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Modeling Wave-Like Patterns of Consumer Price Index of the USA

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ABSTRACT

The Consumer Price Index (CPI) indicates whether the economy of a country is experiencing inflation, deflation, or stagflation. Changes of the CPI are used to assess price changes associated with the cost of living. There is an increasing trend of CPI of the USA. This study design forecast CPI of the USA. Monthly CPI data of the USA for the period of January 2011 to October 2021 were obtained from the International Monitory Fund (IMF) database. Sama Circular Model (SCM), Seasonal Autoregressive Integrated Moving Average (SARIMA), and Holt's-Winters three-parameter additive and multiplicative models were tested to forecast CPI of the USA. The model assumptions were tested by Ljung-Box Q (LBQ) test, Anderson Darling test, and Auto Correlation Function (ACF). The forecasting ability of the model asses by both relative and absolute measurements of errors. Results of the study revealed that the SCM is not suitable due to the autocorrelation of residuals. SARIMA and the Holt-Winters' models can be used to forecast CPI of the USA. But the Holt-Winters additive model of α ; 0.999, γ ;0.900, and δ; 0.999 is the most suitable model to forecast CPI in the USA. The rate of change of CPI identified as 6 months. It is strongly recommended to design more studies on capturing the behaviors of the CPI for other countries.

Keywords: Consumer Price Index, Inflation, Holts Winters Model

1. INTRODUCTION

1.1 Background of the Study

The Consumer Price Index (CPI) is a statistical composite indicator that measures the average change in the prices over time that consumers pay for a basket of goods and services (Fernando, 2021).The prices of goods and services are often changed due to the different dynamic situations within the country. It depends on the effectiveness of economic policies and various other factors including natural disasters. Further, CPI indicates whether the economy of a country is experiencing inflation, deflation, or stagflation. Inflation is a general increase in prices and a fall in the purchasing value of money. It will be further classified as Demand-Pull Inflation and Cost-Push Inflation. Demand-pull inflation, or the increase in aggregate demand, is categorized by the four sections of the macro economy: households, businesses, governments, and foreign buyers (Hall, 2021). Cost-push inflation, or the decrease in the aggregate supply of goods and services stemming from an increase in the cost of production (Hall, 2021). Deflation is a reduction of the general level of prices in an economy and Stagflation is a situation in which the inflation rate is high, the economic growth rate slows, and unemployment remains steadily high. Changes of the CPI are used to assess price changes associated with the cost of living (Fernando, 2021).The CPI cover a variety of individuals with different incomes, including retirees, but does not include certain populations, such as patients of mental hospitals (Fernando, 2021). The CPI attempts to quantify the overall price level in an economy and to measure the purchasing power of a country's currency unit (Fernando, 2021). The weighted average of the prices of goods and services that approximates an individual's consumption patterns is used to calculate CPI (Fernando, 2021).The CPI is used in the calculation of many key economic indicators that require real- or constant- country's unit of currency measures, including estimates of income, earnings, productivity, output, and poverty (Kenneth et al , 1999). The value of the CPI leads to control the price of the goods and services. The USA holds the highest GDP according to the World Bank statistics. The worth is 20.894 Trillion US$ in 2020 (World Bank, 2020).The USA CPI shows an upward trend according to statistics from the International Monitory Fund (IMF).

1.2 Research Problem

The increasing behavior of the CPI shows an increasing price of the basket of goods and services in the USA. It may lead to an inflation. Therefore, it is essential to predict the CPI of the country.

1.3 Objectives of the Study

To forecast Consumer Price Index of the USA.

1.4 Significance of the Study

The results of the study give insight into the effectiveness of the economic policies and performances of CPI of the USA. The findings of the study would guide the imposition or revision of monetary policies, fiscal policies, other price controlling and develop proactive strategies to increase consumer confidence in the USA. The results of the study would be a lighthouse for investment decisions, technology, and other innovations to gain

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optimum benefits. Further, it is a guide to increase the production and identify new demand of the consumers.

2. LITERATURE REVIEW

The review of the study was focused on research activates of modeling CPI. Stochastic models and soft computing techniques have been applied for the aim.

