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Modeling and Forecasting of Milk Production in the SAARC countries and China

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Abstract
This study uses yearly data from 1961 to 2018 to forecast milk production in South Asian countries (including China) using ARIMA/GARCH models and Holt's Linear approach. It is revealed that not all the methods are equally effective in forecasting. Comparison of mean absolute percentage errors between ARIMA and Holt's Linear model shows that Holt's approach reveals higher errors. ARIMA forecasting results show that India will be the country with the highest milk production, followed by Pakistan and China while GARCH model fits better to Bangladesh. This paper has policy implications as it can be used for the proper planning of dairy products in the South-Asian counties to safe guard the nutritional security.

Keywords: ARIMA, GARCH, Holt's model, Modeling, Time Series.

1. Introduction:

Dairy products are part of daily life, and perception about them have evolved through time from a luxurious product accessible from the "elite" into a common product consumed by millions of people. One glass of milk can tremendously improve the nutritional levels of the children in the region of Asia (Siddiky 2015). One of the core dairy products is milk, which has grabbed the attention of governments trying to implement policies which could forecast its subproducts whilst enterprises are becoming dairy driven as the best way to make profitable margins as consumer's preference are rising for high-quality milk. Hence, the manufactured dairy product output is estimated to grow 10% to INR 283,000 crore ($37.58 billion) during the current financial year (April 2020-March 2021,*www.fao.org.*) Currently, South Asian countries including China are leading milk producer (China sustain milk output growth in Asia and FAO, 2020). India ranked first position in the world for milk production, which is accounted for 196.18 million tones (2019) and China ranked 5th position (*FAO*,2019).

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we show cow's milk production as share per region indicating that in comparison to other countries, Asia counts the highest share. European Union countries have the highest second level of milk production whilst Africa and Oceania have the lowest level of milk production in the world.

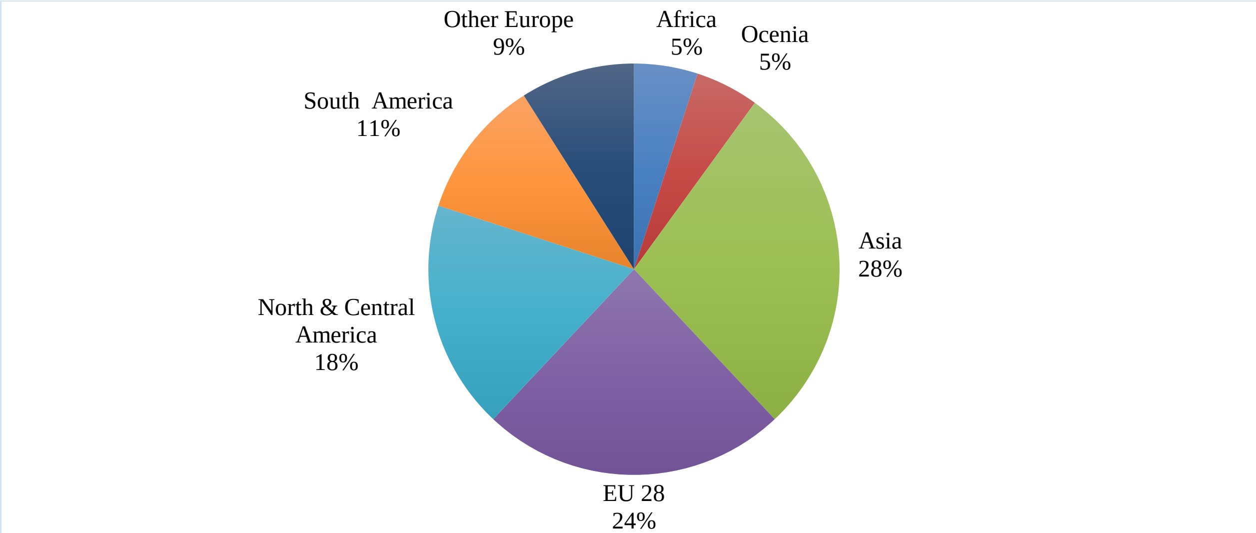

Figure 1 Cow's Milk Production (Share per region)

In **Table 1**we show total milk production in the recent years revealing that world total milk production has increased. As the level of milk production has increased, trade has raised too 77.9 million tones in November 2020.

			2020 (forecast)		Change: 2020 over 2019 (tonnes)
	2018	2019	June	November	
Total milk production	840.3	848	858.9	860.1	1.4
Total Trade	76	76.8	73.6	77.9	1.5

Table 1 World milk production[1]*(million tonnes)*

There is vast existing literature on milk production, which focus in a particular country or firm while the studies in SAARC region including China seem scant so far. Mainly, the SAARC region, most households rear livestock either as a mainstay and/or complementary to crop production (Ahuja and Staal, 2012). Therefore, due to the importance of dairying, we try to estimate and forecast milk production in order to promote the commercialization of dairying in SAARC member countries (SAARC diary outlook, 2015). Forecasting of milk production is required so that necessary policy formations can be done (Mishra et al. 2020; Deshmukh and Paramasivam2016). Lohano and Soomro (2006)have used a random walk model with drift autoregressive model to forecast milk production in Pakistan.Schmit and Kaiser (2006)indicate that decline in retail per capita demand would persist but at a reduced rate from years past. In a similar approach to ours, (Akter and Rahman 2010)forecasts milk supply up to 3 years for a dairy cooperative in UK.Murphy et al. (2020)have conducted a study to identify the different modeling techniques for the prediction

[1]Food and Agriculture Organization of the United Nations (FAO)

of total daily herd milk yield in Ireland and non-linear model especially for short-term milk-yield predictions.Li (2020)also studied the genome-wide association study of milk production using statistical models. Taye et al. (2020)have considered the trends of actual yield of cow milk production. They have forecasted the volume of milk in Andassa dairy farm in Ethiopia using ARIMA (1, 2, 1). Mishra et al. (2020) used time series models in milk production and forecasted for 2020. Uddin et al. (2020)determine that Bangladesh will be self -sufficient in milk production 2029.

