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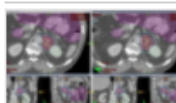
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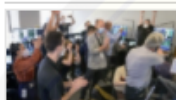
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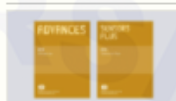
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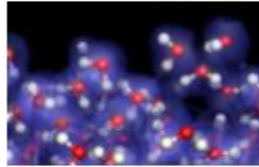
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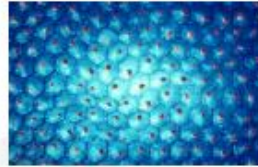
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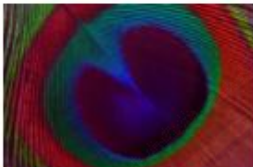
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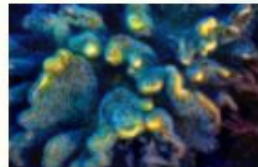
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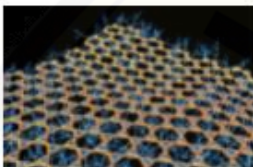
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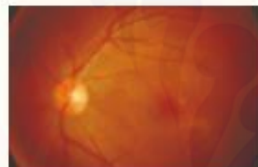
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### Impacts of Earthquakes on Consumer Price Index and Inflation: A Case Study in West Nusa Tenggara Province, Indonesia

Wahyu Wibowo<sup>1</sup>, Taly Purwa<sup>2</sup>, Elya Nabila Abdul Bahri<sup>3</sup>, Brodjol Sutijo Suprih Ulama<sup>1</sup> and Regina Niken Wilantari<sup>4</sup>

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## Abstract

Since Indonesia is located in the Ring of Fire, it is well understood that it has been highly vulnerable to earthquakes. Earthquakes can have many effects, including infrastructure damage and socioeconomic disruption. During 2009 to 2019, West Nusa Tenggara Province had the most earthquake frequencies. This paper aims to investigate the impacts of earthquakes on the regional economy of West Nusa Tenggara Province on the consumer price index (CPI) and inflation using the autoregressive integrated moving average with exogenous variables (ARIMAX) method. The data used in this paper are monthly CPI and the inflation in West Nusa Tenggara Province from January 2008 to December 2018. Based on the modeling process, two models for CPI and inflation are obtained. The forecast values of CPI are converted to inflation values to produce an indirect inflation forecasting, and the RMSE of four models are compared. The overall best model, with the smallest RMSE, for inflation is ARIMAX with stochastic trend and seasonal variable, which indicates that direct forecasting using inflation data is better than indirect inflation forecasting using CPI. From the best model, the earthquake effect, i.e., the real and estimated effects, has positive and negative effects on CPI and inflation with the magnitude of the real effect that is larger than the estimated effect. These two conditions indicate that the model cannot forecast well the earthquake effect. Therefore, much greater anticipation is necessary from local governments regarding the impact of the earthquake on the prices of essential commodities that is likely to occur in the future.

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## Impacts of Earthquakes on Consumer Price Index and Inflation: A Case Study in West Nusa Tenggara Province, Indonesia

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# Impacts of Earthquakes on Consumer Price Index and Inflation: A Case Study in West Nusa Tenggara Province, Indonesia

Wahyu Wibowo<sup>1\*</sup>, Taly Purwa<sup>2</sup>, Elya Nabila Abdul Bahri<sup>3</sup>, Brodjol Sutijo Suprih Ulama<sup>1</sup>, Regina Niken Wilantari<sup>4</sup>

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**Abstract.** Since Indonesia is located in the Ring of Fire, it is well understood that it has been highly vulnerable to earthquakes. Earthquakes can have many effects, including infrastructure damage and socioeconomic disruption. During 2009 to 2019, West Nusa Tenggara Province had the most earthquake frequencies. This paper aims to investigate the impacts of earthquakes on the regional economy of West Nusa Tenggara Province on the consumer price index (CPI) and inflation using the autoregressive integrated moving average with exogenous variables (ARIMAX) method. The data used in this paper are monthly CPI and the inflation in West Nusa Tenggara Province from January 2008 to December 2018. Based on the modeling process, two models for CPI and inflation are obtained. The forecast values of CPI are converted to inflation values to produce an indirect inflation forecasting, and the RMSE of four models are compared. The overall best model, with the smallest RMSE, for inflation is ARIMAX with stochastic trend and seasonal variable, which indicates that direct forecasting using inflation data is better than indirect inflation forecasting using CPI. From the best model, the earthquake effect, i.e., the real and estimated effects, has positive and negative effects on CPI and inflation with the magnitude of the real effect that is larger than the estimated effect. These two conditions indicate that the model cannot forecast well the earthquake effect. Therefore, much greater anticipation is necessary from local governments regarding the impact of the earthquake on the prices of essential commodities that is likely to occur in the future

