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The Inflation Forecasting of Major Cities in East Kalimantan: A Comparison of Holt-Winters And SARIMA Models

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Abstract: This research aims to compare the performance of Holt Winters and Seasonal Autoregressive Integrate Moving Average (SARIMA) models in predicting inflation in Balikpapan and Samarinda, two biggest cities in East Kalimantan province. The importance of East Kalimantan province cannot be overstated since it has been declared as the venue for the capital of Indonesia. Hence, inflation prediction of the two cities will give valuable insights about the economic nature of the province for the country's new capital. The data used in this study extended from January 2015 to September 2021. The data were divided into training and test data. The training data were used to model the time series equation using Holt winters and SARIMA models. Later, the models derived from training data were employed to produce forecasts. The forecasts were compared to the actual inflation data to determine the appropriate model for forecasting. Test data were from January 2015 to December 2020 and test data extended from January 2021 to September 2021. The result showed that Holt-Winters performed better than SARIMA in prediction inflation. The Root Mean Squared Error (RMSE) values are lower for Holt-Winters Exponential Smoothing for both cities. It also predicts better timing of cyclicality than SARIMA model.

Keywords: Inflation; Holt-Winters; SARIMA; Seasonality

1. Introduction

Inflation is the main target for monetary and economic policy made by central bank in Indonesia [1]. It is formally stated in the Bill of Central Bank of Indonesia that the main task of Bank Indonesia is to control inflation. The pivotal role of inflation stems from the fact that inflation signifies the general increase in price of goods and services. Uncontrolled inflation means the economy is experiencing turbulence that affects the general population with far-reaching consequence. Higher inflation has been proven to hamper economic growth, render exchange rate at disadvantageous position, limit government expenditure, and negatively affect capital market [2][3][4][5]. Inflation can be curbed by limiting the growth of money supply. Decrease in money supply will result in less liquidity in the economy. This will be followed by a shrinking general price increase in goods and services. To be able to lessen supply of money in the economy central bank will stimulate funds to seek higher return by increasing the interest rate or profit sharing ratio of central bank's marketable securities [6]. Money supply will be absorbed by the banking system to seek for higher return. Holding money will reward less. Hence the reverse mechanism will work if central banks want to spur inflation. Lowering the interest rate or profit-sharing ratio of central bank's marketable securities will also lower market interest rate. Liquidity will flow out of the banking system to the economy. Eventually, there will be a surge in the general price level. A good and controlled inflation will make it easier for companies, financial institutions, or individuals to plan and prepare budget. Since general price level is well maintained, a good plan can be developed by many parties so that inflation targeting is of ultimate importance. The discussion on inflation in East Kalimantan province occupies the center stage because Presiden Joko Widodo has announced in 2019 that the capital city of Indonesia will be relocated to a location near Balikpapan city, East Kalimantan. Ever since the announcement, the discussion regarding capital location has been trending in the social media [7]. Insights regarding current condition of inflation in East Kalimantan province is very valuable since it will be the center of Indonesian government. Forecast of inflations in East Kalimantan will notify whether the current macroeconomic policy will likely result in a conducive atmosphere for economic development and progression. To the knowledge of the author, no research has been conducted to investigate the inflation pattern in East Kalimantan. Existing literature focus on national inflation forecasting [8] and prediction of inflation in the city of Malang [9].