2.1 Studies Based on Modeling CPI

Djami et al (2021) have applied the ARIMA model to forecast CPI of Ambon city of Indonesia. Shinkarenko et al (2021) have applied ARIMA and Holt-Winters' to forecast CPI of Ukraine. Konarasinghe (2021) has applied Double Exponential Smoothing (DES) to forecast CPI of the USA. Purbasari et al (2020) have applied ARIMA and Artificial Neural Network (ANN) to predict the Indonesian CPI. The results of the study revealed that the ANN outperformed ARIMA. Konarasinghe (2020) has applied Auto-Regressive Distributed Lag Model (ADLM) to forecast CPI of Thailand. Aabeyir (2019) has applied Simple Exponential Smoothing (SES), DES, and Winters' additive and multiplicative models to forecast CPI of Ghana. The results of this study revealed that Winters' multiplicative model performed better than other models. Jere et al (2019) have applied Error Correction Model (ECM) and ARIMA to forecast CPI of Zambia. The results of the study revealed that ECM is the most suitable for this purpose. Nyoni (2019-a) has applied ARIMA to forecasting CPI of Mauritius. Konarasinghe, W.G.S. (2019-a) has applied the Sama Circular Model (SCM) and ARIMA on the forecasting CPI of India and found that SCM performed better than ARIMA. Nyoni (2019-b) has applied ARIMA to model the CPI of Germany. Singla et al (2019) have applied Holt-Winters' additive and SARIMA model to forecast CPI of India. The performances of both models were satisfactory. Sinha et al (2018) have applied Neural Network Models to forecast CPI of India. Gjika et al (2018) have applied Seasonal Auto-Regressive Integrated Moving Average (SARIMA) and Multiple Regression model to forecast CPI of Albania. The results revealed that SARIMA outperformed Multiple Regression. Ambukege, et al (2017) have applied Neuro-Fuzzy modelling for forecasting CPI of Tanzania. Norbert et al (2016) have applied Auto-Regressive Integrated Moving Average (ARIMA) to model the CPI of Rwanda. Kharimah et al (2015) has applied ARIMA to forecast CPI of Bandar Lampung City, Indonesia from 2009-2013. Adams et al (2014) have applied ARIMA to model CPI of Nigeria. Alibuhtto (2014) applied the Vector Auto Regressive (VAR) model to predict the Colombo Consumer Price Index (CCPI) of Sri Lanka. Zhang et al (2013) have applied ARMA to forecast CPI of China.

The ARIMA was highly applied to model CPI of various countries and states. Besides, other stochastic models namely; SARIMA, ADLM, ECM, DES, SCM, SES, VAR, Holt-Winters' and Multiple Regression have been applied for the aim. Soft computing approaches namely; ANN and Neuro-Fuzzy modelling have been applied to forecast CPI. ARIMA was not successful in a few studies. Literature has found that the SCM, ECM, Holt-Winters' and ANN outperformed ARIMA on a few occasions.

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3. METHODOLOGY

Monthly data of CPI of the USA for the period of January 2011 to October 2021 were obtained from the International Monitory Fund (IMF) database. The pattern of the CPI paves the path for the model selection to forecast CPI of the USA (Konarasinghe, 2016-a; 2016-b); and (Konarasinghe, W.G.S., & Abeynayake, 2014). There could be seasonal, cyclical, trends, heavy and minor volatility within the period of the data set of CPI. (Konarasinghe, W.G.S. & Abeynayake, 2014). Due to the above reasons, the data series would follow an irregular wave-like pattern with; constant amplitude, increasing amplitude, decreasing amplitude, or a mix of them (Konarasinghe, W.G.S., & Konarasinghe, 2021). The Auto Correlation Function (ACF) and time series plot was used to recognize the behavior of the data series, as done by Konarasinghe, W.G.S., & Abeynayake (2014). As per the behavior of the data series, Sama Circular Model (SCM), Seasonal Auto-Regressive Integrated Moving Average (SARIMA), and Holt-Winters' three-parameter additive and multiplicative models were tested to forecast CPI of the USA. The model assumptions were tested by Ljung-Box Q (LBQ) test, Anderson Darling test, and ACF, (Konarasinghe, W.G.S., et al, 2015). The forecasting ability of the model asses by three measurements of errors, as per Konarasinghe, (2018; 2016-c; 2015-a; 2015-b). They are; Mean Absolute Percentage Error (MAPE), Mean Square Error (MSE), and Mean Absolute Deviation (MAD) Konarasinghe, (2018; 2016-c; 2015-a; 2015-b).

