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Dynamic Relationship Among Crude Oil Price, Stock Price, and Exchange Rates in Indonesia

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Abstract

This study aimed to examine the causal relationship among oil prices, JCI stock prices, and exchange rates in Indonesia. Observational data were from the period 2015M01-2020M06. The research analysis model used was Toda-Yamamoto (1995) causality test. The results showed a two-way causal relationship between exchange rates and oil and a one-way relationship between exchange rates and stocks. There was a one-way effect of stocks on oil. Stock shocks occurred due to the influence of the stocks themselves—only 10 percent of the exchange rates and 0.62 percent of the oil price. Meanwhile, oil prices experienced shocks from stocks of 35.95 percent and exchange rates of 20.87 percent. Changes were found in the exchange rates because stocks were 57.21 percent and oil prices were 11.27 percent. It is recommended to control the exchange rates so that the economy becomes stable, explore oil in the country or use renewable energy technology to break away from dependence on fossil oil, and maintain the value of stocks to be strong and stable.

Keywords: Oil prices, stocks, exchange rates, TY causality

1. Introduction

In today's modern era, crude oil is an important commodity, and many countries greatly depend on it to boost their economy. Oil contributes to economic growth and economic activities such as employment and macroeconomics (Kisswani et al., 2019; Bhatia & Basu, 2021). The current price per barrel is a country's reference for crude oil consumption. The higher the price of crude oil, the less consumption of the oil, and vice versa, where the lower the oil price, the more a country consumes the oil.

The price of oil is not always sticky. Changes in oil prices are very dependent on demand and supply. Changes in oil prices often increase or decrease and even tend to be extreme due to external factors (Figure 1b). Among them are war, economic crisis, and oil embargo by OPEC (Jobling & Jamasb, 2017). The recent external factor was the COVID-19 pandemic which caused oil prices to drop drastically because all countries carried out lockdowns, and demand fell to reduce the rate of the coronavirus.

Issues regarding the price of crude oil are often associated with stock prices. From a theoretical point of view, oil has a relationship with the stock market through stock valuation channels, monetary channels, output channels, fiscal channels, and uncertainty channels (Gomez-Gonzalez et al., 2020). Bhatia & Basu (2021) states that if oil prices increase, industrial shares will increase. In addition, changes in oil prices also provide a positive signal for the latest energy, which is a competitor (Reboredo et al., 2016). The development of Jakarta Composite Index (JCI) stocks in Indonesia so far has tended to experience a positive trend. Figure 1.2 explains that from 2015M01 to 2019M12, the JCI stock value continued to grow. However, in the 2020M01 period, the share price plunged drastically due to the COVID-19 pandemic. After the pandemic period passed, the JCI share value continued to recover until the 2022M06 period (Figure 1a). The effect of crude oil on stocks is also believed to be a succession of other macroeconomic variables, one of which is the exchange rates.