2. Related Works

Time-series econometrics is a branch of econometrics that is widely used for prediction purpose. Holt-Winters model is especially well know for its predictive capabiity that takes seasonality into account. Therefore, for movement of variable that involves certain seasonality pattern, Holt-Winters is specifically useful. Tourists' arrival is an area in which Holt-Winters is often applied. Tourists' visit to certain tourism destination is highly seasonal. In certain times in year, tourists' visit is high, especially during summer holiday or other long holiday. Tourists have leisure times for vacations. Yusuf and Anjasari [10] used Holt-Winters to forecast arrival at Banyuwangi. The, model produced constants α = 0.18, β = 0.1, and γ = 0.03. These constants produced forecasts with lowest MAPE and MSE. Aryati, Purnamasari, & Nasution [11] predicted tourists arrival at Indonesia. The model generated constants value of α = 0.9, β = 0.1, and γ = 0.9. According to them, multiplicative exponential smoothing is better for prediction than additive exponential smoothing. Supriatna, Hertini, Susanti, & Supian [12] compared Holt-Winters and SARIMA (seasonal autoregressive moving average) for forecasting tourists' arrival at Bali. The constants for Holt-Winters were α = 0.1, β = 0.1, and γ = 0.3 and the SARIMA model was (0,1,1)(1,0,0). SARIMA performed better than Holt-Winters with MAPE 5.788615 compared to 6.171873 of Holt Winters. Rundupadang, Massora, & Prasetyo [13] used Holt-Winters to predict inflation in Indonesia. However, they did not separate the data into train and test data. Therefore the forecast accuracy could not bet determined. Nevertheless, the model was able to capture seasonality. In case of trend, the model was virtually unable to pick up any trending movement. Fitri, Anwar, Zohra, & Nasution [14] employed triple exponential smoothing to predict inflation rate in Padang city. The constants generated were were α = 0.06, β = 0.08, and γ = 0.33. The forecasted inflation lied between -1% and 1%. ARIMA is the other well known time series model often used for prediction purpose. Estiko & S.W. [15] compared the performance of ARIMA and Neural Network (NN) in predicting Indonesian inflation. They found that NN managed to outperform ARIMA in the prediction by yielding smaller Root Means Squared Error (RMSE). Newton, Kurnia, & Sumertajaya [16] compared the eprformance of ARIMA and ARIMAX to predict inflation in Jakarta. ARIMAX is a variation of ARIMA in which an independent variable is added as a predictor. Both model used (2,0,3) factors. The number 2 indicates the autoregressive components and number 3 indicates the moving-average components. The result showed that ARIMAX performed better than ARIMA in prediction.