## 1. Introduction

Indonesia has been highly vulnerable to earthquakes because of its location in the Ring of Fire and the confluence of four tectonic plates. According to [1], from 2009 to 2019, there have been 71,628 earthquakes in Indonesia. West Nusa Tenggara Province is one of the provinces that had the most earthquake frequencies, i.e., 6,802 earthquakes during that period. In fact, the highest number of monthly earthquakes during that period also occurred in West Nusa Tenggara Province in August 2018, i.e., 1,658 earthquakes. The existence of three active volcanoes, i.e., Mounts Rinjani, Sangeangapi, and Tambora, would increase the potential for earthquakes [2].



An earthquake can lead to several impacts, including infrastructure damage and socioeconomic disruption. It is known as the most significant disaster [3] and the costliest event, particularly in developed areas [4]. In July and August 2018, the major series of earthquakes in West Nusa Tenggara Province have caused 561 fatalities, destroying almost 110,000 houses and displacing over 396,000 people, i.e., approximately US\$854 million in damages and losses [5]. These impacts were also followed by a disruption on the supply chain and aggregated a demand that further impacts on the price of commodities, as stated by [6]. Consequently, investigating the impact of earthquakes is necessary to support the post-disaster policy.

Several previous studies have quantified the impact of disasters on macroeconomic variables that can be grouped based on the method they used. First, some studies utilized the econometric approach, i.e., [7] and [8] used a panel regression model and [9] used a dynamic panel regression model. Second, other studies utilized the time series approach, i.e., [10] and [11] used an intervention model based on the autoregressive integrated moving average (ARIMA) method [12]. Instead of using an intervention model, the present study utilizes the ARIMA with exogenous variables (ARIMAX) to investigate the impacts of earthquakes on the monthly consumer price index (CPI) and the inflation in West Nusa Tenggara Province. The modeling process from [13] is conducted, and the best model, i.e. the model with the smallest root-mean-square error (RMSE), for CPI and inflation will be used to quantify the impact of earthquakes, i.e., real effect and estimated effect.

## 2. Materials

The data used in the present study are the secondary monthly data of CPI, inflation, and earthquake incidents from January 2008 to December 2018 (132 observations). The CPI and inflation data are obtained from the Statistics Indonesia (Badan Pusat Statistik) West Nusa Tenggara Province (NTB). Conversely, the data of earthquake incidents in the Province of NTB are obtained from The National Disaster Management Authority (Badan Nasional Penanggulangan Bencana).

## 3. Methods

Before the modeling process, the baseline of the CPI data should be equalized first since the CPI data from the Statistics Indonesia have several baselines. The baseline used in the present study is 2012 (2012 = 100). The modeling process in the present study uses both ARIMAX models proposed by a previous study [13], i.e., ARIMAX model with stochastic trend and seasonal variable and ARIMAX model with deterministic trend and seasonal variable. The differences compared to this previous study, the present study does not incorporate dummy variables for calendar variation and includes dummy variables of earthquake incidents.

Therefore, the ARIMAX model with stochastic trend and seasonal variable used in the present study is

$$Y_t = \beta_1 G_t + \frac{\theta_q(B)\theta_Q(B^S)}{\phi_p(B)\Phi_P(B^S)(1-B)^d(1-B^S)^D} a_t \quad (1)$$

Conversely, the ARIMAX model with deterministic trend and seasonal variable used in the present study is

$$Y_t = \beta_1 G_t + \beta_2 t + \alpha_1 M_{1,t} + \dots + \alpha_{12} M_{12,t} + \frac{\theta_q(B)}{\phi_p(B)} a_t \quad (2)$$

$Y_t$  denotes the monthly CPI or inflation at time  $t$ . While,  $\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - \dots - \phi_p B^p$  is regular autoregressive polynomial with order  $p$ ,  $\theta_Q(B^S) = 1 - \theta_1 B^S - \theta_2 B^{2S} - \dots - \theta_P B^{PS}$  is seasonal autoregressive polynomials with seasonal period  $S$  and order  $P$ ,  $\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q$  is regular moving average polynomial with order  $q$  and  $\Phi_P(B^S) = 1 - \Phi_1 B^S - \Phi_2 B^{2S} - \dots - \Phi_P B^{PS}$  is seasonal moving average polynomial with order  $P$ .



