to AIC, BIC, and MAE the best model was exponential/compound, and according to MAPE the both the models quadratic and exponential/compound was the best. Taking a close look at the growth rates of Chittagong region calculated using these three models and given at Table 13 reveals that all the three models more or less represent the same picture. The calculated growth rates are not very much different. If we consider the exponential growth rate we can say that the rice production in Chittagong region grew at the rate of 1.6 percent throughout the study period. But we have considered the quadratic model as the best model for Chittagong as our analysis suggested. This model assumes that the growth rate increases with time as a constant rate. If we look at the quadratic growth rates of Chittagong region we see that at beginning of the study period the growth was only 0.92 percent and on the average it was increasing up to the end of the study period. During the period 1997/98 to 1999/2000 the actual growth rate were over 2 percent where the exponential/compound model reported of only a growth of 1.6 percent.

The best model for Khulna region was the exponential/compound model and according to the model selection criteria the fitness of the cubic model was also good, although the coefficients of this model were insignificant. The analysis reveals that the annual growth rate in percent of rice production in this region may be considered as constant throughout the study period. The rice production in this region grew at the rate 2.6 percent, on the average, per year throughout the study period. The quadratic model shows the same situation that the growth rate was more or less constant throughout the study period. The cubic model shows some variation from the exponential model. The cubic model indicates that there were different, compared to the exponential/compound model, growth rates of rice production in this region in several years at the beginnin~ and also at the ending of the series. Since, the quadratic and cubic coefficients are not statistically significant, we do not want to give much emphasis on these models.

The best model for Rajshahi region was the exponential/compound model. It appears from Table 13 that rice production grew at the rate of 3.3 percent over the study period in this region. Although the quadratic and cubic models are not appropriate for this region, taking a close look at the growth rates calculated using these models for this region would reveal that the annual growth rate in percent was more or less constant throughout the study period. This is another evidence of appropriateness of the exponential growth model for this region. This also confirms that the exponential/compound model is not appropriate for describing the growth pattern of the rice production in Bangladesh and Dhaka region during the study period.

Forecasting

The best fitted models for different regions are used to make forecasts with 95 percent confidence interval for each region and are given in Table 14. The prediction period extends from 2001/02 to 2004/05. An important limitation of making forecasts is that the forecasting error increases as the period of forecast increases. For this reason short-term forecast are more reliable compared to long term forecast. Close examination of the forecasted values and confidence intervals given in Table 14 would reveal that forecasting errors are sufficiently small and consequently the intervals are not too large. Bangladesh Bureau of Statistics has already estimated that the rice production of Bangladesh for the year 2001/02 was 25086 thousand tons. We can use this figure for the verification of the prediction performance of our estimated model for rice prediction in Bangladesh. In Table 14 we see that our forecasted rice production for the year 2001/02 was 24251 thousand ton with a 95 percent confidence interval of (21761, 26741). The estimated rice production of BI3S is close to our forecasted value and it also lies within the confidence interval. Notice that The sums of the divisional forecasts are not equal to the respective total forecasts, as the models are estimated independently but they are consistent as they lie within the confidence interval of the total forecast.

Table 14. Five-year 95 percent forecasts of rice production in different regions of Bangladesh

Region (Model)	Description	Forecast year				
		2001/02	2002/03	2003/04	2004/05	2005/06
Bangladesh (Cubic)	Lower limit	21761	22712	23684	24680	25706
	Forecast	24251	25535	26947	28495	30187
	Upperlimit	26741	28357	30210	32311	34669
Chittagong (Quadratic)	Lower limit	4776	4863	4950	5035	5120
	Forecast	5220	5327	5436	5547	5661
	Upper limit	5665	5790	5921	6059	6202
Dhaka (Cubic)	Lower limit	5836	6354	6924	7549	8235
	Forecast	6712	7347	8072	8892	9812
	Upper limit	7588	8340	9220	10234	11389
Khulna (Exponential)	Lower limit	3692	3786	3882	3980	4081
	Forecast	4393	4511	4631	4755	4883
	Upper limit	5228	5375	5526	5681	5842
Rajshahi (Exponential)	Lower limit	6336	6540	6751	6968	7192
	Forecast	7346	7591	7844	8106	8376
	Upper limit	8517	8811	9115	9430	9756

Thus, the prediction performance of the model can be considered as reasonable. The analysis found that if the present growth rate continues the rice production of Bangladesh would be 30187 thousand tons in the year 2005/06 with approximately plus/minus 4500 tons. Similar forecast values have also been estimated for a period of five years for all the regions of Bangladesh using appropriate model on the basis of model selection criteria, which are shown in Table 14.

IV. SUMMERY AND CONCLUSION

A time series model accounts for patterns in the past movement of a variable and uses that information to predict its future movements. In a sense a time series model is just a sophisticated model of extrapolation. Time series data have become very popular to be intensively used in empirical research and econometricians have recently begun to pay very careful attention to such data. Among the two types of models that are used to describe time series data, we have considered only the deterministic type of models in this study. These models are very quick, inexpensive, and capable of describing time series data adequately in many situations.

In this study, nine different deterministic time series models are considered. They are all fitted to data of rice production in Bangladesh and its four regions Chittagong, Dhaka, Khulna and Rajshahi during the period 1973/74 to 2000/01. To select the best model for a particular region seven contemporary model selection criteria are used. They are coefficient of determination (R^2), adjusted coefficient of determination ($\bar{R}^2$) , Root Mean Square Error (RMSE), Akaike Criterion (AIC), Bayesian Information Criterion BIC), and Mean Absolute Percent Error (MAPE). The study revealed that different models are appropriate for different regions. For the country as a whole the cubic model is the most appropriate, for Chittagong the quadratic model, for Dhaka the cubic model and for the regions Khulna and Rajshahi exponential/compound model. It means that the annual growth rates in percent were significantly different from time to time in the country as a whole and in the regions Chittagong and Dhaka. The annual growth rates in percent of rice production in Khulna and Rajshahi may were more or less constant over time throughout the study period.

It is observed from the study that using an exponential model the growth rate of rice production in Bangladesh is estimated to be 2.27 percent during the study period. But the cubic model, which is the most appropriate for the country as a whole, reveals that at the beginning of the study period the growth rate was 5.76 percent and after then it starts declining and keeps declining till 1985/86. In this year the growth rate was only 1.38 percent and after then it starts increasing and maintained the increasing nature till the end of the study period in which it was 4.43 percent. Similar patterns of growth were observed in both Chittagong and Dhaka Regions. The noticeable pattern in Dhaka was that during 1982/83 to 1989/90 the growth rate was negative while at the beginning of the study period it was more than 13 percent and at the end of the study period it was near about 8 percent. The rice production in Khulna and Rajshahi regions grew more or less in a constant pattern during the study period with 2.6 and 3.3 percent per year respectively. Five-years forecasts (from 2001/02 to 2004/05) of rice production has also been made for each region using the best fitted model for that region and it is observed that if the present growth rate continues the rice production of Bangladesh would be 30187 thousand tons in the year 2005/06 with approximately plus/minus 4500 tons. It is to note that the short term forecast is better as the error of forecast increases with the increase of the period of forecast.

We firmly believe that this study has shed some important light on the subject area encompassing time series modeling to estimate the growth rate of rice production in Bangladesh. These empirical findings can be an important source of information to many researchers and policy formulators.

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