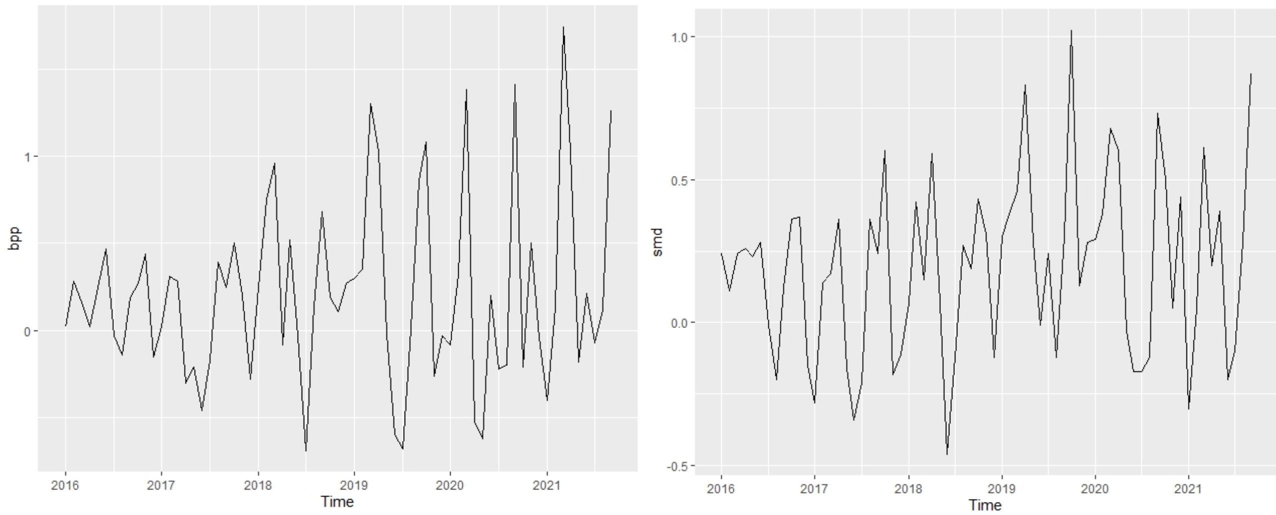
3. Experiment and Analysis

The data used in this research are monthly data extending from January 2016 to September 2021. The data were taken from Badan Pusat Statistik's website https://kaltim.bps.go.id. They contain inflations rate in Balikpapan and Samarinda, two major cities in East Kalimantan. The data will be divided into two sections namely, training data and test data. Training data extended from January 2016 to December 2020. Test data were from January 2021 to September 2021. Holt-Winters exponential smoothing and ARIMA models will be applied to the training data to model the pattern in the data. Subsequent to that, the model derived from Hot-Winters and ARIMA will be employed to produce forecasts for January 2021 until September 2021. The forecasts produced will later be compared to the test data. This comparison will show the forecast accuracy of each model. The parameter for forecast accuracy is RMSE (root means squared errors). The lower the number of RMSE, the better the model in forecasting the inflation. The first method employed is Holt-Winters exponential smoothing. The equation for Holt-Winters is as follows:

$$\hat{y}_{t+h|t} = \ell_t + hb_t + s_{t+h-m(k+1)}$$

ℓ_t denotes equation in level form. The dependent variabel has the index of t+h that shows forecast h periods ahead. ℓ_t can further be measured by the equation $\ell t = \alpha(y_t - s_{t-m}) + (1- \alpha)(\ell_{t-1} + b_{t-1})$. We can see that it is seasonally adjusted, i.e the equation $(y_t - s_{t-m})$. The term b_t is denotes the trend component of the equation. It will further be detailed into $b_t = \beta(\ell_t - \ell_{t-1}) + (1- \beta) b_{t-1}$. A trend in a period is affected by the trend in previous period. The last component is seasonal component $s_{t+h-m(k+1)}$. We can derive the seasonal component by the equation $s_t = \gamma(y_t - \ell_{t-1} - b_{t-1}) + (1- \gamma)s_{t-m}$. The parameter α from the level equation, β from trend component, and γ from seasonal components are parameters of interest. We will use R Studio to estimate these parameters. The second model we use is SARIMA. In general the SARIMA model will be denoted by the term (P.D.Q) (p,d,q). The term P is autoregressive component. So the value of a variable in a month will be affected by the value in previous month. It is formally stated as: $y_t = c + y_{t-1}$ (if only one autoregressive component. For two or more we will have to add y_{t-2} and so on). This is a feature of time-series component in which a period is dependent upon previous period. The term D denotes the difference component. If the series are not stationary, we have to make it stationary by differencing them. Formally it is stated as: $d(y_t) = y_t - y_{t-1}$. By differencing, we can avoid the problem of spurious regression [17]. The next component in SARIMA is Q. It is basically an equation involving error and lags of errors $e_t = c + e_{t-1} + e_{t-2} + \dots$ (depending on the q terms). Subsequently, the term p,d,q concern autoregressive seasonality component. The term p is seasonal autoregressive. So the value of a variable in a month will be affected by the value in previous period of the same month. The term d denotes the difference seasonal component. The last component in SARIMA is q. It is basically an equation involving seasonal error and lags of errors. Finally we will compare forecast accuracy based on RMSE, that is denoted by the equation: RMSE = $1/t \times (\sum_{n=1}^{t} \xi_n^2)^{0.5}$. The symbol ξ is forecast error derived from the difference between forecasts generated by the model and test data.

The first analysis will concern the plot of inflation data in the city of Balikpapan and Samarinda. Below is the plot of the inflation data in the two cities:

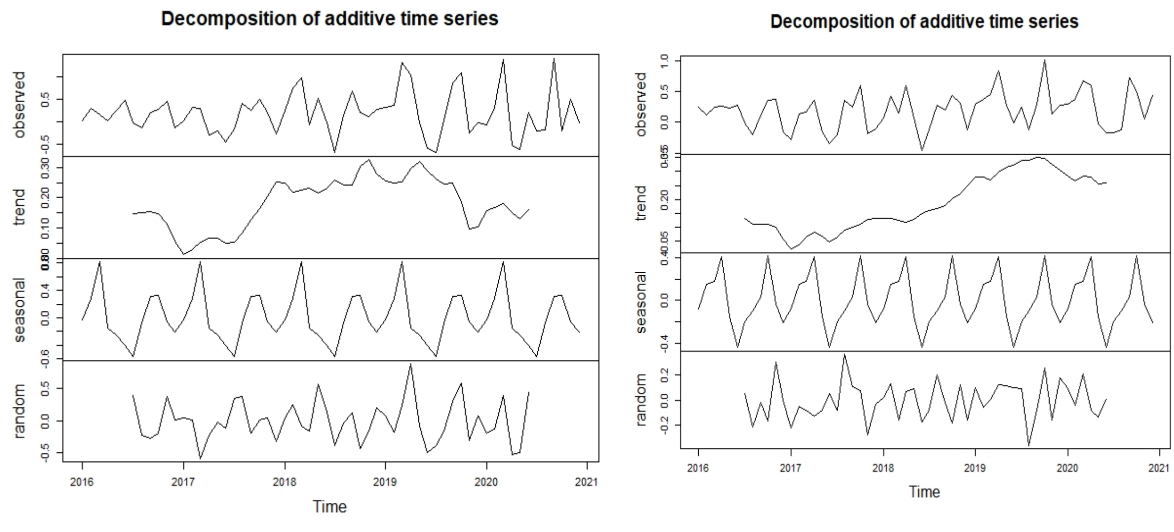


(a) (b)

Figure 1. (**a**) Inflation in Balikpapan; (**b**) Inflation in Samarinda

The above figures plot the inflation rate in Balikpapan and Samarinda. We can see that seasonality is very apparent in both figures. Valleys and troughs are markedly present. There are times when inflation surges distinctly and there are times when it decreases sharply. The data appear to be stationary. They begin in the middle and hover around the same mean numbers. The pattern of inflation in both cities are very alike. This shows that whenever prices surge in one city, the also rise in another city. In Samarinda, the trend is pretty visible. There is a slight upward trend of inflation year to year. On the other hand, the trend is barely visible in Balikpapan. We will see more about the trend after the models have been employed. Next we will decompose the data into trend and seasonal components. The figures below display the result of decomposition.

Figure 2. (**a**) Decomposition of Inflation in Balikpapan; (**b**) Decomposition of Inflation in Samarinda



The above figures both have seasonal components. The seasonality is regular and of obvious pattern. In certain times inflation increases and also in certain period it decreases. The trend is more visible in the city of Samarinda. There is a clear upward trend, before the inflation finally decreases. Balikpapan shows no clear trend. Sometimes it trends upward and in the other time it trends downward. The random component plays a significant role. We can see that errors also form the seasonality in both cities. Next, we proceed first with Holt-Winters exponential smoothing.