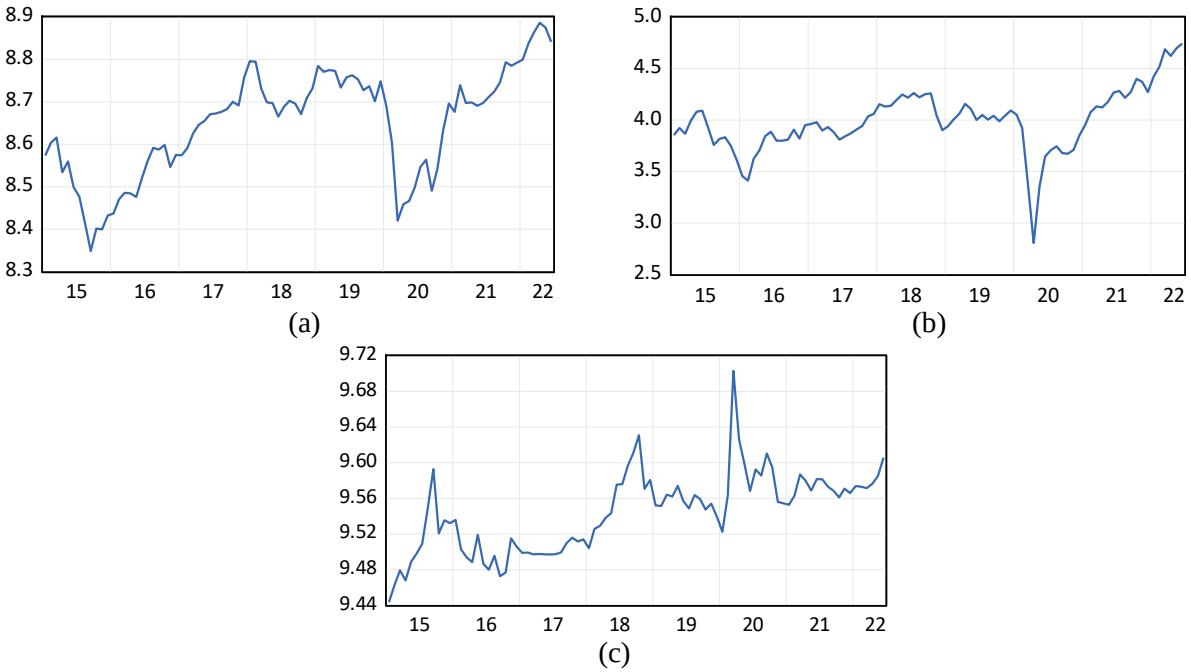

Figure 1: (a) JCI Stock Trend (b) Oil Price Trend
(C) Rupiah Exchange Rate Trend (1USD)
Source: Author's work

Previous researchers believed that exchange rates and stock prices have a strong relationship. One of the references is that the exchange rates' appreciation will encourage foreign institutional investors' entry, causing an increase in demand and stock prices (Kumar, 2019). Depreciation of the domestic exchange rates, on the other hand, will stimulate exports and reduce imports (Xie et al., 2020). According to research data, the value of the rupiah currency against the dollar is not always stable (Figure 1c). This also shows that the local currency tends to be vulnerable to other currencies, such as the US dollar. Indonesia is an importing country and relies on the import sector to boost the domestic economy. One of them is using dollars for import activities to buy technology. However, the use of uncontrolled imports will affect economic growth.

Based on the previously stated background, studying the relationship between oil prices, exchange rates, and stock prices is an important and very interesting topic. Especially in Indonesia, based on the knowledge of researchers, very few studies have been conducted. In addition, these variables will have a very large influence on the economy as the economy continues to grow.

2. Literature Review

This section describes previous research literature on oil prices, stocks, and exchange rates. The selected literature deals with the causality method. In the first study between stock prices and exchange rates, Gomez-Gonzalez et al. (2020) analyzed the relationship between stock price returns and oil in several countries using the Time-Varying Granger method. The findings show that oil and stock prices have a two-way causality relationship after 2010. Bhatia & Basu (2020) tested these two components in emerging countries using the quantile causality method and found a two-way relationship between oil prices and stocks, especially in stocks for each sector.

A similar method is also used by Xiao & Wang (2020). The study results show that changes in world oil prices affect stocks in Europe, America, and Asia and vice versa (two-way causality). Meanwhile, Tuna et al. (2021) used Islamic stocks. This study used an asymmetric model. The results show that oil prices respond more to stocks in the financial, health, technology, and basic materials sectors. Jiang et al. (2021) examined the relationship between oil prices and renewable energy stocks with quantile causality. A causal relationship occurs between oil prices and renewable energy stocks compared to gas and coal. A recent study by Li et al. (2022) using geopolitical risk in oil and stock prices with a non-linear causality method found that oil and stock prices have a two-way relationship due to geopolitics.

Next is the literature on the relationship between oil prices and exchange rates. Brahmasrene et al. (2014) used Vector Autoregressive (VAR) in OPEC and non-OPEC countries. The results show that the exchange rates have a one-way effect on oil prices in 3 to 7 months, and oil prices have a one-way effect on the exchange rates in 8 to 12 months. Sayyedi (2017) conducted research in India with VAR and found that oil prices and exchange rates have a two-way relationship. In different countries, MENA has been studied by Nouria (2019) using an asymmetric non-

causality method. The study's findings explain that a positive shock to oil prices has a one-way effect on stocks in Saudi Arabia, which applies to a negative shock.