... -  $\Phi_Q B^{QS}$  is seasonal moving average polynomials with seasonal period  $S$  and order  $Q$ .  $a_t$  is white noise process with  $E(a_t) = 0$ ,  $Var(a_t) = \sigma_a^2$ , and  $Cov(a_t, a_{t+k}) = 0$  for  $k \neq 0$ . The dummy variable of an earthquake incident is  $G_t = 1$  if earthquake occurred at time  $t$  and  $G_t = 0$  if there is no earthquake at time  $t$ . The deterministic trend variable  $t = 1, 2, 3, \dots, 132$  depicts the linear trend, and the deterministic seasonal variable  $M_{s,t}$  with  $s = 1, 2, \dots, 12$  depicts the seasonal pattern. As an example, in January,  $M_{1,t} = 1$ , whereas for other months,  $M_{1,t} = 0$ .

The modeling procedures for both ARIMAX models in the present study are as follows:

1. Remove the effect of earthquake incident from equation (1) by estimating the following:

$$Y_t = \beta_1 G_t + N_t \tag{3}$$

Then, remove the effect of earthquake incident and deterministic trend and seasonal variable from equation (2) by estimating the following:

$$Y_t = \beta_1 G_t + \beta_2 t + \alpha_1 M_{1,t} + \dots + \alpha_{12} M_{12,t} + N_t \tag{4}$$

2. Conduct Box–Jenkins ARIMA procedures for modeling the non-white noise  $N_t$  series.
3. Re-estimate both ARIMAX models in equations (1) and (2) using the order of ARIMA models obtained in step 2.
4. Conduct a significance test of parameters using backward elimination by eliminating nonsignificant parameters with the highest p-value one by one until all significant parameters remain in the model ( $\alpha = 0.05$ ).
5. Diagnostic check whether the residual is white noise and normally distributed, using Ljung–Box test [14]

$$Q = n(n + 2) \sum_{k=1}^K \frac{\hat{\rho}_k^2}{n - k} \tag{5}$$

and Kolmogorov–Smirnov test, respectively. Incorporate the outliers as dummy variables, i.e.,  $I_t^{(T)} = 1$  if  $t = T$  and  $I_t^{(T)} = 0$  if  $t \neq T$ , in the model if residuals have not normally distributed yet.

6. Convert the forecast value of CPI to forecast the value of inflation (indirect forecasting) using the following formula [15]:

$$\hat{Y}_{inf,t} = \left( \frac{\hat{Y}_{CPI,t} - \hat{Y}_{CPI,t-1}}{\hat{Y}_{CPI,t-1}} \right) \times 100 \tag{6}$$

7. Choose the best model for inflation data based on RMSE of the forecast value from indirect forecasting using CPI from step 6 and direct forecasting using inflation. The formula of RMSE is as follows:

$$RMSE = \sqrt{\frac{\sum_{t=1}^n (Y_t - \hat{Y}_t)^2}{n - p}} \tag{7}$$

where  $n$  is the number of observations, and  $p$  is the number of parameters in the model. The smallest value of RMSE indicates the best model.

8. Estimate the best model without dummy variable of earthquake incident  $G_t$  and get the forecast value  $\hat{Y}_{-G,t}$ . The impact of earthquakes on inflation is measured using the real effect, i.e.,  $Y_t - \hat{Y}_{-G,t}$ , and the estimated effect, i.e.,  $\hat{Y}_t - \hat{Y}_{-G,t}$ . The estimated effect can be used to estimate the impact if earthquakes occur in a certain month outside the reference time of the present study.

#### 4. Results and Discussion

##### 4.1. Identification of Time Series Plot

The time series plot of CPI and inflation with time when an earthquake occurs (vertical dashed lines) is presented in Figure 1. Visually, the series of CPI has an increasing linear trend, whereas the series of inflation does not show a linear trend because it is the growth value of the CPI.