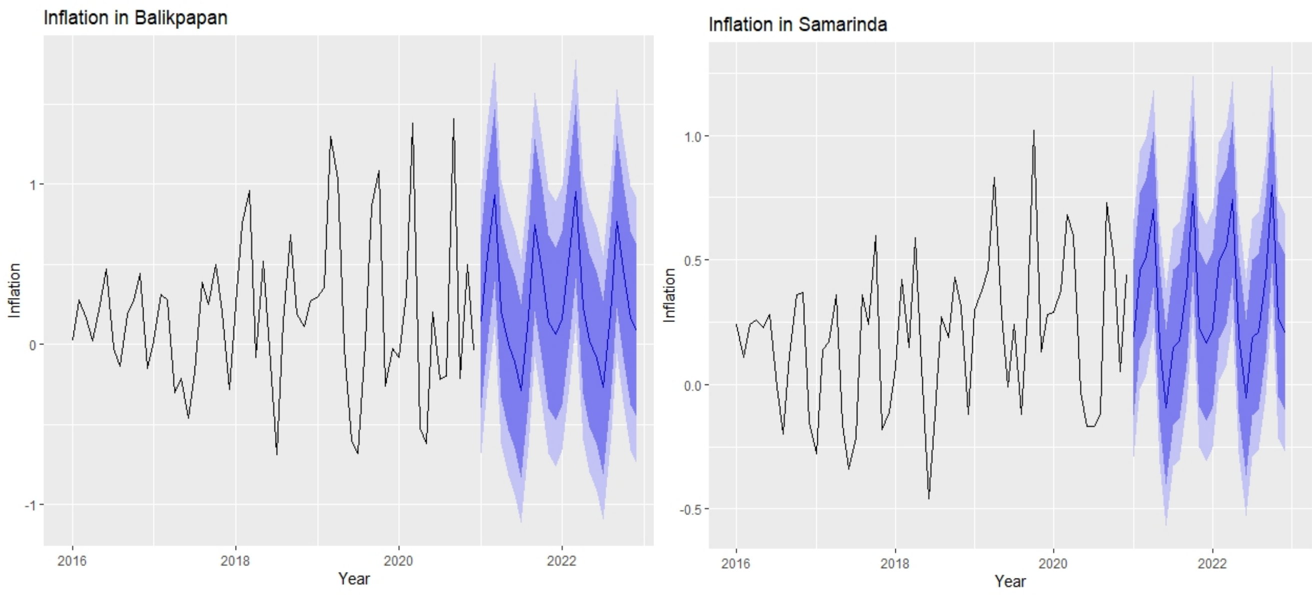
3.1 Holt-Winters Exponential Smoothing

Firstly, the inflation training data is fed into Holt-Winters model and then the estimation of parameters is conducted. Later, we will use the parameters from the estimation of training data to forecast results for January to September 2021. The table below shows the result of Holt-Winters estimation.

Table 1. Holt-Winters Parameters Estimation

City	Alpha	Beta	Gamma
Balikpapan	0.0004	0.0004	0.0006
Initial States (Balikpapan): l = 0.1322 b = 0.0019 s = -0.197; -0.1171; 0.1897; 0.4917; -0.0777; -0.5431; -0.361; -0.2446; -0.0385; -0.6899; 0.307; -0.0994 sigma = 0.4205			
Samarinda	0.0001	0.0001	0.0398
Initial States (Samarinda): l = 0.11 b = 0.0032 s = -0.1763; -0.1149; 0.4482; 0.0598; -0.1446; -0.1517; -0.4222; -0.1599; 0.4055; 0.2183; 0.1643; -0.1264			

The above table shows the parameters estimation results. For Balikpapan, α = 0.0004, β = 0.0004, and γ = 0.0004. While for Samarinda, the results are α = 0.0001, β = 0.0001, and γ = 0.0398. Indeed the trend component in Samarinda is much higher than that of Balikpapan (0.032 versus 0.0004) suggesting a clear trend in Samarinda as suggested by visual inspection earlier. The s numbers give us the parameters for each months. So there are 12 s numbers for each city for forecasting purpose. The figures below give us the visual results of forecasting usingHolt-Winters exponential Smoothing.



(a) **(b)**

Figure 3. (**a**) Forecast of Inflation in Balikpapan; (**b**) Forecast of Inflation in Samarinda

The above figures show that the forecast result for Samarinda is more stable and regular. Due to the apparent seasonality in the training data, the forecast reveals the seasonality in a more apparent way so that it has more visible pattern. Seasonality also exists for Balikpapan forecast. However, the pattern is much more random. The dark blue region shows the prediction interval of 80%, while the light blue is the 95% prediction interval. Overall, the Holt-Winters Exponential Smoothing succedded in picking up the seasonal components in both cities. The forecast results in number is shows by the following table.