(Wood 1967,Ali and Schaeffer 1987; Wilmink 1987; Guo 1995)tried to fit a lactation curve to the data while (Ptak and Schaeffer 1993 and (Shallo et al., 2004) proved the nutrition of milk through genetic analysis and bio-economic modeling. Milk production is highly influenced from certain factors such as nutritional interventions (Kolver and Muller 1998), disease (Collard et al 2000), seasonality of pasture production (Adediran et al. 2012), grazing conditions (Baudracco et al. 2012) or other factors such as (Olori et al. 1999;Tekerli et al. 2000; Brun-Lafleur et al. 2010). Macciottaet al.(2002) and Vasconcelos et al. (2004)have used auto-regressive models to forecast lactation while (Sharma et al. 2006; and Sharma et al. 2007) have used large models such as multiple regression and artificial neural networks. Other studies have revealed the set of variables which could influence milk production such as :season of calving (Wood 1967), climatic conditions (Smith 1968), number of DIM (Grzesiak et al.2006) and stocking rate (McCarthy et al. 2011).

In general, there is much success in production of dairy products in the developed countries than in developing countries such as South-Asian countries. Even though the government has implemented policies, growth process has been low. Smallholders constitute a large portion of the dairy industry while privately-owned and state-owned farms constitute the other portion. Lack of dairy animals with good generic merit, lack of good quality feed, limited knowledge of and skills of farmers, high cost of inputs and lack of good marketing are the main challenges that South-Asian countries are facing now. The ability to forecast milk production is important as it will affect energy consumption and farmer's income. Predicting milk production is the best tool in order to adjust its supply. Hence, due to the importance of milk as dairy production and as South-Asian countries are leading the production we try to forecast milk production using ARIMA/GARCH models and Holt's Linear Model (Oliveros 2019).

The results show ARIMA approach indicates that India would be the leading state in milk production with 91 MMT in the year 2024-2025 among South Asian countries. The second country ranked is Pakistan which milk production would reach 26 MMT in 2024-2025, China is the third country with 3MMT, while Bangladesh and Sri Lanka seem to be the countries with the lowest production of milk.Since the residuals of the fitted ARIMA models for China, India, Nepal, Pakistan, and Sri Lanka is having absence of ARCH effects, we can not estimate an ARCH/GARCH model. Hence, we proceed by fitting a GARCH model only for Bangladesh and

Myanmar and the findings suggest that Bangladesh forecasts an abundance of milk production. In comparison to the ARIMA model, Holt's linear model forecasts higher levels of milk production for the region. It indicates that India's forecasted level will reach 105 MMT, Pakistan 58 MMT and China 4 MMT in the year 2024-2025. We compare the mean absolute percentage error (MAPE) between ARIMA and Holt's models and the findings suggest that ARIMA model shows higher errors. The only exception is China, Nepal and Pakistan which errors are higher using Holt's model.

2. Material and Methods:

The main approaches to the research problem with their methodologies are discussed here.

2.1 Data Collection

Milk production data of SAARC countries and China were collated separately. The milk production data are in tons. The data set contains annual data from 1961 to 2018 (www.fao.org.in). The data sets were divided into two parts as 80% and 20% for the model building and model validation, respectively. The statistical packages used for model building are R and E-views software.

2.2 ARIMA Model

ARMA (*p*,*q*) model where *p* is the order of the autoregressive part and *q* is the order of the moving average part (as defined below).

Autoregressive model

The notation AR (*p*) refers to the autoregressive model of order *p*. The AR(*p*) model is written equation 1

$$X_t = c + \sum_{i=1}^{P} \rho_i X_t + \varepsilon_t \quad (1)$$

Where $\rho_1, \rho_2 ..... \rho_p$ are the parameters of the model, c is a constant and ε_t is white noise. Sometimes the constant term is avoided.

Moving Average model

The notation MA (*q*) refers to the moving average series of order *q*:

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} \quad (2)$$

Where the $\theta_1, ..., \theta_q$ are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0), and the $\varepsilon_t, \varepsilon_{t-1} \ldots$

Stationary time series can be modelled with ARIMA models.The non-seasonal ARIMA model can be written as in Equation 3.

$$z`_t = c + \emptyset_1 z`_{t-1} + \emptyset_2 z`_{t-2} + ... + \emptyset_p z`_{t-p} + e_t + \Theta_1 \varepsilon_{t-1} + \Theta_2 e_{t-2} + \cdots + \Theta_p e_{t-p} \quad (3)$$

where$z`_t$is the differenced series. The “predictors” on the right-hand side include both lagged values of z_t and lagged errors. This is defined as the ARIMA (p,d,q) model where p, d and q respectively represent the order of the autoregressive part, the degree of the differencing involved and the order of the moving average part. ARIMA has four major steps as model building and identification, estimation, model diagnostics and forecast. Firstly, tentative model parameters are identified through ACF (Auto Correlation Function) and PACF (Partial Auto Correlation Function), then the best coefficients for the model are determined through MSE,MAPE etc. next steps involve is to forecast and finally validate and check the model performance by observing the residuals through Ljung Box test and ACF plot of residuals.

