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Forecasting of Lentil Pulse Production: An Econometric Analysis

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Abstract: The paper describes an empirical study of modeling and forecasting time series data of lentil pulse production in Bangladesh. The Box Jenkins ARIMA methodology has been used for forecasting. The diagnostic checking has shown that ARIMA (0, 1, 9) is appropriate. The forecasts from 2011-12 to 2015-16 are calculated based on the selected model. These forecasts would be helpful for the policy makers to foresee ahead of time the future requirements of grain storage import and/or export and adopt appropriate measures in this regard.

Key words: ARIMA, Lentil, Production, Bangladesh.

INTRODUCTION

Bangladesh is an agro-based developing country. Most of the people (75 per cent) live in rural areas and 62 per cent of the total labor force of the country is employed in agricultural sectors. Agriculture contributes 15.23 percent to the gross domestic product (GDP) in 2009-10 where crops contribute 11.43 percent to the GDP (BBS, 2010). Pulses contribute 2.3 per cent value added to agriculture. Total cultivated area in Bangladesh is 8031161 hectares of which pulses constitute 420763 hectares i.e., 5.24 per cent of total cultivated land (BBS, 2004). About a dozen pulse crops are grown in the winter and summer seasons. Among these, Grass pea, lentil, chickpea, black gram, mung bean, field pea, cowpea, and fava bean are grown during the winter season (November– March). Collectively, they occupy 82 percent of the total pulse-cultivation area and contribute 84 percent of the total pulse production. Black gram and mung bean can also be grown in late winter (June–March) in southern areas such as the Bhola, Barisal, and Chittagong districts. These are under minor crops in Bangladesh but it has a great importance in the dietary menu, it is the great source of plant protein for the people who are not able to get regularly animal protein (from meat and fish) because of more expensive food item. In Bangladesh, where 42 per cent people are living under the poverty line (BBS, 2005), and pulses are popular and common food, people take this food almost alternate a day, so, this can play an important role to reduce the malnutrition for the poor people of the country if it becomes available to that type of people.

Lentil is very important pulse to consumer in Bangladesh. It is the best in terms of consumer preferences. Lentil had a 37 percent share of total pulse production with 33.33 percent of area of cultivation in Bangladesh (Year book of Agric. Stat. 2008). It is in the second position in terms of production and area of cultivation. Lentils are grown on high and medium-high lands with moderately well drained, high-textured soils. More than 85 percent of lentil area is concentrated within the nine greater districts: Jessore, Faridpur, Kustia, Rajshahi, Pabna, Comilla, Noakhali, Manikganj, and Khulna.

Auto Regressive Integrated Moving Average (ARIMA) is the most general class of models for forecasting a time series. Different series appearing in the forecasting equations are called “Auto-Regressive” process. Appearance of lags of the forecast errors in the model is called “moving average”. (ARIMA) model was introduced by Box and Jenkins in 1976 for forecasting variables. These approaches have been employed extensively for forecasting economics time series, inventory and sales modeling (Brown, 1959). Ljung and Box (1978) and Pindyck and Rubinfeld (1981) have also discussed the use of univariate time series in forecasting. Rachana *et al*. (2010), used ARIMA models to forecast pigeon pea production in India. Badmus and Ariyo (2011), forecasted area of cultivation and production of maize in Nigeria using ARIMA model. They estimated ARIMA (1, 1, 1) and ARIMA (2, 1, 2) for cultivation area and production respectively. Falak and Eatzaz (2008), analyzed future prospects of wheat production in Pakistan. They obtained the parameters of their forecasting model using Cobb-Douglas production function for wheat, while future values of various inputs are obtained as dynamic forecasts on the basis of separate ARIMA estimates for each input and for each Province. The ARIMA methodology have been used extensively by a number of researchers to forecast demands in terms

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of internal consumption, imports and exports to adopt appropriate solutions (Muhammed *et al*., 1992; Shabur and Haque, 1993; Sohail *et al*., 1994).

In this study, these models were applied to forecast the production of lentil pulse production in Bangladesh. This would enable to predict expected lentil pulse production for the years from 2011 onward. Such an exercise would enable the policy makers to foresee ahead of time the future requirements for grain storage, import and/or export of lentil pulse thereby enabling them to take appropriate measures in this regard. The forecasts would thus help save much of the precious resources of our country which otherwise would have been wasted.

MATERIALS AND METHODS

Data:

This study was carried out on the basis of lentil pulse production, data from the period 1968 to 2011 collected from secondary source (BBS).

