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Forecasting Shrimp and Frozen Food Export Earning of Bangladesh Using ARIMA Model

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Abstract: The study was to develop models that could be used to make efficient forecast of shrimp and frozen food export earning of Bangladesh. Two types of models, namely, Box-Jenkins type autoregressive integrated moving average (ARIMA) and deterministic type growth models, are examined to identify the best forecasting models for shrimp and frozen food export earning of Bangladesh. The study found that the ARIMA (2,2,0) was the best for both shrimp and frozen food export earning. Among the deterministic type models, the quadratic model is best for both the series. The study also reveals that the ARIMA model is more efficient for short-term forecasting than the quadratic model.

Key words: Export, growth, ARIMA model, forecasting

INTRODUCTION

Agriculture plays a crucial role in generating foreign exchange through increased agriculture export. Primary products and agricultural commodities are the major sources of foreign exchange for developing countries like Bangladesh. The trade experience of developing countries reveals that there has been a steady decline in their share of the world agriculture export. However, the reasons for such a decline cannot be attributed to the trade policies of the developed countries alone, but also to their own policies. The policies of over-valued exchange rates, low producer earnings, export taxation, excess industry protection and incentive for import substitution are mainly responsible for poor agricultural performance and retarded exports in most of the less developed countries (MacBean, 1989). In Bangladesh fisheries, an important sector of the economy, received due recognition only recently because of increasing role in nutrition, income, employment and foreign exchange earnings. The export sector plays an imperative role in determining the rate and structural pattern of development of any country (Matin, 1992). Fisheries as one of the major sub sectors of agriculture, has been playing significant role in increasing nutritional status, employment of the people, foreign earning. It contributes about 4.91% to the country's Gross Domestic Product (GDP) and more than 6.28% to the foreign exchange earnings (BBS, 1997).

The export earnings from shrimp increased to $356.57 million in 2003-04 from taka $3.76 million in the year 1972-73 and its contribution to total export increased to 4.77% from 0.84% in the same period. But still the performance and earnings from exporting shrimp are not expected level which should have been attained. A study (Hossain *et al*., 1999) predicted that if Bangladesh was able to convert 25% of her existing shrimp cultivable land into semi-intensive farming, foreign exchange earnings by exporting shrimps would be $961.33 million annually. Export sector appears to have a bright future both in employment opportunity and foreign exchange earnings in the years to come if necessary policies are taken for and appropriate supports are provided with the producer and exporters. Approximately, 1.4 million people depend on fisheries as their primary sources of income and another 11 million people are engaged in seasonal or part-time fishing and other ancillary activities and out of a total employment of 28 million in Bangladesh, approximately 7% is in fisheries (Nuruzaman, 1995). Shrimp production in Bangladesh is increasing gradually through horizontal expansion of the farming area not by the desired vertical expansion (Bhattacharjee and Bhuiyan, 1995). But shrimp farming need not require a heavy investment though it bears a bright and prospective future in the years to come. There exists a high potential of employment prospect and earning from exporting shrimp that can be increased several times if only the existing problems relating to its production and marketing activities can be identified appropriately and essential policy measures can be taken timely.

Efficient forecasting of the future movement of shrimp and frozen food export can help policy makers in proper planing to develop the sector. For efficient forecasting, adequate mathematical models are necessary. So far we know no models have yet been developed for

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forecasting shrimp and frozen food export earning of Bangladesh. Here, an attempt has been made to develop ARIMA models for forecasting these two time series. ARIMA models are very powerful and popular as they can, in many situations, successfully describe the observed data and can make forecast with minimum forecast error. The specific purpose of this study is to develop appropriate ARIMA models for the time series of shrimp and frozen food export earning in Bangladesh and to make five years forecasts for both the time series with appropriate prediction interval. Another purpose is to compare the forecasting performance of ARIMA and deterministic models for shrimp and frozen food export earnings in Bangladesh.

MATERIALS AND METHODS

To achieve the stipulated objectives, the present study has been carried out on the basis of shrimp and frozen food export earnings data, expressed in thousand dollars, pertaining the period 1972-73 to 2003-04, which were collected from secondary sources (EPB, 2004). This is a government level institute responsible for collecting and storing necessary data required for future export planning and development of the country. Shrimp export data includes only shrimp and frozen food export data includes fish (not shrimp) and frog legs.