Kisswani et al. (2019) also carried out the asymmetric method in the ASEAN-5 regions using the Toda-Yamamoto approach. Two-way causality results (positive & negative) occur in Indonesia, and negative causality occurs in Malaysia. One way effect occurs in the Philippines, Singapore, and Thailand. For cases in the US-Canada, a study by Jung et al. (2020) found that the exchange rate has a one-way effect on oil prices, both positive and negative. Albulescu & Ajmi (2021) examined the relationship between oil prices and exchange rates in 60 countries using the Time-Varying Granger Causality method. The study found a two-way relationship between oil prices (WTI) and the effective exchange rate. The most recent study conducted by Jiang et al. (2022) in 11 selected countries using the linear causality method found a two-way relationship between oil prices and the exchange rate (Brazil and Russia), a one-way effect of the exchange rate on oil prices (UK, Korea, Canada), and no two-way relationship (Europe, India, Japan, Norway, Mexico, South Korea).

Next is the literature between stock prices and exchange rates. Tudor & Popescu-Dutaa (2012) tested the causality relationship between the two in 13 developed countries. The method used was Pairwise Granger. The results found a one-way effect of stocks on exchange rates. Śmiech & Papiez (2013) retested it in Europe using VAR. Their research found a two-way relationship between exchange rates and stock prices in European countries. Meanwhile, Liang et al. (2013) conducted research with the ASEAN-5 as the sample. The method used was the causality panel. The results found a one-way effect of the exchange rate on the stocks in the short and long term.

Kumar (2019) used the asymmetric method in India and found that Indian exchange rates and stocks have a two-way relationship. A recent study on this theme was also conducted by Xie et al. (2020) and Nusair & Olson (2022). Xie et al. (2020) used an asymmetric method in 20 selected countries. This study found a one-way effect of stocks on exchange rates and between exchange rates and stocks. Meanwhile, Nusair & Olson (2022) used the G7 countries as the sample using the linear Granger method. The findings of this study explain that stocks have a one-way effect on exchange rates.

Based on the findings of previous studies, the researchers made several hypotheses, including:

H_1: Oil and stock prices have a two-way causal relationship.
H_2: Oil prices and the exchange rates have a two-way causal relationship.
H_3: Stocks and exchange rates have a two-way causal relationship.

3. Materials and Methods

3.1. Materials

This research was conducted within the scope of the study of crude oil prices, JCI stocks, and the exchange rates in Indonesia. Data observations were taken from 2015M01-2022M06 with a total sample of 90 observations. Data on crude oil and rupiah exchange rates accessed from FRED St. Louis (https://fred.stlouisfed.org). While the JCI data comes from yahoo finance (https://finance.yahoo.com). This sample selection was chosen because the three variables fluctuated

3.2. Methods

Methods include: the stages and formulas that are used in data analysis, arranged sequentially step by step. The research aims to examine the causal relationship of the variables studied. The analytical model used is Toda-Yamamoto (1995) or abbreviated as TY. The reason for using this method is that the previous Granger concept was started by not carrying out a stationarity test. Then the stationarity test developed so that two models of causality were formed. First, for all levels of stationarity, the best causality method is Vector Autoregressive (VAR). Second, if the stationary at the first difference level is co-integration, then the Vector Error Correction Model (VECM) is used. However, a problem occurs if the stationarity is found to be different. TY tries to solve this problem with his non-causality granger concept. The TY method is unique because the causality test can be carried out if the stationarity is different. Then there is no need to do co-integration testing because it is robust. And the model is done with Ordinary Least Square (OLS) estimation (Tastan, 2015).

The beginning of TY model, we begin with the Granger VAR causality form by Sim (1972) as follows:

$$x_t = a_0 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{j=1}^{p} \gamma_j z_{t-j} + \varepsilon_t \quad (1)$$

$$y_t = b_0 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{j=1}^{p} \gamma_j z_{t-j} + \varepsilon_t \quad (2)$$

$$z_t = c_0 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{j=1}^{p} \gamma_j z_{t-j} + \varepsilon_t \quad (3)$$