2.3 Holt’s Linear Trend Method

Holt’s Linear Trend Method is an extension of the simple exponential smoothing and allows forecasting data with a trend. This method involves a forecast equation and two smoothing equations: one for the level and one for the trend given by Equation 4, Equation 5 and Equation 6 respectively.

$$\textit{Forecast Equation} \quad \hat{z}_{t+h|t} = k_t + hd_t \quad (4)$$
$$\textit{Level Equation} \quad k_t = \rho z_t + (1-\rho)(k_{t-1} + d_{t-1}) \quad (5)$$
$$\textit{Trend Equation} \quad d_t = \sigma^*(k_t - k_{t-1}) + (1 - \sigma^*)d_{t-1} \quad (6)$$

Where k_t denotes an estimate of the level of the series at time t, d_t denotes an estimate of the trend (slope) of the series at time t, $\rho$is the smoothing parameter for the level, $0 \leq \rho \leq 1$, and σ^* is the smoothing parameter for the trend, $0 \leq \sigma^* \leq 1$.

2.4Generalized Autoregressive Conditionally Heteroscedastic (GARCH) process:

The generalized autoregressive conditional heteroscedasticity (GARCH) model describes the error variance of a modelBollerslev (1986).

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + ... + \alpha_q \varepsilon_{t-q}^2 + \beta_1 h_{t-1} + ... + \beta_p h_{t-p} \quad (7)$$

$$h_t = a_0 + \sum_{i=1}^{q} a_i \rho_{t-1}^2 + \sum_{j=1}^{p} b_j h_{t-j} \quad (8)$$

A sufficient condition for the conditional variance to be positive is

$$a_0 > 0, a_i \geq o, i = 1, 2, ..., q; b_j \geq 0, j = 1, 2, ..., p$$

The GARCH model is equivalent to an infinite ARCH model. In that case, the GARCH (p, q) model, where p is the order of the GARCH terms $\rho^2$and q is the order of the ARCH termse^2 is shown in Equation .9

$$\rho_t^2 = \theta_0 + \alpha_1 e_{t-1}^2 + \cdots + \theta_q e_{t-q}^2 + \omega_1 \rho_{t-1}^2 + \cdots + \omega_p \rho_{t-p}^2 (9)$$

3. Results and Discussion:

Some descriptive statistics such as mean, maximum, minimum, standard deviation, skewness, and kurtosis are given in Table 1. When Table 1 is examined, India's produced approximately three times the milk of Pakistan, the closest competitor, between 1961 and 2018. Bangladesh had the lowest mean milk production among the studied seven countries. From Table 1 anyone can see this; during the periodstudy under investigation, India has a tremendous growth of 422.33 %. Myanmar reached 193841 tonnes in 2018, with 560.41 percent. In all counties taken in the study is positive skewness,which indicates that milk production increased from 1961 to 2018.Except the Myanmar, other counties found negative kurtosis in milk production indicating steadiness in production.

After seeing the nature through descriptive statistics, the next steps is validated and forecast the milk production time series. For projection purpose different time series models used ARIMA, GARCH and Holt's winter model and compared .ARIMA model selections for seven countries obtained by making use of some goodness of fit criteria such as Akaike information criterion (AIC), Bayesian information criterion (BIC), and bias-corrected Akaike information criterion (AIC), and the results are given in Table 2. In Table 2, Holt's model results and also shown.

The best models of India, China, and Myanmarare selected ARIMA(1,2,1) for milk production data over the period of 1961 to 2018. ARIMA(0,1,0) model is also specified for Sri Lanka and Bangladesh. ARIMA(1,2,2) and ARIMA(1,2,0) models are determined, respectively, by Nepal and Pakistan.

Milk production from different counties in time series of the ARIMA model equation is given except for Bangladesh and Sri Lanka:

$$\mathbf{Z_t = 2 * Z_{t-1} - Z_{t-2} + \varepsilon_t \quad , \mathbb{E}(\varepsilon_t) = 0}$$

For Sri Lanka and Bangladesh only first differencing is required for making data stationary .ForBangladesh and Sri Lanka milk production ARIMA model is equation.

$$\mathbf{Z_t = 1 * Z_{t-1} + \varepsilon_t \quad , \mathbb{E}(\varepsilon_t) = 0}$$

ARIMA-GARC models fitting for milk production data are given in Table 3. Because the residuals of the ARIMA models of China, India, Nepal, Pakistan, and Sri Lanka do not indicate the ARCH effect, thesecountries' residuals cannot be modeled by the GARCH models. These results were obtained by using the ARCH test given in the third column of Table 3. GARCH(1,1) model is also specified for Bangladesh and Myanmar. Milk production data is using fitted models between 1961 and 2007.

While the part of milk production data between 1961 and 2007 was used for modeling, the part between 2008 and 2018 was used to test the model validity. Model validation results for the ARIMA-GARCH models given in table 4 between 2008 and 2018 for the milk production data. From table 4 it is observed that the actual values of the milk productions are very close to point forecasted milk productions in both Bangladesh and Myanmar.The comparison of ARIMA and ARIMA-GARCH models is given in Table 5. The lowest values of the RMSE, MAE, and MAPE are shown the best model. The model with the lowest values of RMSE, MAE, and MAPE shows the best model. From Table 5, because ARIMA(0,1,0)-GARCH(1,1) and ARIMA(1,2,1)-GARCH(1,1) has the lowest value for the RMSE, MAE, and MAPE, these models selected in the best models for Bangladesh and Myanmar, respectively.