The time series of shrimp and frozen food export earnings were modeled by Box-Jenkins type stochastic autoregressive integrated moving average (ARIMA) process. The Box-Jenkins type ARIMA process (Box and Jenkins, 1978) can be defined as $\phi(B)(\Delta^d y_t - \mu) = \theta(B)\varepsilon_t$. Here, y_t denotes shrimp and frozen food export earnings in '000 dollars, μ is the mean of $\Delta^d Y_t$, $\phi(B)$ is $1-\phi_1 B - \cdots - \phi_p B^p$, θB is $1-\theta_1 B-...-\theta_q B^q$, θ_i is the ith moving average parameter, ϕ_i is the ith autoregressive parameter, p, q and d are the autoregressive, moving average and difference orders of the process respectively, Δ and B are the difference and back-shift operators, respectively.

The estimation methodology of the above model consists of three steps, namely, identification, estimation of parameters and diagnostic checking. For identification purpose the values of p, d and q are determined by using autocorrelation function (ACF), partial autocorrelation function (PACF) and augmented Dickey-Fuller (ADF) test. The model used for ADF is $y_t - y_{t-1} = \alpha+\beta t+(\rho-1) y_{t-1}+\lambda\Delta y_{t-1}$ (Pindyck and Rubinfeld, 1991). The method of maximum likelihood is used for estimation purpose. The third step is to check whether the chosen model fits the data reasonably well. For this reason the residuals are examined to find out if they are white noise. To test if residuals are white noise the ACF of residuals and the Ljung and Box (1978) chi-square statistic are used. In case of two or more competing models passing the diagnostic checks the best model is selected using the criteria of multiple R^2, root mean squared error (RMSE), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Mean Absolute Error (MAE) and Mean Absolute Percent Error (MAPE).

Five deterministic types of growth models are also considered in this study for comparing the forecasting efficiency of stochastic models. These models are $Y = a+bt+\varepsilon$, $Y = a+bt+ct^2+\varepsilon$, $Y = a+bt+ct^2+dt^3+\varepsilon$, $Y = ae^{bt\varepsilon}$ and $Y = ab^te^{\varepsilon}$, where, Y is the time series considered, t represents time taking integer values starting from 1, ε is the regression residual and a, b, c and d are the coefficient of the models.

RESULTS AND DISCUSSION

Stationarity checking using ACF: The ACF and PACF of both the time series of shrimp and frozen food export earnings (not shown here to save space) show that both the time series are non-stationary. So, the 1st-differences of both the time series are taken and autocorrelation functions of them are constructed to see if their 1st-difference forms are stationary or not.

The autocorrelation functions of 1st-difference time series of shrimp and frozen food export earning are presented in Fig. 1 and 2 respectively. Both the series, now, seem to be stationary, as the autocorrelation