3.1 Circular Model and Sama Circular Model

The development of the CM was based on; Fourier transformation, uniform circular motion theory and multiple regression analysis (Konarasinghe, W.G.S., 2016). The SCM is the improved version of the CM (Konarasinghe, W.G.S., 2020-a; 2018-b).

3.1.1 Circular Model (CM)

As explained in Konarasinghe, W.G.S.(2016),a variable Y_t, with an irregular wave pattern was modeled by the Circular Model ;

$$Y_t = \sum_{k=1}^{n} (a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t \tag{1}$$

Model assumptions of the CM are; the series Y_t is trend-free, k is a positive real number, $\sin k\omega t$ and $\cos k\omega t$ are independent; residuals are Normally distributed and independent.

3.1.2 Sama Circular Model (SCM)

A limitation of the CM is that it is not applicable for a series with a trend. Konarasinghe, W.G.S. (2020-a; 2019-b; 2018-a; 2018-b) suggests the method of differencing to mitigate the limitation of the CM. In usual notation, differencing series of Y_t are as follows;

First differenced series: $Y_t^{'} = Y_t - Y_{t-1} = (1-B)Y_t$ (2)

Second differenced series:

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$$Y_t^{''} = Y_t^{'} - Y_{t-1}^{'} = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2)}) = Y_t - 2Y_{t-1} + Y_{t-2} = (1-B)^2 Y_t \quad (3)$$

Similarly, d th order difference is, $Y_t^d = (1-B)^d Y_t$ (4)
Where, B is the Back Shift operator; $BY_t = Y_{t-1}$.

Assume Y_t^d is trend-free. Let, $Y_t^d = X_t$ then X_t could be modeled as;

$$X_t = \sum_{k=1}^{n} (a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t \quad (5)$$

Hence; $(1-B)^d Y_t = \sum_{k=1}^{n} (a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t$ (6)
the model (6); improved Circular Model, is named as "Sama Circular Model (SCM)".

3.2 Seasonal Auto Regressive Integrated Moving Average (SARIMA)
ARIMA modeling can be used to model many different time series, with or without trend or seasonal components, and to provide forecasts (Box & Jenkins, 1970); (Box, & Jenkins, 1976). The model as follows;

An ARIMA model is given by:

$$\phi(B)(1-B)^d y_t = \theta(B)\varepsilon_t$$

Where; $\phi(B) = 1 - \phi_1 B - \phi_2 B^2 ....\phi_p B^p$

$$\theta(B) - 1 - \theta_1 B - \theta_2 B^2 ......\theta_P B^q \quad (7)$$

ε_t = Error term

D = Differencing term

B = Backshift operator ($B^a Y_t = Y_{t-a}$)

Analogous to the simple SARIMA parameters, these are:
Seasonal autoregressive - (Ps)
Seasonal differencing - (Ds)
Seasonal moving average parameters - (Qs)
Seasonal models are summarized as ARIMA (p, d, q) $(P, D, Q)_s$
Number of periods per season - S

$$(1-\phi_1 B)(1-\varphi_1 B^s)(1-B)(1-B^s)Y_t = (1-\theta_1 B)(1-\theta_1 B^s)\varepsilon_t \quad (8)$$

3.3 Holt-Winters' Three Parameter Models
This model may be applied when both trend and seasonality they are present, these two components being additive or multiplicative (Holt, 1957). Winters' Method calculates