The best models for modeling and forecasting milk production for seven countries are also given in Table 6. For Sri Lanka and Myanmar GARCH (1,1) is betted in milk production and equation is

$$\varepsilon_t^2 = a_0 + \sum_{i=1}^{Max(p,q)} \left(a_i + b_j\right)\varepsilon_{t-i}^2 + \eta_t + \sum_{j=1}^{p} b_j \eta_{t-j}$$

Thus a GARCH model can be regarded as an extension of the ARMA approach to squared series $\left\{\varepsilon_t^2\right\}$.Parameter estimates for the exponential growth model using Holt's methods are given in Table 7. The point forecasting (PF), the lower bound (Lo), and higher bound (Hi) for α=0.2 and α=0.2 are presented in Table 8 for the milk production using Holt's linear models trend from 2019 to 2025. From Table 8, it is concluded that the upward milk production trend in India and Pakistan will continue. It is expected to exceed 100 million metrictone (MTT) milk productions in 2025 in India.It is also expected to exceed 55 million tone milk productions in 2025 in Pakistan. While milk productions in China, India, and Pakistan will be expected to increase significantly, in Nepal, Sri Lanka, and Myanmar will be expected to increase more slowly over the years. It will also be expected to decrease milk productions in Bangladesh over the years.

From Table No. 9, Table 10, and Table No. 11, we find that a model in Holt's Linear model achieves the lowest MAPE in China, India, Nepal, Pakistan, Sri Lanka, and Bangladesh, and thus a Holt's Linear Model is the best in Forecasting production in these countries as well. Anyone can find that a model in Myanma that GARCH model is better than ARIMA and when we compare MAPE Myanmain Holt's Linear model and GARCH model, we find that GARCH model more accurate than Holt's Linear model and achieve low MAPE in GARCH model.

The dairy sector is an important activity in the agriculture sector. Milk production plays a crucial role in development. The dairy sector: Data were analyzed in the following seven countries, China, India, Nepal, Pakistan, Sri Lanka, and Bangladesh during the study period. For all the milk production data, we expect China there will be an increase in milk production during the coming period, while India we expect an increase in milk production in the coming period, and by 2024, dairy production in India will exceed 100 million tons annually and will have a good impact on the rest of the sectors in India. Of the dairy production in India during the coming period, and we expect Nepal, there will be an increase in milk production. The annual increase in milk production in Nepal will be a slight increase in the annual production rate.

For Pakistan, we also expect more annual production for the amount of milk production. Also, there will be a slight increase in the rate of production. Annual for Albanians in Pakistan. We expect Sri Lanka that there will also be an increase in the amount of dairy production during the coming period, but there will be a decrease in the annual production rate of milk, thus it will have a negative impact in Sri Lanka in the sectors related to dairy production. Therefore, attention must be paid to the dairy production sector in Sri Lanka in order to prevent further losses in The period is the leader in the sectors related to dairy. In Bangladesh, we expect that there will be stability in the amount of dairy products in the coming period. We expect in Myanmar increases in dairy production, but there will be a difference in growth rates. It will witness a decrease and increase and an increase in the growth rates of milk production.

However, lower growth rates are expected in 2025 compared to the previous period. To increase milk production, you need to provide the animals with good fodder and proper health care. This projection helps strategize to meet our future milk demand. To increase the need for milk production to educate dairy owners and farmers about the animal breeding program and health care practices.

4. Conclusions

This paper uses annual data from 1961 to 2018 to forecast milk production in South-Asian countries using an Auto Regressive Integrated Moving average model (ARIMA) model, a Generalized Autoregressive Heteroskedastic (ARCH-GARCH) model and then Holt's Linear Trend.The findings employing the ARIMA approach show that India would be the leading state in milk production with 91 MMT in the year 2024-2025 among South Asian countries. The second country ranked is Pakistan which milk production would reach 26 MMT in 2024-2025, China is the third country with 3MMT, while Bangladesh and Sri Lanka seem to be the countries with the lowest production of milk.Since the residuals of the fitted ARIMA models for China, India, Nepal, Pakistan, and Sri Lanka is having absence of ARCH effects, we proceed by fitting a GARCH model only for Bangladesh and Myanmar. GARCH model for Bangladesh forecasts an abundance of milk production. In comparison to the ARIMA model, Holt's linear model forecasts higher levels of milk production for the region. It indicates that India's forecasted level will reach 105 MMT, Pakistan 58 MMT and China 4 MMT in the year 2024-2025. We compare the mean absolute percentage error (MAPE) between ARIMA and Holt's models and the findings suggest that ARIMA model shows higher errors. The only exception is China, Nepal and Pakistan which errors are higher using Holt's model. This study has policy implications, as it can be used by policymakers in the national agriculture sector to forecast milk production and other dairy productions.

5.1 The limit of the study:

In this paper, we use annual data to forecast milk production in South Asian countries using autoregressive models. As a matter of fact, autoregressive models are used with high-frequency data, and the usage of annual data instead of quarterly or monthly data can reduce the robustness of our results. Another limitation is related to the models' properties; we use ARIMA models with different lags, while the autoregressive models are sensitive to the number of lags. Instead, GARCH models are the benchmark among the autoregressive models; the coefficients are restricted to be positive, and by imposing artificial restrictions, it makes the model less reliable and far from reality. Hence, the researcher should be careful while using autoregressive models as fitting an ARIMA or GARCH models is more an "art than of science ".