Table 2. Holt-Winters Forecast Results

Time	Actual Balikpapan	Forecast Balikpapan	Actual Samarinda	Forecast Samarinda
Jan-21	0.02	0.1413	0.24	0.1878
Feb-21	0.28	0.5492	0.11	0.4576
Mar-21	0.16	0.9339	0.24	0.5148
Apr-21	0.02	0.2071	0.26	0.7046
May-21	0.25	0.0032	0.23	0.1612
Jun-21	0.47	-0.1113	0.28	-0.0912
Jul-21	-0.03	-0.2919	-0.01	0.1491
Aug-21	-0.14	0.1751	-0.2	0.1737
Sep-21	0.19	0.7464	0.12	0.3966
RMSE	**0.1213**		**0.0522**	

The column "Actual Balikpapan" shows the result of real inflation in Balikpapan from January 2021 until September 2021. These are the test data mentioned earlier. The same goes to the column "Actual Samarinda". Next to each column is the forecast results generated by Holt-Winters Exponential Smoothing. Inflation data are in decimal because it is a rate number. For Balikpapan in the month of June, the model predicts that the inflation rate will be negative. However, it is not supported by the test data. The real inflation in June shows a positive number. Negative inflations occur in July and August. The forecasts say they will happen in June and July. Hence Holt-Winters correctly predict that negative inflation happens is July, a pretty good result. For Samarinda, Holt-Winters predict that negative inflation will happen only once, in June. In reality, it happens twice, in July and August. Therefore, it incorrectly predicts the occurrence of negative inflation. The RMSE for both cities are 0.1213 and 0.0522 respectively. Although it does not predict correctly negative inflation for Samarinda, in general the deviation of forecast results from the actual number is very small. Next we continue with ARIMA model.

3.2 SARIMA

In testing ARIMA, we firstly map the ACF and PACF pattern of the SARIMA models for Balikpapan as shown in the below figures.

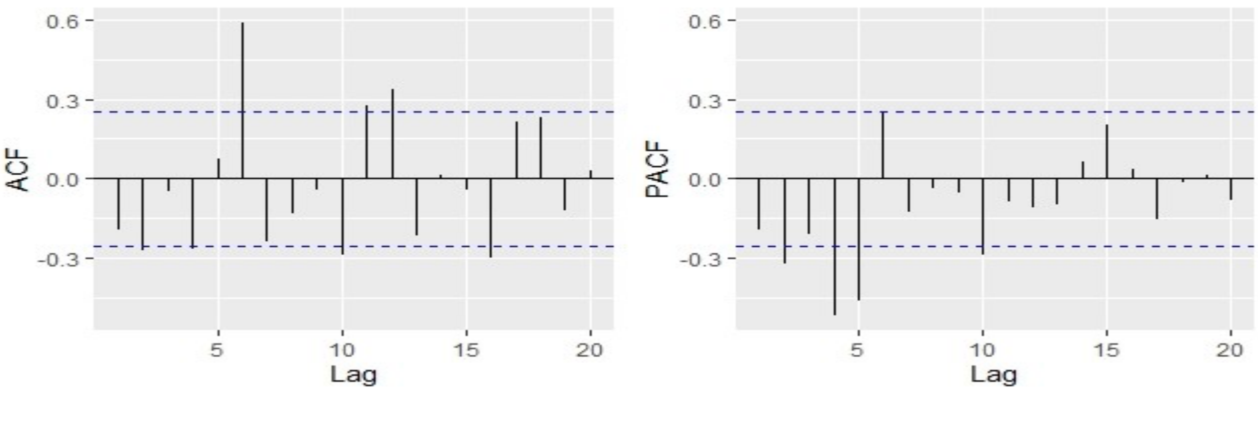


Figure 4. ACF and PACF of Balikpapan

ACF shows a significant correlation at lag 6. Only at this lag the correlation stands out among the rest of the lags. However, if we include 6 autoregressive components, the model might lose its parsimony. PACF shows the significant spike at lag 4 and 5. This is also very distant. Judging from the appearance of ACF and PACF, the SARIMA model usually requires one seasonal autoregressive as the appropriate model, namely the model (0,0,0)(1,0,0). Below is ACF and PACF of Samarinda.