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dynamic estimates for 3 components; level, trend and seasonal which denotes α, β, and γ (with values between 0 and 1) (Holt, 1957). Formulae of Winters' multiplicative model is;

$$L_t = \alpha (Y_t / S_{t-p}) + (1-\alpha) [L_{t-1} + T_{t-1}] \quad (9\text{-}1)$$

$$T_t = \beta [L_t - L_{t-1}] + (1 - \beta)T_{t-1} \quad (9\text{-}2)$$

$$S_t = \gamma (Y_t / L_t) + (1 - \gamma) S_{t-p} \quad (9\text{-}3)$$

$$\hat{Y}_t = (L_{t-1} + T_{t-1}) S_{t-p} \quad (9\text{-}4)$$

Where,

L_t = is the level at time t, α is the weight for the level, T_t = is the trend at time t, β is the weight for the trend, S_t = is the seasonal component at time t, γ is the weight for the seasonal component, p = is the seasonal period, Y_t = is the data value at time t, $\hat{Y}_t$ = is the fitted value, or one-period-ahead forecast, at time t.

Formulae of Winter's additive model is;

$$L_t = \alpha (Y_t - S_{t-p}) + (1- \alpha) [L_{t-1} + T_{t-1}] \quad (10\text{-}1)$$

$$T_t = \beta[L_t - L_{t-1}] + (1 - \beta)T_{t-1} \quad (10\text{-}2)$$

$$S_t = \gamma (Y_t - L_t) + (1 - \gamma) S_{t-p} \quad (10\text{-}3)$$

$$\hat{Y}_t = L_{t-1} + T_{t-1} + S_{t-p} \quad (10\text{-}4)$$

Where,

L_t = is the level at time t, α is the weight for the level, T_t is the trend at time t, β is the weight for the trend, S_t = is the seasonal component at time t, γ is the weight for the seasonal component, p = is the seasonal period, Y_t = is the data value at time t, $\hat{Y}_t$ = is the fitted value, or one-period-ahead forecast, at time t.

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4. RESULTS

The analysis contains two main parts:

4.1 Pattern recognition of CPI of the USA.
4.2 Forecasting CPI of the USA.

4.1 Pattern Recognition of CPI of the USA

Figure 1 is the time series plot of CPI of the USA for the period of January 2011 to October 2021. The pattern of the CPI shows an increasing trend with minor fluctuations. After January 2020 there is an exponential growth within the behavior.

Figure 1: Time Series Plot of CPI of the USA

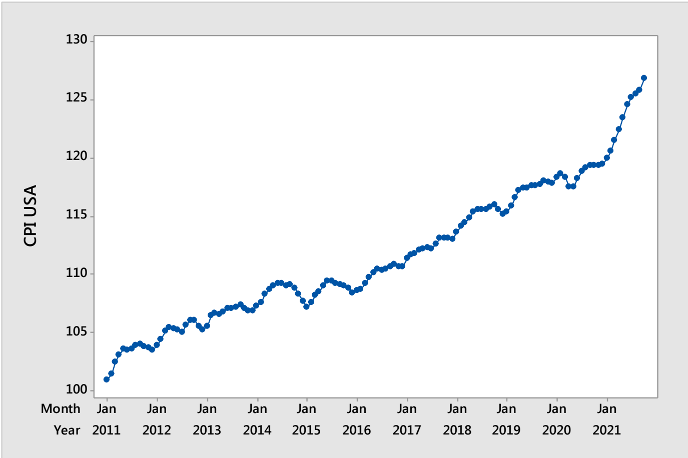

Figure 2 shows that the pattern of CPI after August 2011 is that the most suitable part of the data series to forecast CPI of the USA. Hence, the period of August 2011 to October 2021 was examined furthermore. According to Figure 2, there is an increasing trend of CPI and exponential growth after January 2020.