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	Mean	Minimum	Maximum	Standard Deviation	Skewness	Kurtosis

China, mainland	1957335	917000	3100000	791574	0.09699714	-1.599469
India	34725088	10929000	91817140	22691830	0.7834235	-0.5095129
Nepal	678285	340000	1338277	279431.2	0.7466306	-0.6696471
Pakistan	12627086	4209000	28109000	7540331	0.51971	-1.183356
Sri Lanka	45636	18320	85914	17528.07	0.3599365	-1.181533
Bangladesh	23377	13090	39000	6580.095	0.6333173	-0.6418137
Myanmar	103086	18180	305631	74419.61	0.9259912	0.09181194

Table 2 Descriptive statistics of milk production data

Note: Population of seven countries (SAARC) milk production (China, mainland, India, Nepal, Pakistan, Sri Lanka, Bangladesh, and Myanmar), Milk Production data for SAARC cover the period of 1961 to 2018

	Model	Drift	AR	MA	LL	AIC	BIC	AICc	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1	LB(*)
China, mainland	ARIMA (1,2,1)	-	-0.16	-0.77	-542.17	1090.35	1095.77	1090.93	177943.5	245563.4	178239.4	5.33	5.34	-	0.76	0.08
India	ARIMA (1,2,1)	-	0.14	-0.79	-620.29	1346.57	1351.99	1347.16	-3912409	6015012	4207575	-5.22	5.71	-	0.65	0.07
Nepal	ARIMA (1,2,2)	-	-0.49	-0.05	-484.53	977.06	984.29	978.06	-35288.29	45132.93	35552.66	-3.12	3.14	-	0.25	0.54
Pakistan	ARIMA (1,2,0)	-	-0.63	-	-603.39	1210.77	1214.39	1211.06	-2198966	2511836	2198966	-9.67	9.67	-	0.72	0.54
Sri Lanka	ARIMA(0,1,0)	-	-	-	-485.23	972.46	974.29	972.55	-25776.36	30083.48	25776.36	-94.56	94.56	-	0.35	0.97
Bangladesh	ARIMA(0,1,0)	-	-	-	-405.99	813.99	815.82	814.08	-4032.82	4265.16	4032.82	-12.60	12.60	-	0.43	0.80
Myanmar	ARIMA(1,2,1)	-	-0.27	-0.76	-481.61	969.21	974.63	969.8	95303.58	130655	109765.8	26.87	32.32	-	0.74	0.92
Holt's Linear Model																
China, mainland	Holt's Model	-	-	-	-	-1279.844	-1270.593	-1278.381	-3844.146	44415.05	24190.94	-0.1955345	1.202316	0.5032381	-0.2975724	-
India	Holt's Model	-	-	-	-	275.4604	284.7111	276.9238	90158.63	684422.9	474951.9	0.430057	2.210809	0.4377875	0.1083532	-
Nepal	Holt's Model	-	-	-	-	-407.2761	-398.0254	-405.8127	502.267	11073.18	7838.862	-0.02164949	1.40627	0.5221118	0.1572573	-
Pakistan	Holt's Model	-	-	-	-	-816.1363	-806.8855	-814.6729	-44082.97	252917.5	165840.1	-0.1034639	1.377794	0.4659282	0.6672319	-
Sri Lanka	Holt's Model	-	-	-	-	1086.306	1095.556	1087.769	-1370.963	9204.253	4867.231	-6.332225	13.80561	0.9811848	-0.02080074	-
Bangladesh	Holt's Model	-	-	-	-	813.99	814.08	815.82	-4032.82	4265.16	4032.82	-12.60	12.60	0.80	0.43	-
Myanmar	Holt's Model	-	-	-	-	437.0612	446.3120	438.5246	784.4944	10200.05	5720.191	-1.374684	6.90126	0.9976296	0.07656917	-

Table 3 ARIMA Models fitted and Holt's Linear Model for milk production over the period (1961-2018)

(*)It corresponds to the P-value of Ljung-Box test.

Note: Population of seven countries (SAARC) milk production (China, mainland, India, Nepal, Pakistan, Sri Lanka, Bangladesh, and Myanmar), Milk Production data for SAARC

GARCH Models

- GARCH models were fitted using EViews software.
- 80% of data was used in fitting the models (i.e., from 1961 -2007)
- The remaining 20% was used in model validation (i.e., 2008-2018)

	ARIMA model (Mean equation)	ARCH Test (*)	GARCH Model (Variance equation)	AIC	RMSE	MAE	MAPE
China, mainland	ARIMA (1,2,1)	0.23	[redacted]				
India	ARIMA (1,2,1)	0.41					
Nepal	ARIMA (1,2,2)	0.79					
Pakistan	ARIMA (1,2,0)	0.59					
Sri Lanka	ARIMA(0,1,0)	0.80					
Bangladesh	ARIMA(0,1,0)	0.04	GARCH(1,1)	17.17	1503.719	864.94	2.45
Myanmar	ARIMA(1,2,1)	0.03	GARCH(1,1)	21.29	113250.5	98114.64	51.58

Table 4 ARIMA-GARCH Models fitting for milk production over the period (1961-2018)

- Since the residuals of the fitted ARIMA models in the countries China, India, Nepal, Pakistan, and Sri Lanka do not show the ARCH effect, the residuals cannot be models by using ARCH/GARCH Models.