Furthermore, Toda & Yamamoto (1995) and Dolado & Lütkepohl (1996) modified the granger to non-granger model into equations (4), (5), and (6) by adding $d_{max,}$ which is the maximum of integration. These variables are required as exogenous variables. Dolado & Lütkepohl (1996) suggest calculating the statistics of this model with the Wald Test. The TY model equation is as follows:

$$x_t = a_0 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{j=1}^{p} \gamma_j z_{t-j} + \sum_{k=p+1}^{p+d_{max}} \alpha_k x_{t-k} + \sum_{k=p+1}^{p+d_{max}} \beta_k y_{t-k} + \sum_{k=p+1}^{p+d_{max}} \gamma_k z_{t-k} + \varepsilon_{1t} \quad (4)$$

$$y_t = b_0 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{j=1}^{p} \gamma_j z_{t-j} + \sum_{k=p+1}^{p+d_{max}} \alpha_k x_{t-k} + \sum_{k=p+1}^{p+d_{max}} \beta_k y_{t-k} + \sum_{k=p+1}^{p+d_{max}} \gamma_k z_{t-k} + \varepsilon_{2t} \quad (5)$$

$$z_t = c_0 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{j=1}^{p} \gamma_j z_{t-j} + \sum_{k=p+1}^{p+d_{max}} \alpha_k x_{t-k} + \sum_{k=p+1}^{p+d_{max}} \beta_k y_{t-k} + \sum_{k=p+1}^{p+d_{max}} \gamma_k z_{t-k} + \varepsilon_{3t} \quad (6)$$

Where x_t (*oil*) is the price of oil (measured by the spot price of WTI USD/barrel), and y_t (stk) is the JCI (composite stock price index based on the closing price), and z_t (exr) is the rupiah exchange rate (the nominal value of the rupiah against 1 USD dollar). a_0, b_0 and c_0 are constants, α_j is the coefficient value of each lag for variable X, β_j is the coefficient value of each lag for variable Y, and γ_j is the coefficient value of each lag for variable Z. $\alpha_k, \beta_k, \gamma_k$ are the maximum integration coefficient values for variable X, and β_k is the maximum integration coefficient value for variable Y. p is the optimal lag based on the Akaike Information Criterion (AIC).

The results of the causality test have four forms, including the following: (Gujarati & Porter, 2009):

a. *Unidirectional causality.* It indicates that there is a one-way influence of X on Y.
b. *Conversely.* It indicates that the result is the same as unidirectional; that is, it affects one direction, but the opposite occurs, namely, Y to X.
c. *Feedback or bilateral causality*. It indicates that there is a bidirectional relationship between variables X and Y.
d. *Independence.* Indicates that there is no relationship between the variables X and Y,

In addition, this study also uses the Impulse Response Function (IRF) to see the shocks of each variable and the Forecast Error Variant Decomposition (FEVD) to see the contribution that will shake the variables. The research analysis used steps from the studies of Singh & Singh (2016), Obadiaru et al. (2020), and Soytas et al. (2022). The research work steps are presented in Figure 2.

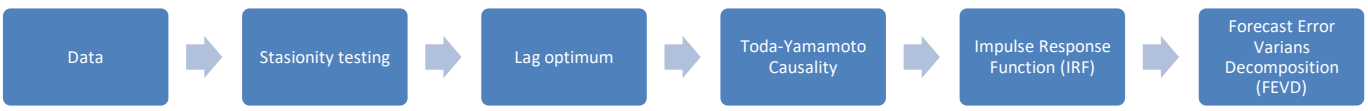

Figure 2: Framework research.

4. Results and Discussion

The initial stage in analyzing causality is stationarity testing. This test must be done because it relates to the tools used. Most macroeconomic data are disturbed or unstable due to other economic factors. Researchers used the ADF method to test the stationarity of the data. Table 1 shows two stages tested at level and the first difference level. If the data is significant at level, then the data is said to be stationary at level. If it is not significant, it is carried out in the next stage.

The results in Table 1 explain the stationary stock price and oil price at the first difference level with a significance of 1 percent. Meanwhile, the exchange rate is stationary at level with a significance of 5 percent. The results of this test indicate that there are differences in stationarity in the research data.

Table 1: Stationarity test based on Augmented Dickey-Fuller (ADF)

Variable	Level	First difference	Conclusions
Oil Price (oil)	-2.407	-7.747***	First difference
Stock (stk)	-1.202	-8.119***	First difference
Exchange rate (exr)	-3.210**		Level

Note: **, *** significance 5 percent, 1 percent.

The next stage is to test the optimal lag in the causality model. The TY model is not much different from the granger model in general. This method still uses lag to see the influence from the past to the present. However, the determination of the number of lags must be appropriate because certain lag information has a significant effect. Therefore, it is necessary to do the best lag test in the model. This research is AIC criteria with a maximum lag test of 6 lags. Table 2 shows that the best lag is found in lag 3 because the determination of the lag is seen from the smallest value.