Figure 2: CPI after August 2011

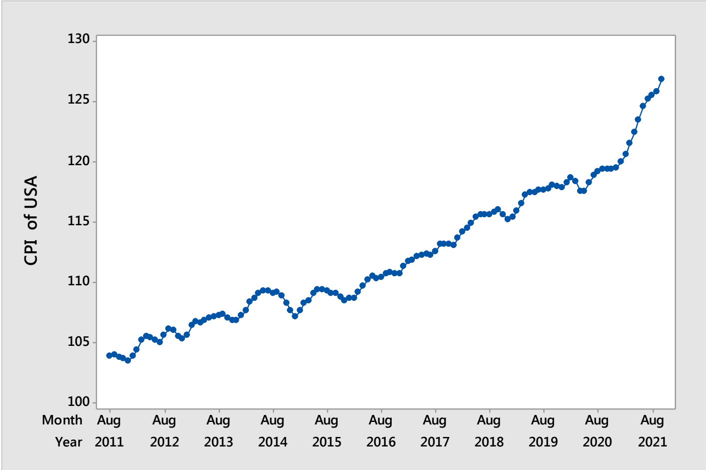

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Figure 3 is the ACF of the CPI. It shows a trend with a seasonal behavior. But the seasonal length cannot be identified clearly. There are a few significant lags. The series has confirmed the weak stationary of the data series.

Figure 3: ACF of CPI

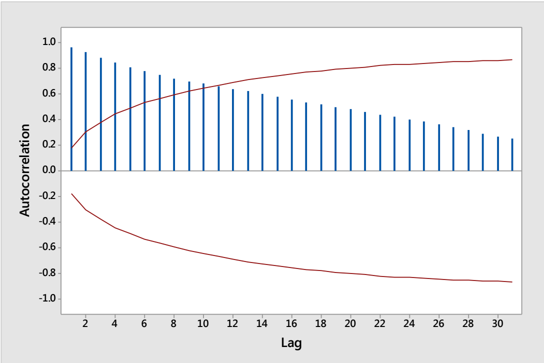

Figure 4: Plot of 1st Difference of CPI

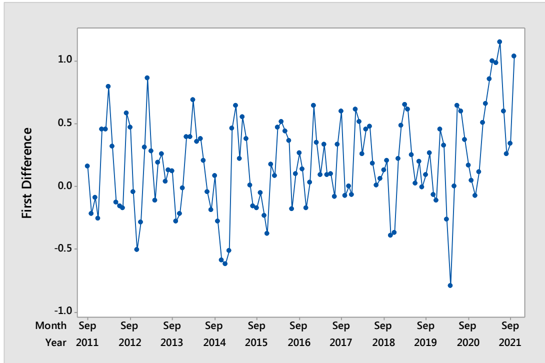

Figure 4 has shown the first difference series of CPI.The first difference series is required to examine the wave-like behavior of the data series to pick up SCM (Konarasinghe, W.G.S., 2019-a ; 2020-b). The high volatility of the wave-like pattern with a trend of the series has been observed in Figure 4. This behavior would be another evidence to pick and apply SCM to forecast the CPI of the USA. The stationary of the series is another evidence to pick and apply SARIMA for the aim. Further, suspected seasonal behavior would be another fact to pick up SARIMA and Holt-Winters' additive and multiplicative models to forecast the CPI of the USA.

4.2 Forecasting CPI of the USA

The SARIMA model was tested with several seasonal lengths. The results given in Table 1.

Table 1: Model Summary of SARIMA

Model	Model Fitting		Model Verification	
ARIMA (1,1,0)(1,1,1)$_6$	MAPE	0.0475	MAPE	0.3067
	MSE	7.058446E-06	MSE	0.0003
	MAD	0.0022	MAD	0.0146
	Normality	P = 0.205		
	Independence of Residuals	Yes		

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SARIMA model is significant with 6 months of seasonal length. ARIMA $(1,1,0)(1,1,1)_6$ satisfied all model validation criterion of normality and the independence of the residuals. The measurements of errors were low under the fitting and verification. Actual vs fits of ARIMA$(1,1,0)(1,1,1)_6$ are shown in Figure 5. The fits of the CPI follow an analogous pattern of the actual series. The deviation between actual and fits are very low. Figure 6 is that the actual vs. forecast of ARIMA $(1,1,0)(1,1,1)_6$.The deviation between actual and forecast is satisfactorily low.