	Bangladesh		Myanmar	
Years	Actual	Forecasted	Actual	Forecasted
2008	34000	32794.63	238704	232357.1
2009	35000	34794.63	265117	251728.6
2010	36000	35794.63	302974	279622.2
2011	37200	36794.63	305631	320096.4

2012	38000	37994.63	171184	322595.5
2013	39000	38794.63	175526	174928.1
2014	35173	39794.63	179751	173228.3
2015	35303	35967.63	184142	178422
2016	35432	36.97.63	188490	183665.5
2017	35562	36226.63	192134	188760.1
2018	35691	36356.63	193841	192993.4

Table 5 Milk Production Forecasting & Model Validation using ARIMA-GARCH Models (PF:Point Forecast)

Country	Model	RMSE	MAE	MAPE
Bangladesh	ARIMA(0,1,0)	4265.16	4032.82	12.60
	ARIMA(0,1,0)-GARCH(1,1)	**1503.719**	**864.94**	**2.45**
Myanmar	ARIMA(1,2,1)	130655	109765.8	32.32
	ARIMA(1,2,1)-GARCH(1,1)	**113250.5**	**98114.64**	51.58

Table 6 Comparison of ARIMA and ARIMA-GARCH Models

Country	**Best Model**
China, mainland	ARIMA (1,2,1)
India	ARIMA (1,2,1)
Nepal	ARIMA (1,2,2)
Pakistan	ARIMA (1,2,0)
Sri Lanka	ARIMA(0,1,0)
Bangladesh	**ARIMA(0,1,0)-GARCH(1,1)**
Myanmar	**ARIMA(1,2,1)-GARCH(1,1)**

Table 7 Best time series models selected for modelling and forecasting milk production

Holt's Linear Model

- Holt's Linearmodels were fitted using R software.
- 80% of data was used in fitting the models (i.e., from 1961 -2007)
- The remaining 20% was used in model validation (i.e., 2008-2018)

Using Holt's Linear Trend Method, this is the average of smoothing variability as a random process, and also called a moving average of exponentially weighted.

Country	Box-Coxtransformation	Smoothingparameters		Initial states		Sigma
	Lambda	**Alpha**	**Beta**	**L**	**B**	
China, mainland	-0.8014	0.9365	0.5325	1.2478	0	0
India	0.2582	0.9999	0.1536	250.1244	1.1341	2.5688
Nepal	-0.1848	0.9999	1e-04	4.8944	0.002	0.0018
Pakistan	-0.4138	0.9999	0.0327	2.4125	0	0
Sri Lanka	1.0369	0.9265	0.0086	36086.5029	2113.4565	14320.69
Bangladesh	0.0809	0.1845	0.0116	-14.586	0.4601	4.6949
Myanmar	0.4266	0.7669	1e-04	148.0494	6.224	14.3336

Table 8 Holt's Linear Trend Models fitted for milk production over the period (1961-2018)

Parameter Estimates for Exponential Growth Model using Holt's method
Note: Population of seven country (SAARC) milk production (China, mainland, India, Nepal, Pakistan, Sri Lanka, Bangladesh, and Myanmar), Milk Production data for SAARC

Milk Production - China					
Year	PF	Lo 80	Hi 80	Lo 95	Hi 95
2019	3803153	2334634	8570512	1916533	19654561
2020	3901199	2267432	10414588	1831379	36433249
2021	4003894	2200145	13209086	1749273	139105924
2022	4111564	2133179	17867331	1670424	NA
2023	4224564	2066875	26932789	1594951	NA
2024	4343285	2001518	50733409	1522905	NA
2025	4468154	1937337	206213189	1454276	NA

Milk Production - India					
Year	PF	Lo 80	Hi 80	Lo 95	Hi 95
2019	86427539	70712785	104595440	63309095	115286482
2020	89348068	71930530	109714449	63803187	121793926
2021	92341178	73132357	115060949	64256495	128642974
2022	95408035	74317617	120643307	64668870	135848776
2023	98549815	75485734	126470048	65040292	143426887
2024	101767701	76636186	132549877	65370842	151393293
2025	105062884	77768495	138891691	65660682	159764448

Milk Production - Nepal					
Year	PF	Lo 80	Hi 80	Lo 95	Hi 95
2019	1305156.9	1172820.3	1455560	1109222.7	1543465
2020	1340245.3	1198502.9	1502290	1130683.8	1597437
2021	1376457.1	1225055.8	1550542	1152925.0	1653221
2022	1413833.9	1252493.1	1600394	1175948.4	1710919
2023	1452419.2	1280832.6	1651926	1199760.6	1770634
2024	1492258.6	1310094.2	1705218	1224371.2	1832473
2025	1533399.4	1340300.8	1760353	1249792.4	1896542

Milk Production - Pakistan					
Year	PF	Lo 80	Hi 80	Lo 95	Hi 95
2019	38981232	33101611	46453264	30487296	51249271
2020	41509487	34786079	50227985	31837846	55920638
2021	44275938	36596478	54447602	33277424	61210659
2022	47310414	38544632	59183362	34812931	67231377
2023	50647458	40643847	64520886	36452060	74120538
2024	54327238	42909114	70563778	38203378	82048951
2025	58396660	45357355	77438304	40076417	91230389