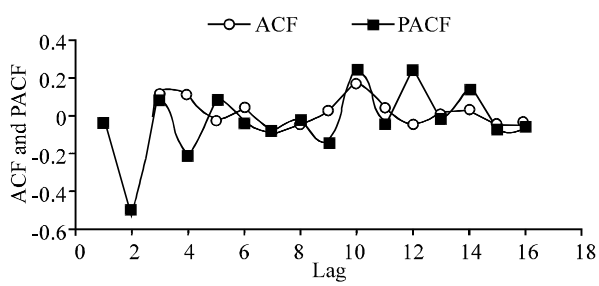

Fig. 1: 1st-difference shrimp

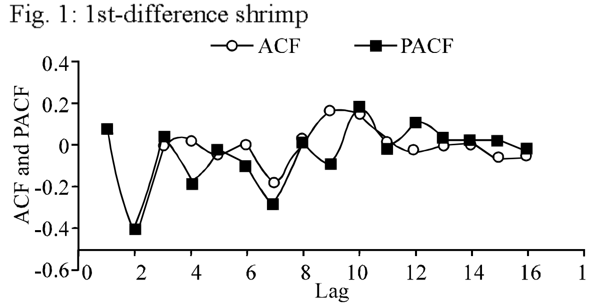

Fig. 2: 1st-difference frozen food

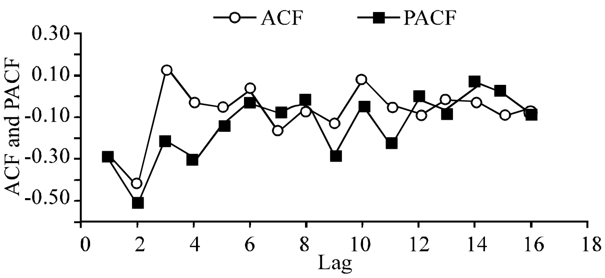

Fig. 3: 2nd-difference shrimp

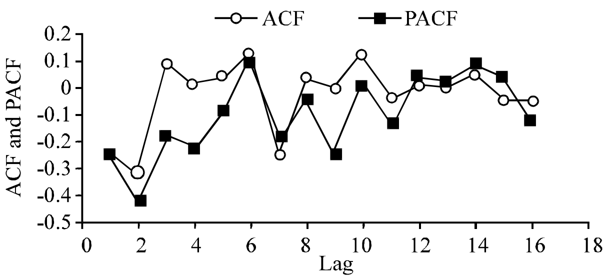

Fig. 4: 2nd-difference frozen food

functions decline more rapidly. The autocorrelation functions of 2nd difference (Fig. 3 and 4) series are similar to the 1st difference series.

In both 1st and 2nd-difference series significant autocorrelation and partial autocorrelations are found at lag 2 and there are no significant spikes after lag 2. So, at this stage, it can be said that both the time series are stationary of order one or two.

Stationarity checking using ADF: Apart from the graphical methods of using ACF for determining stationarity of a time series, a very popular formal method of determining stationarity is the augmented Dickey-Fuller test. Here, this test is done for both the time series. The estimates of necessary parameters and related statistics for the time series of shrimp and frozen food export earning are presented in Table 1.

The analysis exposed that the hypothesis of random walk that underlying process of generating the

Table 1: ADF tests of stationarity of shrimp and frozen food export earning in Bangladesh

Area	Model	α	β	(ρ-1)	λ	F
Frozen food	Unrestricted	-39215.59	7590.43	-0.55	0.30	3.40
	S. Error	17457.73	2227.88	0.16	0.18	
	Restricted	12238.05			0.05	
	S. Error	6358.77			0.19	
Shrimp	Unrestricted	-41369.08	7584.80	-0.59	0.21	6.68
	S. Error	17613.88	2229.93	0.18	0.19	
	Restricted	12396.38			-0.04	
	S. Error	6117.68			0.19	

At 5% level of significance with 32 degree of freedom the critical value of F is 7.09

Table 2: ADF tests of stationarity of 1st difference shrimp and frozen food export earning

Area	Model	α	β	(ρ-1)	λ	F
Frozen food	Unrestricted	9412.30	443.40	-1.43	0.47	17.09
	S. Error	13790.86	684.44	0.27	0.19	
	Restricted	2810.79			-0.25	
	S. Error	8057.78			0.18	
Shrimp	Unrestricted	9240.20	552.23	-1.76	0.62	27.81
	S. Error	12026.50	599.36	0.26	0.17	
	Restricted	2726.59			-0.27	
	S. Error	8141.74			0.18	

At 5% level of significance with 32 degree of freedom the critical value of F is 7.11

time series is nonstationary cannot be rejected, as the related F-statistics is insignificant at 5% level. So, both the undifferenced time series are nonstationary and they must be 1st-difference to see if 1st-difference series are nonstationary. To perform the ADF test for the 1st-difference time series of shrimp and frozen food export earning the essential analysis are presented in Table 2. A further, the analysis shows that all the 1st-difference time series are stationary as the F-statistics are significance at 5% level.

ADF tests for both the 2nd difference series are also carried out and they also revealed that both the series are stationary of order two. So, it can be said that both the series are of course stationary of order one or two.

Shrimp export: The ACF and PACF given in Fig. 1 and 3 suggest that the autoregressive and moving average orders of shrimp export cannot be greater than 2, as there are no significant spikes in both the graphs after lag 2. We have examined models with stationarity order both one and two. So, the tentative specifications were ARIMA(2,1,2), ARIMA(2,1,1), ARIMA(2,1,0), ARIMA(1,1,2), ARIMA(0,1,2), ARIMA(2,2,2), ARIMA(2,2,1), ARIMA(2,2,0), ARIMA(1,2,2) and ARIMA(0,2,2). All these models are estimated and their fitness is checked using ACFs of residuals and Ljung-Box chi-squares test. In addition, model selection criteria R^2, RMSE, AIC, BIC, MAE and MAPE are used to select the best model. It appeared from the analysis that the specification ARIMA (2,2,0) was the best for shrimp export, as its chi-square value is the lowest and insignificant (Table 3) and the MAPE is also much lower compared to the other estimated models. The estimated model with standard errors of the estimates of the parameters is given below. The significant estimates are marked by star and double star when they are significant at 5 and 1% level, respectively.