Table 2: Lag optimum AIC

Lag	AIC
0	-5.309
1	-10.141
2	-10.347
3	-10.416*
4	-10.287
5	-10.221
6	-10.159

Note: * the best lag.

Entering the next stage is testing the TY causality results between oil prices, stock prices, and exchange rates. Reading the results of the TY causal relationship with the Granger method is no different where X has a relationship to Y. The test results are shown in Table 3. The researcher found a two-way relationship between oil prices and the exchange rate. This finding supports the H1 hypothesis and is in line with Sayyedi (2017), Albulescu & Ajmi (2021), and Jiang et al. (2022). The purchase of this oil depends on the value of the currency itself. The strengthening of the currency will increase oil purchases. But in the case of dependence on crude oil, the state must continue to buy regardless of the price (Jobling & Jamasb, 2017). Conditions like this are unfavorable for developing countries like Indonesia.

Meanwhile, the one-way relationship between stock values and oil prices was found, where stock values influence oil prices. But these findings partially support the H2 hypothesis. This test's results differ from Gomez-Gonzalez et al. (2020) and Bhatia & Basu (2020). This one-way effect indicates that stock changes cause changes in oil prices. This indication is reasonable because, as a developing country, Indonesia still needs fossil energy as the main energy to drive the economy. When stocks, especially stocks in the industrial sector, increase, the oil demand also increases.

Furthermore, the researcher found a two-way causality relationship between stock values and exchange rates, supporting the H3 hypothesis. This finding is in line with research conducted by Śmiech & Papiez (2013). Investors buy stocks because the selling price always goes up from time to time. This led to an increase in foreign currency in the country.

Table 3: Toda-Yamoto Granger Casaulity based on Wald Test

Dependent	Independent		
	Oil	Stk	Exr
Oil		13.539***	10.527**
Stk	1.889		6.880*
Exr	7.958**	11.772***	

Note: *, **, *** significance 10 percent, 5 percent, 1 percent.

Causality testing only examines the relationship between variables but does not predict how it will be in the future. For this reason, researchers used two additional analyses, IRF and FEVD, as predictive tools. In Figure 3, the effect of oil price shocks on stocks is more stable. Compared with the exchange rate, changes in the exchange rate shook positively from periods 1 to 3 but experienced a decline from 6 to 10. The shock from stocks is stronger against oil in periods 2 to 4. This indicates that an increase in stocks causes oil prices to increase drastically within a certain time, then return to a gentler slope until the 10th period. The market can respond to the increase so that there will be more offers and a decrease in prices. Interestingly, stock shock on the exchange rate and oil price shock on the exchange rate gave a positive response. This means that these shocks can weaken the rupiah currency.

Furthermore, the percentage that contributes can be seen using FEVD and is presented in Appendix A1. The contribution of oil to stocks tends to be lower than the exchange rate, which reaches 10 percent. Meanwhile, the contribution of oil prices came from JCI stocks by 35 percent and the exchange rate by 20.87 percent. Finally, the contribution of stocks to the exchange rate is greater, namely 57 percent, while the oil prices' contribution is 11.27 percent.