ARIMA Model:

The data were model using Autoregressive Integrated Moving Average (ARIMA) stochastic model popularized by Box and Jenkins (1976). An ARIMA (p,d,q) model is a combination of Autoregressive (AR) which shows that there is a relationship between present and past values, a random value and a Moving Average (MA) model which shows that the present value has something to do with the past residuals. The ARIMA process can be defined as:

$$\phi(B)(\Delta^d y_t - \mu) = \theta(B)\varepsilon_t$$

Where, y_t = Represents Grass pea and black gram pulse production in metric tons

μ = Mean of $\Delta^d Y_t$,

$\phi(B) = 1 - \phi_1 B - \ldots\ldots.. - \phi_p B^p$

$\theta(B) = 1 - \theta_1 B - \ldots\ldots.. - \theta_q B^q$

ϕ_i = The ith autoregressive parameter,

θ_i = The ith moving average parameter,

p, q and d denote the autoregressive, moving average and differenced order parameter of the process, respectively. Δ and B denote the difference and lag operators, respectively.

The estimation of the model consists of three steps, namely: identification, estimation of parameters and diagnostic checking.

Identification step:

Identification step involves the use of the techniques to determine the values of p,q and d. The values are determined by using Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). For any ARIMA (p, d, q) process, the theoretical PACF has non-zero partial autocorrelations at lags 1, 2, ..., p and has zero partial autocorrelations at all lags, while the theoretical ACF has non zero autocorrelation at lags 1, 2, …, q and zero autocorrelations at all lags. The nonzero lags of the sample PACF and ACF are tentatively accepted as the p and q parameters. For a non stationary series the data is differenced to make the series stationary. The number of times the series is differenced determines the order of d. Thus, for a stationary data d = 0 and ARIMA (p, d, q) can be written as ARMA (p, q).

Estimation of Parameters:

The second step is the estimation of the model parameters for the tentative models that have been selected.

Diagnostic Checking:

The estimated model must be checked to verify if it adequately represents the series. The best model was selected based on the minimum values of Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), Normalized Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC) and highest value of R-square. Diagnostic checks are performed on the residuals to see if they are randomly and normally distributed. Here, the Kolmogorov-Smirnov test for normality was used. An overall check of the model adequacy was made using the modified Box-Pierce Q statistics. The test statistics is given by:

$$Q_m = n(n+2)\sum_{k=1}^{n}(n-k)^{-1} r_k^2 \approx \chi^2_{m-r}$$

where,

r_k^2 = The residuals autocorrelation at lag k

n = The number of residuals
m = The number of time lags included in the test

when the p-value associated with the Q is large the model is considered adequate, else the whole estimation process has to start again in order to get the most adequate model. Here all the tests were performed at the 5% level of significance.

RESULTS AND DISCUSSION

The maximum production of lentil pulse was 99117 metric tons which occurred in the year 2011 and the minimum was 47345 metric tons which occurred in the year 1968. In addition, the average production was 73231 metric tons.

The time series plot of ACF and PACF of lentil pulse production, Fig. 1 showed that the series was not stationary. The data was differenced to make it stationary. The first difference was enough to make the data stationary. The rapid decay in the autocorrelation function and the partial autocorrelation function of the differenced series for production Fig. 2 indicates that the series was stationary.