Milk Production – Sri Lanka					
Year	PF	Lo 80	Hi 80	Lo 95	Hi 95
2019	37869.64	-6350.0160	79482.82	-29412.583	101149.19
2020	38746.03	-7439.7363	82183.18	-31458.244	104795.02
2021	39621.69	-8472.3410	84833.20	-33424.503	108364.83
2022	40496.64	-9455.4610	87438.84	-35321.155	111867.68
2023	41370.89	-10395.2561	90005.08	-37156.323	115311.11
2024	42244.46	-11296.7990	92536.12	-38936.827	118701.50
2025	43117.36	-12164.3326	95035.54	-40668.455	122044.26

Milk Production - Bangladesh					
Year	PF	Lo 80	Hi 80	Lo 95	Hi 95
2019	32000	24685.89	39314.11	20814.03	43185.97
2020	32000	24387.23	39612.77	20357.27	43642.73
2021	32000	24099.86	39900.14	19917.77	44082.23
2022	32000	23822.57	40177.43	19493.71	44506.29
2023	32000	23554.39	40445.61	19083.56	44916.44
2024	32000	23294.47	40705.53	18686.03	45313.97
2025	32000	23042.08	40957.92	18300.04	45699.96

Milk Production – Myanmar					
Year	PF	Lo 80	Hi 80	Lo 95	Hi 95
2019	310747.5	244454.7	386308.2	213004.2	430162.7
2020	319599.4	249749.4	399489.4	216716.3	445959.9
2021	328594.2	255196.8	412809.8	220588.2	461896.8
2022	337732.4	260791.2	426275.7	224611.1	477983.1
2023	347014.6	266528.3	439892.8	228778.1	494226.9
2024	356441.4	272404.4	453665.7	233083.2	510635.0
2025	366013.4	278416.6	467598.5	237521.7	527213.3

Table 9 Milk Production Forecasting using Holt's Linear Trend PF: Point Forecast)

(PF: Point Forecast); Lo 80 and Hi80 are (respectively) the lower and higher bounds of predictive interval for an error term alpha = 0.2; Lo 95 and Hi95 are (respectively) the lower and higher bounds of predictive interval for an error term alpha = 0.05.)

Table 9: MAPE ARIMA Model

	Milk Production - China			Milk Production -India			Milk Production -Nepal			Milk Production -Pakistan		
Years	Actual	Forecasted	Error	Actual	Forecasted	Error	Actual	Forecasted	Error	Actual	Forecasted	Error
2008	2950000	2949706	0.009966 %	57895000	58606485	1.228923 %	987780	990496.7	0.275031 %	20971000	20528277	2.11112 %
2009	3000000	2999460	0.018 %	59758000	60544002	1.315308 %	1031500	1022351.3	0.886932 %	21622000	20957802	3.071862 %
2010	3050000	3049207	0.026 %	62350000	62475926	0.201966 %	1066867	1054216.7	1.185743 %	22279000	21216361	4.769689 %
2011	3050000	3098955	1.605082 %	65352000	64407047	1.445944 %	1109325	1086079.1	2.0955 %	22955000	21581890	5.981747 %
2012	3080000	3148702	2.230584 %	67675432	66338053	1.976166 %	1153838	1117942.4	3.110974 %	23652000	21880490	7.489895 %
2013	3050000	3198450	4.867213 %	70442617	68269043	3.085595 %	1188433	1149805.4	3.250297 %	24370000	22220966	8.818359 %
2014	3100000	3248197	4.780548 %	74709900	70200030	6.036509 %	1167773	1181668.5	1.189914 %	25001000	22535242	9.862637 %
2015	2990666	3297945	10.2746 %	76459000	72131017	5.660528 %	1167154	1213531.6	3.973563 %	25744000	22865910	11.17965 %
2016	3005201	3347693	11.39664 %	81266300	74062003	8.865049 %	1210441	1245394.7	2.887683 %	26510000	23186322	12.53745 %
2017	2946374	3397440	15.30919 %	86261680	75992990	11.90412 %	1245954	1277257.8	2.512436 %	27298000	23513151	13.86493 %
2018	3003323	3447188	14.77913 %	91817140	77923977	15.13134 %	1338277	1309120.9	2.17863 %	28109000	23835965	15.20166 %
MAPE			5.936087 %			5.168313 %			2.140609 %			8.626273 %

	Milk Production – Sri Lanka			Milk Production - Bangladesh			Milk Production – Myanmar		
Years	Actual	Forecasted	Error	Actual	Forecasted	Error	Actual	Forecasted	Error
2008	30105	27260	9.450257 %	34000	32000	5.882353 %	238704	234338.3	1.828918 %
2009	41600	27260	34.47115 %	35000	32000	8.571429 %	265117	250549.5	5.494744 %
2010	46990	27260	41.98766 %	36000	32000	11.11111 %	302974	266123.9	12.16279 %
2011	46330	27260	41.16123 %	37200	32000	13.97849 %	305631	281872.0	7.773753 %
2012	61710	27260	55.82564 %	38000	32000	15.78947 %	171184	297572.6	73.83202 %
2013	54060	27260	49.57455 %	39000	32000	17.94872 %	175526	313286.3	78.48427 %
2014	45854	27260	40.55044 %	35173	32000	9.021124 %	179751	328996.3	83.02891 %
2015	36118	27260	24.52517 %	35303	32000	9.356145 %	184142	344707.4	87.19651 %
2016	66128	27260	58.77692 %	35432	32000	9.686159 %	188490	360418.2	91.21343 %
2017	68591	27260	60.25718 %	35562	32000	10.01631 %	192134	376129.0	95.76389 %
2018	85914	27260	68.2706 %	35691	32000	10.34154 %	193841	391839.9	102.145 %
MAPE			44.07734 %			11.0639 %			58.08402 %