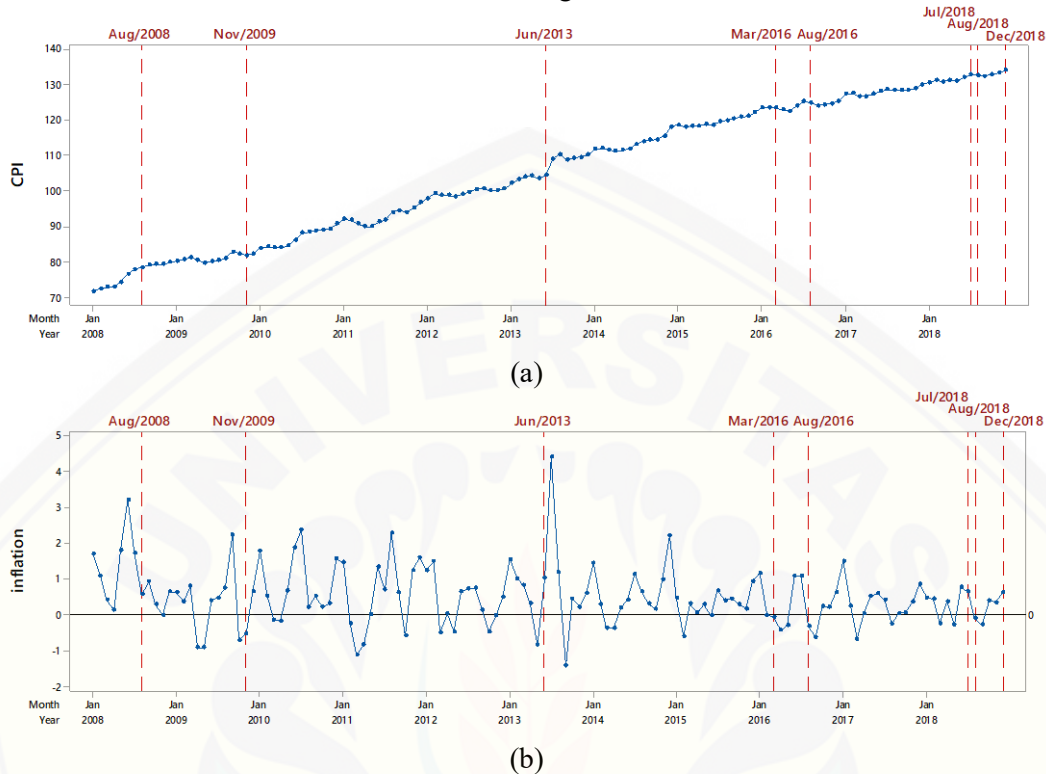


Figure 1. Time Series Plot of CPI (a) and Inflation (b)

As shown in Figure 2, the monthly seasonal pattern in the CPI and inflation is visually different. In the CPI data, the monthly seasonal pattern is not clearly visible, and only a slight increase in the mean is seen from July to December. Conversely, the monthly seasonal pattern in the inflation data is very clear. The inflation rate is relatively higher in December, January, June, and July.

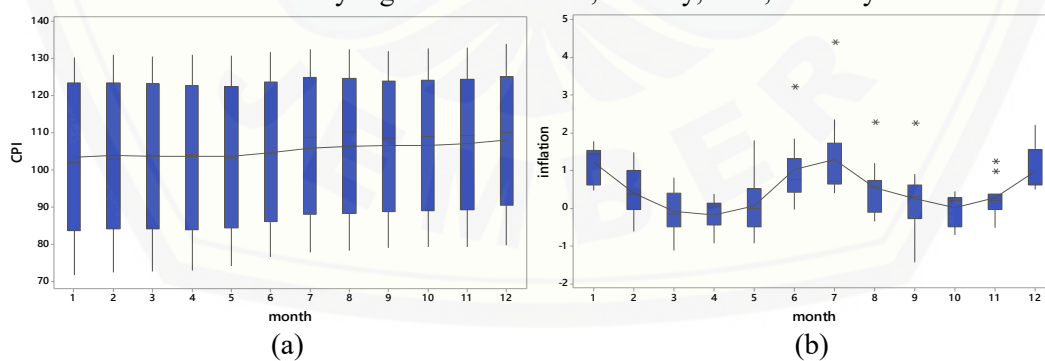


Figure 2. Boxplot of CPI (a) and Inflation (b)

#### 4.2. ARIMAX Modeling

From the modeling process of the CPI data, the model obtained are ARIMAX model with deterministic trend and seasonal variable with residuals  $N_t$  following the ARIMA(2,0,[2]) called the ARIMAX deterministic-1 and ARIMA(1,0,[1,4,5,6]) called the ARIMAX deterministic-2. While for inflation data, the model obtained are ARIMAX model with stochastic trend and seasonal variable with residuals  $N_t$

following the ARIMA([1,2,5,23],0,[1,3]) called the ARIMAX stochastic and ARIMAX model with deterministic trend and seasonal variable with residuals  $N_t$  following the ARIMA(3,0,0) called the ARIMAX deterministic. All these models obtained and details of the estimation results are presented below in Table 1.