$$\left(1+1.52^{**}B+0.81^{**}B^2\right)\left(\Delta^2 Y_t-58.13\right)=\varepsilon_t$$

SE (0.13) (0.17)

Table 3: Estimated values of model selection criteria

Area	Model	R^2	RMSE	AIC	BIC	MAE	MAPE	χ^2	p-value
Shrimp	ARIMA(2,2,0)	0.93	29198.17	622.91	627.11	18956.37	15.99	8.68	0.92
	Quadratic	0.92	26065.96	656.77	661.17	17716.85	29.06		
Frozen	ARIMA(2,2,0)	0.92	34175.03	632.35	636.55	21595.98	16.90	6.68	0.97
food	Quadratic	0.93	30870.23	667.60	672.00	21339.44	37.24		

Among the deterministic type of models, the cubic model can be considered as the best for shrimp export earning in Bangladesh. It is to be noted that the linear part of the model is significant at 10% level only, although cubic part of the model is highly significant (at 1% level). The estimated model with standard errors of the estimates of the parameters is given below.

$$Y = -12342.47 + 4171.62t + 230.98^{**}t^2$$
$$\text{SE} \quad (2162.41) \quad (63.57)$$

Frozen food: The ACF and PACF of 1st and 2nd-difference frozen food export, presented in Fig. 2 and 4, respectively, show that the autoregressive and moving average orders cannot be more than 2, as there are no significant spikes in both the functions after lag 2. So, the tentative specifications of the model were similar to the specifications of shrimp export. After estimation of the models and diagnostic checking, it appears that the model ARIMA(2,2,0) is also the best for frozen food and its fitness appears to be slightly better than the fitness of the model for the shrimp export. The estimated model with standard errors of the estimates of the parameters is given below:

$$\left(1 + 0.54^{**}B + 0.77^{**}B^2\right)\left(\Delta^2 Y_t - 43957\right) = \varepsilon_t$$
$$\text{SE } (0.14) \quad (0.18)$$

The quadratic model is appeared to be the best deterministic model for frozen food export, as it was the best for shrimp export also. It implies that growth rates of both shrimp and frozen food export earning were not constant during the study period. The estimated model with standard errors of the estimates of the parameters is given below:

$$Y = -18773.67 + 6088.74^{*}t + 204.99^{**}t^2$$
$$\text{SE} \quad (2560.97) \quad (75.29)$$

Diagnostic checking: In Table 3 the Ljung-Box chi-square statistics are presented for all best selected stochastic models with p-values. All the chi-square values are insignificant. It implies that the residuals of the respective time series are white noise implying that the model fitness is acceptable. The estimated values of other model selection criteria for both best selected stochastic and deterministic models are also showing in Table 3. The analysis reveals that ARIMA models are more efficient for short term forecasting compared to deterministic models. Since, the ARIMA(2,2,0) model has the lowest mean absolute prediction error for both shrimp and frozen food export compared to other estimated models and the error of the model is simply a white noise and most of the other diagnostic criteria are also favorable to this model, we can use it for forecasting future exports of shrimp and frozen food.

Table 4: Shrimp export earning forecast

	ARIMA(2,2,0)			Quadratic		
Year	Forecast	LPL	UPL	Forecast	LPL	UPL
2004-05	329352	278745	379959	376862	312533	441191
2005-06	329401	253724	405078	396509	330088	462931
2006-07	372176	294600	449752	416619	347741	485496
2007-08	368753	285400	452105	437190	365480	508901
2008-09	373169	275716	470623	458224	383294	533153

Table 5: Frozen food export earning forecast

	ARIMA(2,2,0)			Quadratic		
Year	Forecast	LPL	UPL	Forecast	LPL	UPL
2004-05	379903	316915	442891	405395	329210	481581
2005-06	375393	284318	466467	425219	346555	503882
2006-07	394897	298819	490975	445452	363880	527024
2007-08	408358	308470	508247	466095	381168	551023
2008-09	416845	312019	521671	487149	398409	575888

Forecasts: Five-year forecasts of shrimp and frozen food export earning are estimated using the best selected models and are presented in Table 4 and 5, respectively. Prediction intervals of forecast are also presented.

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