Figure 5: Actual vs. Fits of SARIMA

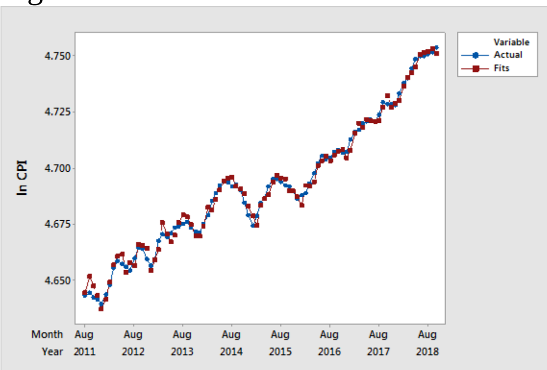
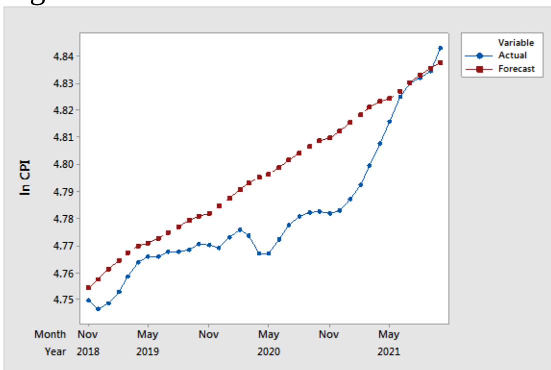


Figure 6: Actual vs. Forecast of SARIMA



The SCM was tested after SARIMA. SCM was significant and the residuals were also normally distributed, but not independent. Therefore, the SCM was not selected for forecasting due to the autocorrelation of the residuals. Finally, Holt-Winters' additive and multiplicative models were tested with several seasonal lengths of 6, 7, and 8 months. Both additive and multiplicative models were fitted and satisfied the assumptions of normality and independence of the residuals for the tested seasonal lengths. Holt-Winters' additive and multiplicative models with a seasonal length of 6 months are the most suitable models among them. The performance of Winters' multiplicative model is given in Table 2.

Table 2: Model Performances of Holt-Winters' Multiplicative Model

Model	Model Fitting		Model Verification	
Multiplicative (6) α (level) 0.999 γ (trend) 0.365 δ(seasonal) 0.999	MAPE	0.0557	MAPE	0.2752
	MAD	0.0026	MAD	0.0132
	MSE	0.0000099	MSE	0.0004
	Normality	P= 0.092		
	Independence of Residuals	Yes		

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The fitted Holt-Winters 'multiplicative model of α; 0.999, γ; 0.365 and δ; 0.999 satisfied the validation criterion of normality and independence of the residuals. The measurements of errors were low under the fitting and verification. Actual vs fits of Winters' multiplicative model shown in Figure 7. The fits of the CPI follow a similar pattern to the actual CPI behavior. The deviation between actual and fits of CPI are very low. Figure 8 is the actual vs. forecast of the Winters' multiplicative model. The pattern of the forecast is quite similar to the actual at the beginning. But the pattern is quite dissimilar at the end along with more deviation.

Figure 7: Actual vs. Fits Winters Multiplicative Model

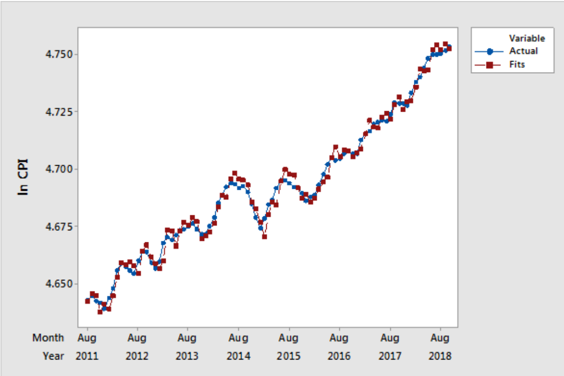
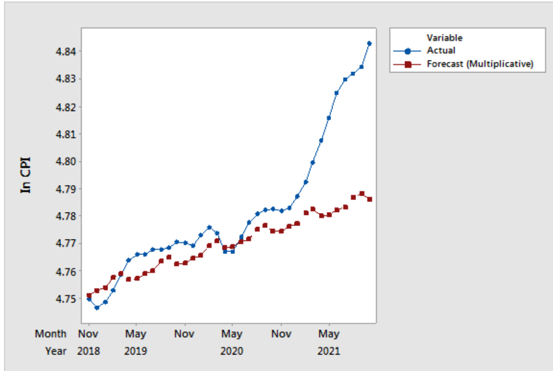