The accuracy: MAPE ARIMA Model in milk production (China mainland, India, Nepal, Pakistan, Sri Lanka, Bangladesh, and Myanmar)

	Milk Production - China			**Milk Production -India**			**Milk Production -Nepal**			**Milk Production -Pakistan**		
Years	Actual	Forecasted	Error	Actual	Forecasted	Error	Actual	Forecasted	Error	Actual	Forecasted	Error
2008	2950000	2961053	0.374678 %	57895000	58767312	1.506714 %	987780	982923.3	0.491678 %	20971000	21371536	1.909952 %
2009	3000000	3023254	0.775133 %	59758000	60963917	2.018001 %	1031500	1007979.1	2.280262 %	21622000	22441794	3.791481 %
2010	3050000	3087849	1.240951 %	62350000	63220851	1.396714 %	1066867	1033795.3	3.09989 %	22279000	23589424	5.88188 %
2011	3050000	3154973	3.441738 %	65352000	65539185	0.286426 %	1109325	1060398.6	4.410466 %	22955000	24821814	8.132494 %
2012	3080000	3224773	4.700422 %	67675432	67919997	0.361379 %	1153838	1087816.9	5.721869 %	23652000	26147232	10.54977 %
2013	3050000	3297405	8.111639 %	70442617	70364375	0.111072 %	1188433	1116079.2	6.088168 %	24370000	27574962	13.15126 %
2014	3100000	3373037	8.807645 %	74709900	72873415	2.458155 %	1167773	1145215.7	1.931651 %	25001000	29115447	16.45713 %
2015	2990666	3451853	15.42088 %	76459000	75448223	1.321986 %	1167154	1175257.9	0.69433 %	25744000	30780470	19.56367 %
2016	3005201	3534050	17.59779 %	81266300	78089913	3.908615 %	1210441	1206238.3	0.347204 %	26510000	32583360	22.90969 %
2017	2946374	3619841	22.85749 %	86261680	80799606	6.331982 %	1245954	1238191.1	0.623049 %	27298000	34539239	26.52663 %
2018	3003323	3709458	0.374678 %	91817140	83578435	8.972949 %	1338277	1271151.6	5.015808 %	28109000	36665316	30.43977 %
MAPE			8.332836 %			2.606727 %			2.791307 %			14.48307 %

	Milk Production – Sri Lanka			**Milk Production - Bangladesh**			**Milk Production – Myanmar**		
Years	Actual	Forecasted	Error	Actual	Forecasted	Error	Actual	Forecasted	Error
2008	30105	28175.23	6.410131 %	34000	32268.47	5.092735 %	238704	222633.8	6.732271 %
2009	41600	29061.09	30.14161 %	35000	32534.80	7.043429 %	265117	229954.1	13.26316 %
2010	46990	29945.95	36.27165 %	36000	32798.96	8.891778 %	302974	237410.5	21.63998 %
2011	46330	30829.86	33.45595 %	37200	33061.02	11.12629 %	305631	245003.7	19.83676 %
2012	61710	31712.83	48.6099 %	38000	33321.01	12.31313 %	171184	252734.3	47.63897 %
2013	54060	32594.89	39.70609 %	39000	33578.99	13.90003 %	175526	260602.9	48.46969 %
2014	45854	33476.08	26.9942 %	35173	33835.00	3.804054 %	179751	268610.2	49.43461 %
2015	36118	34356.41	4.877319 %	35303	34089.10	3.438518 %	184142	276756.7	50.29526 %
2016	66128	35235.91	46.7156 %	35432	34341.31	3.078263 %	188490	285043.1	51.22452 %
2017	68591	36114.60	47.3479 %	35562	34591.68	2.72853 %	192134	293470.0	52.74236 %
2018	85914	36992.51	56.9424 %	35691	34840.25	2.383654 %	193841	302037.9	55.81735 %
MAPE			34.3157 %			6.709128 %			37.91772 %

Table 10 MAPE Holt's Linear Trend Model in milk production

The accuracy:MAPEHolt's Linear TrendModel inmilk production (China mainland, India, Nepal, Pakistan, Sri Lanka, Bangladesh, and Myanmar)

	Bangladesh			Myanmar		
Years	Actual	Forecasted	Error	Actual	Forecasted	Error
2008	34000	32794.63	3.545205882 %	238704	232357.1	2.6589 %

2009	35000	34794.63	0.586771429 %	265117	251728.6	5.049997 %
2010	36000	35794.63	0.570472222 %	302974	279622.2	7.707526 %
2011	37200	36794.63	1.089704301 %	305631	320096.4	4.732962 %
2012	38000	37994.63	0.014131579 %	171184	322595.5	88.44956 %
2013	39000	38794.63	0.526589744 %	175526	174928.1	0.340633 %
2014	35173	39794.63	13.13970944 %	179751	173228.3	3.628742 %
2015	35303	35967.63	1.882644534 %	184142	178422	3.106298 %
2016	35432	36.97.63	89.56415105 %	188490	183665.5	2.559552 %
2017	35562	36226.63	1.868933131 %	192134	188760.1	1.756014 %
2018	35691	36356.63	1.864979967 %	193841	192993.4	0.437266 %
MAPE			10.42302666 %			10.94795 %

Table 11 MAPE Milk Production Forecasting & Model Validation using ARIMA-GARCH Models (PF: Point Forecast)

The accuracy :MAPE GARCH Model in milk production (Bangladesh, and Myanmar)

Milk Production Forecasting (2019-2025)