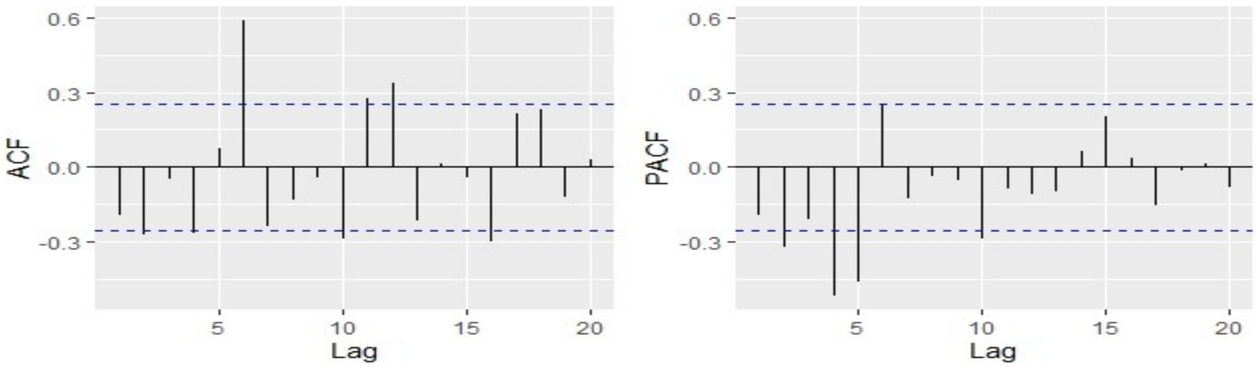


Figure 5. ACF and PACF of Samarinda

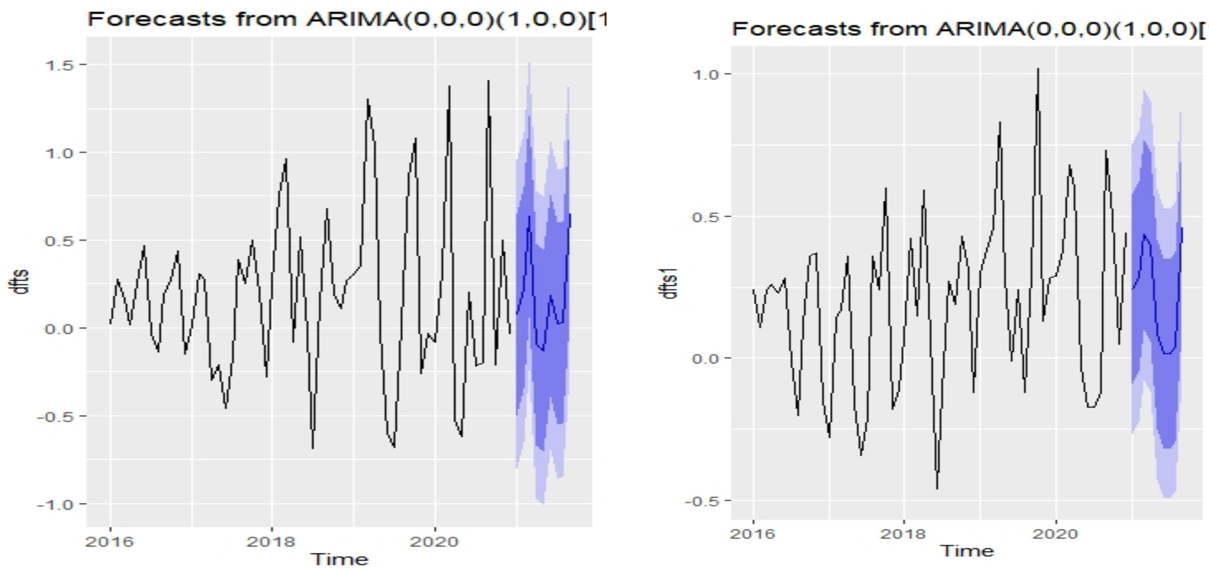
ACF and PACF of Samarinda show the same pattern of Balikpapan since both cities have almost similar inflation pattern. Significant spike at ACF happens at lag 6. PACF has many significant spikes at lag 2,4,5, and 10. In PACF, when significant spikes happen at distant lags, SARIMA models usually includes only one seasonal autoregressive components (0,0,0)(1,0,0). This will become clear when we run auto.arima in R Studio for model selection in the next step.

Having shown ACF and PACF, we search for the best model of SARIMA. Below is the table that shows SARIMA models for both cities.