**Table 1.** Estimation Results of the ARIMAX Model for CPI and Inflation

Variable	CPI				Inflation			
	ARIMAX Deterministic-1		ARIMAX Deterministic-2		ARIMAX Stochastic		ARIMAX Deterministic	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
$G_t$	-0.0557	0.6976	0.0542	0.7391	-0.0495	0.8070	-0.2050	0.4197
$t$	0.4991	<.0001	0.5113	<.0001				
$M_{1,t}$	71.2250	<.0001	71.0032	<.0001			1.1322	<.0001
$M_{2,t}$	71.0501	<.0001	70.8984	<.0001				
$M_{3,t}$	70.5569	<.0001	70.3273	<.0001				
$M_{4,t}$	69.9344	<.0001	69.7378	<.0001				
$M_{5,t}$	69.4788	<.0001	69.2883	<.0001				
$M_{6,t}$	69.9729	<.0001	69.7691	<.0001			0.9922	<.0001
$M_{7,t}$	70.7912	<.0001	70.4752	<.0001			1.3644	<.0001
$M_{8,t}$	70.8469	<.0001	70.5908	<.0001			0.4861	0.0230
$M_{9,t}$	70.5506	<.0001	70.4282	<.0001				
$M_{10,t}$	70.0946	<.0001	69.8485	<.0001				
$M_{11,t}$	69.9435	<.0001	69.6952	<.0001				
$M_{12,t}$	70.4859	<.0001	70.2719	<.0001			0.9386	<.0001
$Y_{t-1}$	1.4157	<.0001	0.8941	<.0001	1.0163	<.0001	0.2970	0.0013
$Y_{t-2}$	-0.4311	<.0001			-0.5504	<.0001	-0.2519	0.0075
$Y_{t-3}$							0.2114	0.0199
$Y_{t-5}$					0.2595	<.0001		
$Y_{t-23}$					0.1316	0.0138		
$a_{t-1}$			-0.3799	<.0001	0.5662	<.0001		
$a_{t-2}$	0.3254	0.0025						
$a_{t-3}$					-0.5125	<.0001		
$a_{t-4}$			-0.2519	0.0083				
$a_{t-5}$			-0.3003	0.0048				
$a_{t-6}$			-0.3123	0.0011				
$I_t^{(21)}$	0.9092	0.0048			2.3982	<.0001		
$I_t^{(43)}$	-0.9078	0.0031						
$I_t^{(44)}$					1.6521	0.0005		
$I_t^{(50)}$	0.9251	0.0025						
$I_t^{(53)}$					-1.1037	0.0167		
$I_t^{(67)}$	1.0564	0.0034	1.2382	0.0016	2.4632	<.0001		
$I_t^{(69)}$	-1.2497	0.0004	-1.5772	<.0001	-1.7301	0.0007		

The results above can be written in the following equations:

The ARIMAX deterministic-1 for CPI

$$\begin{aligned}
 Y_t = & -0.0557G_t + 0.4991t + 71,2250M_{1,t} + 71.0501M_{2,t} + 70.5569M_{3,t} \\
 & + 69.9344M_{4,t} + 69.4788M_{5,t} + 69.9729M_{6,t} + 70.7912M_{7,t} \\
 & + 70.8469M_{8,t} + 70.5506M_{9,t} + 70.0946M_{10,t} + 69.9435M_{11,t} \\
 & + 70.4859M_{12,t} + 0.9092I_t^{(21)} - 0.9078I_t^{(43)} + 0.9251I_t^{(50)} \\
 & + 1.0564I_t^{(67)} - 1,2497I_t^{(69)} + \frac{(1 - 0.3254B^2)}{(1 - 1.4157B + 0.4311B^2)} a_t
 \end{aligned} \tag{8}$$