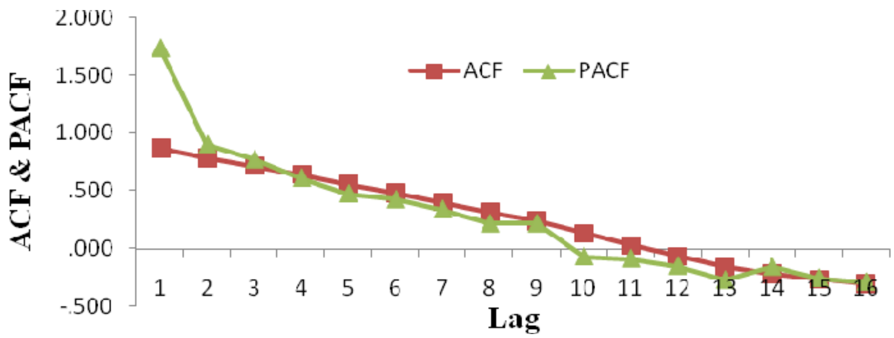

Fig. 1: Undiffernced lentil pulse production in Bangladesh

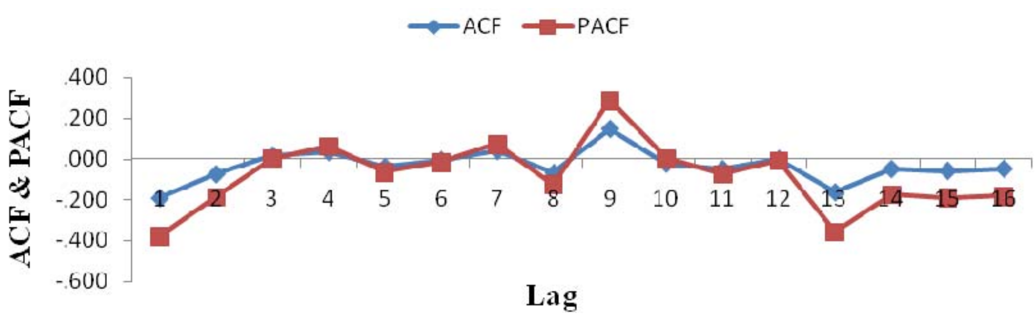

Fig. 2: 1st differnced lentil pulse production in Bangladesh

To identify the orders of the ARIMA (p,d,q) model for production, the autocorrelation functions and partial autocorrelation functions were examined. The Augmented Dickey-Fuller test for the first differenced series shows that the production series were integrated of order one (Table 1). The autocorrelation function and the partial correlation function were examined and different models for lentil pulse production were fitted using different significant values of p and q. ARIMA (0, 1, 9) was selected as the best model for lentil pulse production based on the minimum values of RMSE, MSE, MAE, MAPE, BIC, AIC and highest R-square & Adjusted R-square value as shown in Table 2. From Table 3, the estimates of the parameters of the ARIMA (0, 1, 9) model were highly significant.

Table 1: ADF test of stationarity of pulses production (1st different)

Area	Model	α	β	ρ-1	λ	RSS	DF	DW	F	$F_{05,40}$
Lentil pulse production	Unrestricted SE	1297.69 7767.39	65.52 308.26	-0.909 0.257	-0.041 0.186	14546227765	36	1.86	7.01	6.93
	Restricted SE	1172.20 3829.05			-0.495 0.153	20057024339	34	2.15		

Table 2: Suggested models for lentil pulse production

Model	Values of selection criteria							
	MAE	MSE	RMSE	AIC	BIC	MAPPE	R^2	$\overline{R^2}$
ARIMA(0,1,0)	9365.81	411093129.52	20275.43	831.37	850.22	10.33	0.844	0.810
ARIMA(0,1,1)	9204.72	410425424.43	20258.96	819.14	824.28	10.21	0.844	0.836
ARIMA(0,1,2)	9238.94	409798093.12	20243.47	821.08	827.93	10.20	0.844	0.832
ARIMA(0,1,3)	9219.60	409474784.98	20235.48	823.05	831.61	10.22	0.845	0.827
ARIMA(0,1,4)	9272.34	408756121.42	20217.72	824.97	835.26	10.25	0.845	0.823
ARIMA(0,1,5)	10298.06	407406630.27	20184.32	826.84	838.83	10.29	0.845	0.818
ARIMA(0,1,6)	9214.53	407280369.27	20181.19	828.83	842.53	10.37	0.845	0.813
ARIMA(0,1,7)	11154.79	390905395.70	19771.33	829.14	844.57	13.02	0.852	0.814
ARIMA(0,1,8)	10218.70	374588666.42	19354.29	829.39	846.53	12.04	0.855	0.816
ARIMA(0,1,9)	9164.17	374381738.67	19348.95	817.21	820.63	10.13	0.858	0.840
ARIMA(1,1,0)	9196.94	410371272.43	20257.62	819.14	824.28	11.20	0.844	0.836
ARIMA(1,1,1)	9216.57	410243443.73	20254.47	821.12	827.98	10.22	0.844	0.832
ARIMA(1,1,2)	9248.46	409638424.98	20239.53	823.06	831.63	10.23	0.844	0.827
ARIMA(1,1,3)	9428.96	392531572.98	19812.41	823.31	833.59	10.82	0.851	0.830
ARIMA(1,1,4)	9462.90	392781825.54	19818.72	825.34	837.33	10.78	0.851	0.825
ARIMA(1,1,5)	9357.97	393602143.70	19839.41	827.42	841.13	10.69	0.851	0.819
ARIMA(1,1,6)	10279.56	384004858.81	19596.04	828.41	843.83	11.99	0.854	0.818
ARIMA(1,1,7)	9249.86	393248745.35	19830.50	831.39	848.52	10.61	0.851	0.807
ARIMA(1,1,8)	10329.11	374706261.24	19357.33	831.41	850.26	12.14	0.856	0.810
ARIMA(1,1,9)	9379.45	394094523.74	19851.81	835.48	856.04	10.54	0.850	0.794

The residuals for these model were diagnosed to see if they were normally distributed using the Kolmogorov-Smirnov normality test. The Kolmogorov-Smirnov statistics for the residuals of ARIMA (0, 1, 9) was 1.570 with an observed significance level of 0.05 indicating that the residuals for the model was normally distributed at the 5% (0.05) significance level. In addition, the modified Box-Pierce statistic was used to check the overall model adequacy for lentil pulse production. For production, the modified Box-Pierce statistic is 5.136 at 9 degrees of freedom which has observed significance level 0.822 indicating that it is insignificant at 5% significance level, hence the fit is good. Hence, the diagnostic test indicates that ARIMA (0, 1, 9) model was appropriate for production.