Table 3. SARIMA Models

Balikpapan		**Samarinda**	
ARIMA (0,0,0)(1,0,0)	**SAR1**	**ARIMA (0,0,0)(1,0,0)**	**SAR1**
	0.3846 (0.1274)		0.4926 (0.1128)
	AIC = 79.91		AIC = 16.02

As predicted, both cities have the same SARIMA model, SARIMA (0,0,0)(1,0,0). This shows similar patterns will result in similar SARIMA models. The difference lies in the parameter for the seasonal autoregressive components (0.3846 versus 0.4926). The parameter in SAMARINDA is higher than that of Balikpapan, meaning previous year's month having larger impact 12 months later. Both parameters are statistically significant (t-value more than 3). The forecast results are shown below:



(a) **(b)**

Figure 6. (**a**) Forecast of Inflation in Balikpapan; (**b**) Forecast of Inflation in Samarinda

The forecast results by employing SARIMA models are shown above. The forecasts are much different than that of Holt-Winters Exponential Smoothing. This raises a very interesting issue to look to which method generates better forecast accuracy. The prediction interval for SARIMA is much thicker and wider than that of Holt-Winters. The dark blue signifies prediction interval of 80% and light blue shows interval of 90%. For both Balikpapan and Samarinda, SARIMA predicts less volatile inflation. There are no high spikes exist toward the end of 2021. The below table shows prediction in numbers.

Table 4. Holt-Winters Forecast Results

Time	**Actual Balikpapan**	**Forecast Balikpapan**	**Actual Samarinda**	**Forecast Samarinda**
Jan-21	0.02	0.0756	0.24	0.2428
Feb-21	0.28	0.2294	0.11	0.2871
Mar-21	0.16	0.6371	0.24	0.4349
Apr-21	0.02	-0.0938	0.26	0.3955
May-21	0.25	-0.1323	0.23	0.0851
Jun-21	0.47	0.1833	0.28	0.0162
Jul-21	-0.03	0.0217	-0.01	0.0162
Aug-21	-0.14	0.0294	-0.2	0.0408
Sep-21	0.19	0.6487	0.12	0.4595
RMSE	**0.2822**		**0.1979**	

The above table shows that for Balikpapan, SARIMA predicts negative inflation will happen in April and May. In reality, negative inflation happens in July and August. This is pretty inaccuraty in terms of timing. For Samarinda, it predicts no occurrence of negative inflation, whereas negative inflation happens in July and august. Again, in terms of negative inflation, the model fails to predict the timing of the occurrence. In general, forecast for Samarinda is more accurate due to lower RMSE (0.1979 versus 0.2822). The comparison between Holt-Winters Exponential Smoothing and SARIMA is shown below in terms of RMSE.

Table 5. Comparison of RMSE value between Models and Cities

	Holt-Winters	**SARIMA**
Balikpapan	0.1213	0.2822
Samarinda	0.0522	0.1979

The above table shows that Holt-Winters is more superior in forecasting the inflation in East Kalimantan. For both cities, Holt-Winters scores lower RMSE than SARIMA. It also predicts better the occurrence of negative inflation, a cyclical feature of inflation in which inflation sometimes hold positive number and sometimes negative. SARIMA model can pattern the seasonality since it uses seasonal autoregressive components but the performance is much lower than Holt-Winters. Therefore, the research recommends the use of Holt-Winters Exponential Smoothing in predicting inflation in East Kalimantan province.

4. Conclusions

The aim of this research is to compare forecasting accuracy of Holt-Winters and SARIMA models for major cities in East Kalimantan province. The two biggest cities in East Kalimantan are Balikpapan and Samarinda. East Kalimantan has been chosen as the relocation venue for Indonesian capital. This has made it important to spot light on how inflation can be forecasted in the province. The research results show that Holt-Winters Exponential Smoothing is able to forecast inflation better than SARIMA. It also better predicts the cyclicality in inflation. Future research can endeavor to compare inflation pattern before and after the relocation of Indonesian capital to East Kalimantan.

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