The ARIMAX deterministic-2 for CPI

$$\begin{aligned}
 Y_t = & 0.0542G_t + 0.5113t + 71.0032M_{1,t} + 70.8984M_{2,t} + 70.3273M_{3,t} + \\
 & 69.7378M_{4,t} + 69.2883M_{5,t} + 69.7691M_{6,t} + 70.4752M_{7,t} + 70.5908M_{8,t} + \\
 & 70.4282M_{9,t} + 69.8485M_{10,t} + 69.6952M_{11,t} + 70.2719M_{12,t} + 1.2382I_t^{(67)} - \\
 & 1.5772I_t^{(69)} + \frac{(1+0.3799B+0.2519B^4+0.3003B^5+0.3123B^6)}{(1-0.8942B)} a_t
 \end{aligned} \tag{9}$$

The ARIMAX stochastic for inflation

$$\begin{aligned}
 Y_t = & -0.0495G_t + 2.3982I_t^{(21)} + 1.6521I_t^{(44)} - 1.1037I_t^{(53)} + 2.4632I_t^{(67)} \\
 & - 1.7301I_t^{(69)} \\
 & + \frac{(1 - 0.5662B + 0.5125B^3)}{(1 - 1.0163B + 0.5504B^2 - 0.2595B^5 - 0.1316B^{23})} a_t
 \end{aligned} \tag{10}$$

The ARIMAX deterministic for inflation

$$\begin{aligned}
 Y_t = & -0.2050G_t + 1.1322M_{1,t} + 0.9922M_{6,t} + 1.3644M_{7,t} + 0.4861M_{8,t} \\
 & + 0.9386M_{12,t} + \frac{1}{(1 - 0.2970B + 0.2519B^2 - 0.2114B^3)} a_t
 \end{aligned} \tag{11}$$

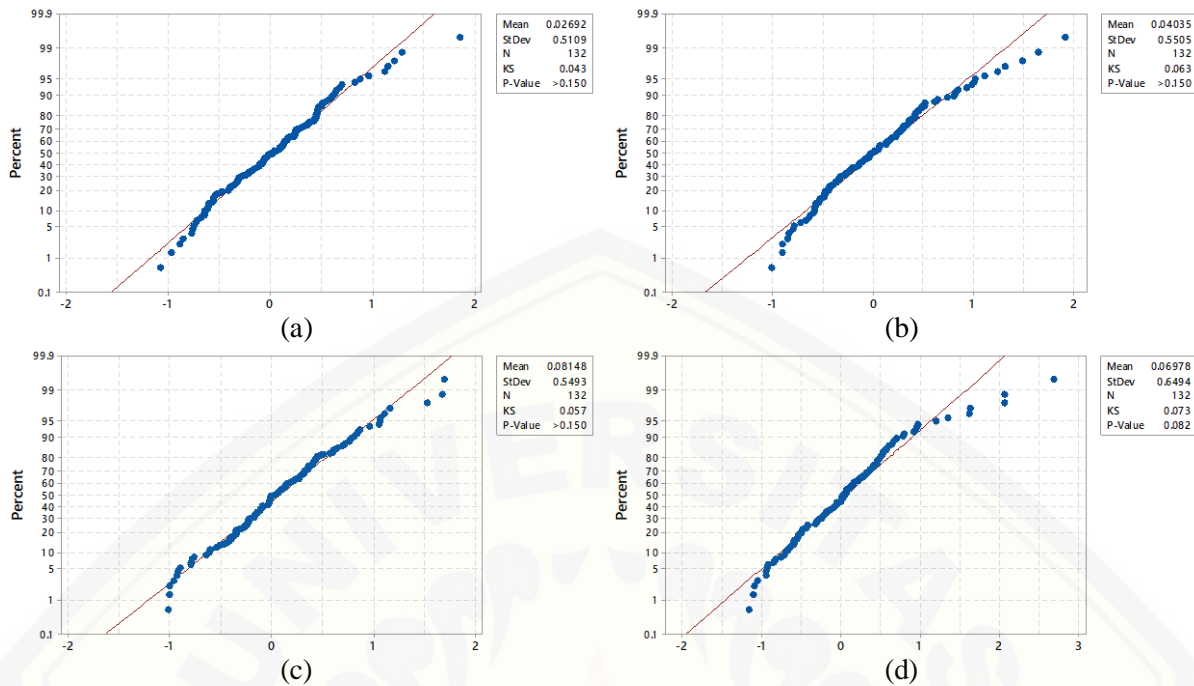
Note that the dummy variable of earthquake incident  $G_t$  in the four models above is not statistically significant (P-value >  $\alpha=0.05$ ) as provided in Table 1. However, this variable is not removed in the backward elimination process since it is used to measure the earthquake impact in the next subsection.