Table 3: ARIMA (0, 1, 9) model parameter estimates

Type	Coefficient	Standard error	t	p value
MA1	0.193	0.182	1.063	0.296
MA2	0.093	0.185	0.503	0.618
MA3	-0.051	0.214	-0.239	0.812
MA4	-0.113	0.231	-0.490	0.627
MA5	0.099	0.232	0.426	0.673
MA6	0.080	0.228	0.350	0.729
MA7	-0.177	0.231	-0.769	0.448
MA8	0.165	0.227	0.725	0.474
MA9	-0.140	0.219	-0.639	0.528

Table 4: Forecast for lentil production of pulse in metric tons

Year	ARIMA(0,1,9)		
	Forecast	LPL	UPL
2011-12	89625	34351	144899
2012-13	72274	1213	143334
2013-14	73803	0	155116
2014-15	85918	0	177633
2015-16	58601	0	162548

The functional form of the model

$$(\Delta Y_t - 5459.629) = (1 - 0.193B - 0.093B^2 \;\; + 0.051B^3 + 0.113B^4 - 0.099B^5 - 0.080B^6$$
$$+ 0.177B^7 - 0.165B^8 + 0.140B^9) \;\; \varepsilon_t$$

Finally, five years ahead forecast was made for lentil pulse production using ARIMA (0, 1, 9). Table 4, shows the forecast for lentil pulse production at the 95% confidence limit. From Table 4, the forecast for the year 2011-2012 for lentil pulse production was 89625 metric tons with a 95% confidence limit of (34351, 144899) metric tons. For the year 2015-2016, the forecast for lentil pulse production was 58601 metric tons with 95% confidence limit of (0, 162548) thousand metric tons.

Rachana Wankhade et. al. (2010), forecasts of pigeon pea pulse production in India using ARIMA model in the year 2008/09 to 2014/15. In his study ARIMA (1, 1, 1) model was best suited for estimation of Pigeon pea pulse production data. From the forecast values obtained the developed model, it can be said that forecasted production will increases to some extent in future i.e. 2008-09 is 2.49479 million tones up to the year 2014-2015 it will be accepted 2.73452million tones. With lower and upper limits of 2.05787 million tones and 3.41116million tones respectively.

From our study, we obtained the best model for forecasting ARIMA (0,1,9). After using this model, it can be said that forecasted production will decrease to some extent in future and from Rachana Wankhade et. al. (2010) study, the best model for forecasting ARIMA (1,1,1) and it can be said that forecasted production will increase to some extent in future.

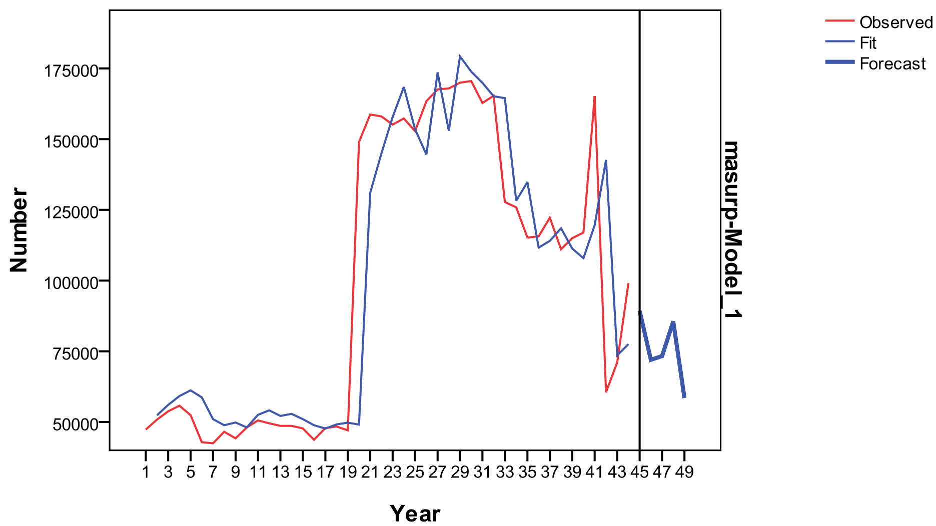

Fig. 3: Observed, fitted and forecasted lentil pulse production

Conclusion:

We employed the Box-Jenkins approach to model and forecast lentil pulse production in Bangladesh. Our forecast showed a decreasing pattern in lentil pulse production. Despite the decrease in production, government has to invest money into lentil pulse production, motivate lentil pulse farmers, and implement good policies for better land tenure systems for lentil pulse cultivation to ensure that production always exceeds consumption to avoid importation of lentil pulse into the country. This is imperative because importation could lead to high prices of lentil pulse and increase inflation rate, hence affecting the economy of the country.

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