Figure 8: Actual vs. Forecast Multiplicative Model



The performances of Holt-Winters' additive model are given in Table 2. The seasonal length of the given model is 6 months.

Table 3: Model Performances of Holt-Winters' Additive Model

Model	Model Fitting		Model Verification	
Additive (6) α (level) 0.999 γ (trend) 0.900 δ(seasonal) 0.999	MAPE	0.0494	MAPE	0.2099
	MAD	0.0023	MAD	0.0106
	MSE	0.0000076	MSE	0.0001
	Normality	P= 0.092		
	Independence of Residuals	Yes		

The fitted Holt-Winters' additive model of α; 0.999, γ; 0.900 and δ; 0.999 satisfied the validation criterion. The forecasting ability of the additive model is similar to the multiplicative model. The behavior of the actual CPI values vs fits of the Winters' additive model is shown in Figure 9 and the actual vs forecast in Figure 10. The behaviors of fits and forecasts in Figures 9 and 10 follow a similar pattern of the actual series. The deviation between the actual vs fits and forecast is also very less.

Figure 9: Actual vs. Fits Winters Additive Model

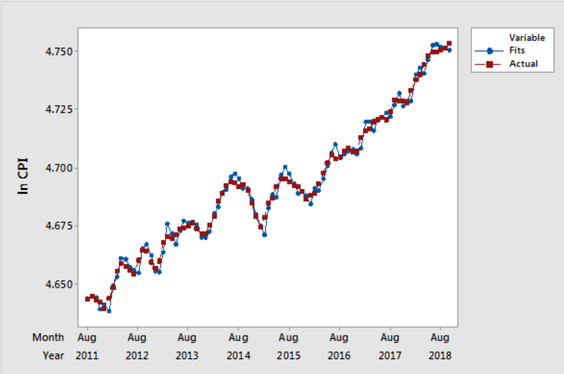
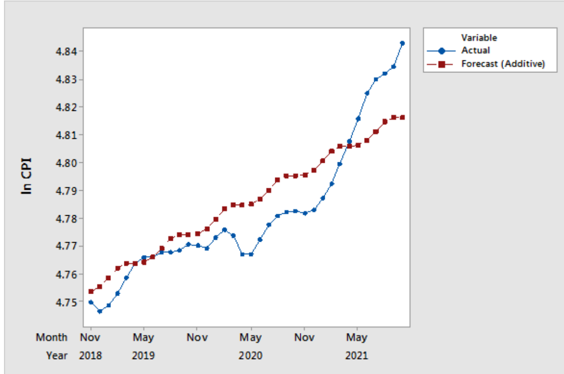
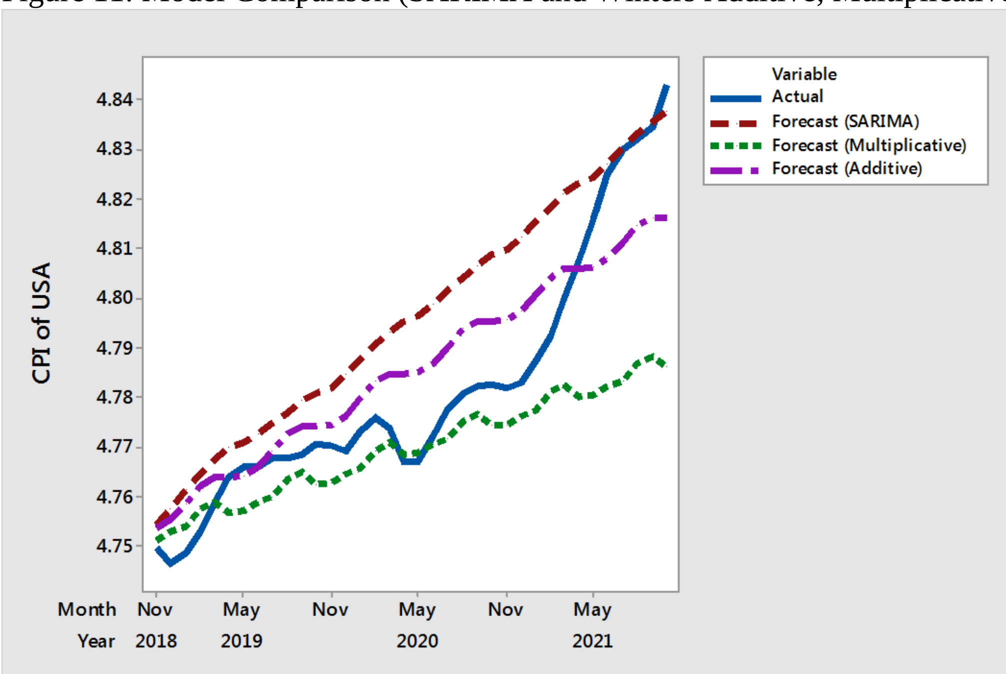