**Table 2.** Ljung-Box Tests Results

to Lag	CPI						Inflation					
	ARIMAX Deterministic-1			ARIMAX Deterministic-2			ARIMAX Stochastic			ARIMAX Deterministic		
	Chi-Square	df	P-value	Chi-Square	df	P-value	Chi-Square	df	P-value	Chi-Square	df	P-value
6	4.44	3	0.2178	2.52	1	0.1122	.	.	.	3.33	3	0.3441
12	12.18	9	0.2035	5.74	7	0.5704	3.98	6	0.6798	9.23	9	0.4159
18	12.18	15	0.1405	12.12	13	0.5178	8.49	12	0.7454	13.59	15	0.5568
24	29.72	21	0.0978	17.29	19	0.5700	10.39	18	0.9185	19.75	21	0.5372

Note: df is degree of freedom





**Figure 3.** The Normal Probability Plot of Residuals from The ARIMAX Deterministic-1 (a), ARIMAX Deterministic-2 (b), ARIMAX Stochastic (c), and ARIMAX Deterministic (d)

From the diagnostic checking process, the Ljung-Box tests in Table 2 show that the residuals produced by all four models above are white noise indicated by  $P\text{-value} > \alpha = 0.05$  until lag 24. The normal probability plots in Figure 3 also show that the residuals for each model do not departed too far from normality supported by Kolmogorov–Smirnov test that has  $P\text{-value} > \alpha = 0.05$ .

#### 4.3. Performance Comparison

First, the RMSE of two ARIMAX models of CPI in equations (8) and (9) are compared. The best model for CPI data is ARIMAX deterministic-1, which produces smaller RMSE than the ARIMAX deterministic-2. These result shows that more complex model produces better forecasting performance, although not necessarily [16]. After converting the forecast values of CPI from these two models to forecast values of inflation, the RMSEs from all of the models are compared again. The result shows that the overall best model, i.e., the inflation model with the smallest RMSE, is the ARIMAX deterministic. This indicates that in this study direct forecasting using inflation data is more recommended than indirect inflation forecasting using CPI data.

**Table 3.** Performance Comparison of ARIMAX Models

Variable	ARIMAX model	Number of parameters	RMSE	
			CPI	Inflation
CPI	Deterministic-1	22	0.5583*	0.7469
	Deterministic-2	21	0.5997	0.8526
Inflation	Stochastic	12		0.5802**
	Deterministic	9		0.6741

Note: \*) the best model of CPI, \*\*) the best model of inflation

4.4. Measuring the Impact of Earthquakes on CPI and Inflation

Before measuring the impact of an earthquake, the forecast values are generated from the best model for CPI, i.e., the ARIMAX deterministic-1, and the best model for inflation, i.e., the ARIMAX stochastic, both without variable  $G_t$  to calculate the real effects  $Y_t - \hat{Y}_{-G,t}$  and estimated effects  $\hat{Y}_t - \hat{Y}_{-G,t}$  of the earthquake.