Figure 10: Actual vs. Forecast Additive Model



The model performances of Tables 1, 2, and Figures 7, 8, 9, and 10 are good pieces of evidence to suggest Holt-Winters' additive model is more accurate than the multiplicative model. Model comparison of SARIMA and Holt-Winter's multiplicative and additive model is shown in Figure 11.

Figure 11: Model Comparison (SARIMA and Winters Additive, Multiplicative)



The model comparison is another solid evidence to select a suitable model. Figure 11 confirmed the accuracy of the Holt-Winters' additive model than the multiplicative model and SARIMA in forecasting CPI of the USA. SARIMA shows a tiny over estimation behavior, whereas Winters' multiplicative shows wide deviation at the end. Hence, the Holt-Winters' additive model of α; 0.999, γ; 0.900, and δ; 0.999 with 6 months seasonal length is the most suitable model to forecast CPI of the USA.

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5. CONCLUSION AND RECOMMANDATIONS

It was concluded that the seasonal length of the of CPI 6 months and the Holt-Winters' additive model of α; 0.999, γ; 0.900 and δ; 0.999 is the most suitable model to forecast the CPI of the USA.

The selected stochastic model is a perfect tool to predict the future and act accordingly. The results of the study can be taken as a guide to control the price of the goods and services. There could be increasing demand for the goods and services within the consumer basket, decreasing available supply, consumers are willing to pay more and demand-pull inflations are a few causes of increasing the price. The seasonal behavior could be another factor in increasing the price. Whatever it would be explored and controlling the price is important under any circumstances. There are many ways to control the prices namely; minimum price, maximum price, limiting price increases, buffer stocks, etc. The authorities would decide which way is the most suitable for the aim. Forecasting the CPI is a reliable approach to forecasting the country's inflation. It improves financial planning in both the public and the private sectors. The results would be helpful for investors for risk assessment and hedge investments. The results of the study would be another guide for the creation and evaluation of monetary policies. The results of CPI forecasting are essential for the banking sector in order to keep their investments profitable. They can achieve it by forecasting inflation through the predicted CPI results. It would be helpful to achieve their operating capital requirements. The results of the study would be another guide to calculate expenditures accurately in business. They can prepare their potential needs in wage shifts and necessary adjustments in human capital and resource.

Further, the results of the study would be another guide for monetary policy decision-making. The authorities would be able to understand the inflation through CPI forecasting. It would be helpful to estimate the economic effects of their policies. In other words, they can apply the results of the study to calculate inflation and how it would affect the value of domestic products in an international market. Finally, the results of the study would be a lighthouse to impose, revise both monitory and fiscal policies in the USA. It is strongly recommended to design more studies on capturing the behaviors of the CPI for other countries.

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