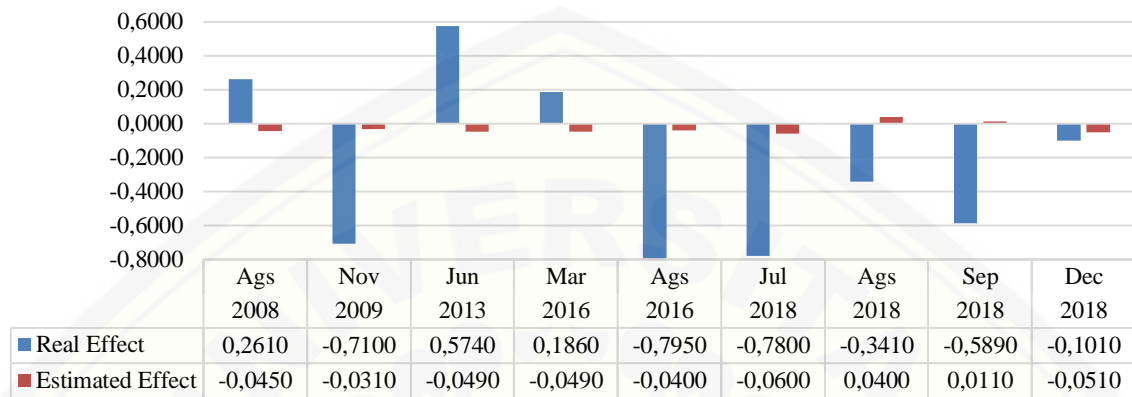


Figure 4. Real and Estimated Effect of Earthquakes on CPI

Generally, the real effect is much larger and more varied than the estimated effect of earthquakes on the CPI. The highest real effect is 0.5740, which occurred in June 2013, and the lowest real effect is  $-0.7950$ , which occurred in August 2016. Conversely, for the estimated effect, the highest value is 0.0400 and the lowest value is  $-0.0600$ , which occurred in August 2018 and July 2018, respectively. The direction of the real effect does not show a certain pattern. Meanwhile, the estimated effects generally show negative impact on CPI, except for that in August and September 2018. There are several months with real and estimated effects that have different directions, i.e., in August 2008, June 2013, March 2016, and August and September 2018.

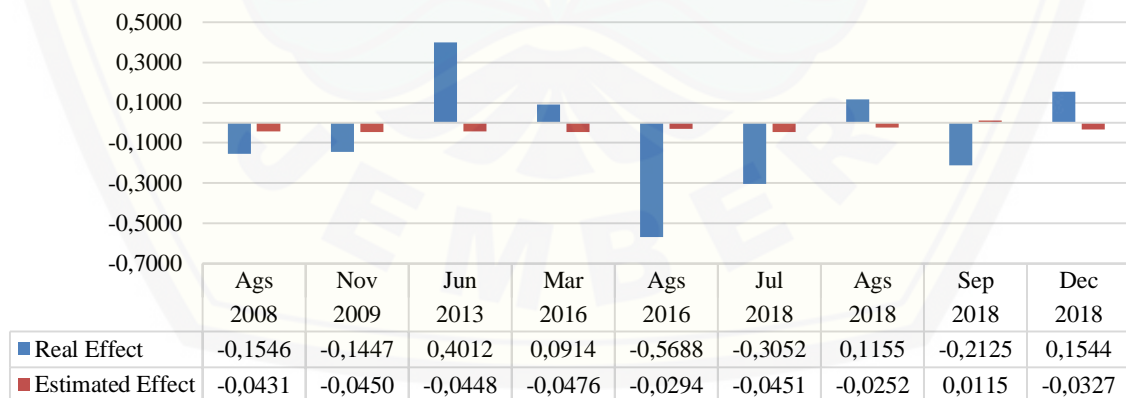


Figure 5. Real and Estimated Effects of Earthquakes on Inflation

The characteristic of real and estimated effects on inflation (Figure 5) is very similar to the real and estimated effects on CPI (Figure 4), i.e., the real effect is much larger and more varied than the estimated effect, the direction of the effects does not have a certain pattern, and the highest and lowest real effects that occurred in the same month as in the CPI case, i.e. in June 2013 and August 2016, respectively. The only difference is the highest estimated effect that occurred in September 2018 and the lowest estimated effect that occurred in March 2016.

From the results above, the real effect is much larger than the estimated effect, which indicates that the model cannot investigate well the earthquake effects outside the reference time of the present study, i.e., 2008–2018. The directions of these two effects are found in both ways, i.e., positive and negative impacts, that in line with the result from a previous study [17]. These two conditions are confirmed by the insignificant dummy variable of earthquake incident in all ARIMAX models of CPI and inflation that is consistent with a previous study [8].

## 5. Conclusion

Both the ARIMAX model of CPI, i.e., deterministic-1 and deterministic-2, show that the deterministic trend and seasonal variable are statistically significant. However, the ARIMAX deterministic for inflation, the significant monthly seasonal variables are only in January, June, July, August, and December, confirmed by the monthly boxplot of inflation that has higher values range in these months compared to other months. According to the RMSE value, the best model for CPI is ARIMAX deterministic-1, and the overall best model for inflation is ARIMAX stochastic. The single dummy variable of earthquake used in this study is not sufficient to depict the impact of earthquake on CPI and inflation indicated by statistically insignificant dummy variable, the estimated effects that not close enough to the real effects, and there is no co-movement of these two effects. Therefore, there is a need for much greater anticipation from local governments regarding the impact of the earthquake on the price volatility of commodities in inflation measurement. For future study, the impact of earthquakes needs to investigate separately by using a different dummy variable for each earthquake event. This strategy aims to see which earthquakes are significant and which are not.

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