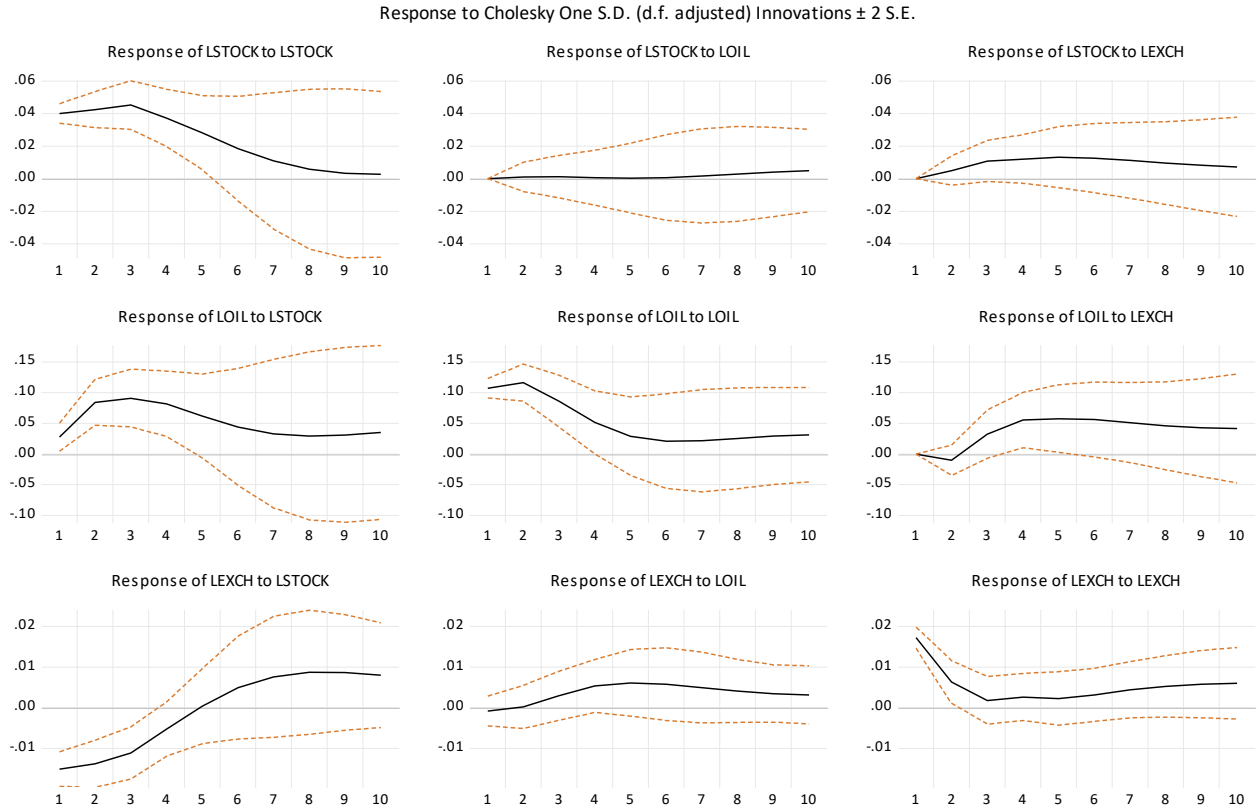

Figure 3: Impulse Response Function (IRF)
Source: Author Works, Eviews

5. Conclusion

This research investigates the possible relationship between oil prices, stocks, and the exchange rates in Indonesia. So far, previous studies have examined the relationship between the variables we examined separately, although the methods varied. Thus, researchers see gaps that there are gaps that have not been studied, namely linking the three-in-one causality test. Researchers used relationship testing with the Toda-Yamamoto method. This method is a development of the Granger concept with several advantages, such as no need to do co-integration testing, and it can be done when it has different stationarities. In addition, researchers use impulse responses to see the shocks of the variables studied.

The study found that exchange rates and stocks have a two-way relationship, supporting the H_2 hypothesis. Furthermore, a two-way relationship occurs between oil prices and exchange rates. This finding supports the H_3 hypothesis. Meanwhile, this study found that the H_1 hypothesis is partially supported, where there is a one-way relationship between stocks and oil prices. Based on the impulse response function results, it was found that exchange rate shocks positively affected stocks from periods 6 to 10. The stock shock strongly impacted oil prices early in the period and declined steeply through period 10. Interestingly, stock shocks make the exchange rate increase continuously until period 10. Oil price shocks on the exchange rate and vice versa follow the same pattern.

Our research findings are important in making policy decisions for investors. Indonesian stocks are very promising for investors, where their value continues to increase and must decrease significantly during a pandemic. But after going through the pandemic, stock values continued to improve. Even though it looks very good, the impact is quite serious, especially on the exchange rates, which will later disrupt economic stability. This is because stock activity causes oil demand to increase and causes global oil prices to increase. In addition, stock values tend to fluctuate, resulting in investors not staying long in Indonesia. So far, Indonesia is an oil-importing country, so the ability to buy crude oil depends on the exchange rates. The weakening of the currency causes the burden on the government to add several dollars. Based on this study, policymakers need to make the right decisions, including controlling the exchange rate so that the economy becomes stable, exploring for oil in the country or using renewable energy technology so as not to break away from dependence on fossil oil and keeping stock values stable to provide a sense of security to investors.

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Appendix A1. Forecast Error Variance Decomposition

Variance Decomposition of STOCK:				
Period	S.E.	Stock	Oil	Exch
1	0.040012	100.0000	0.000000	0.000000
2	0.058526	99.25450	0.037515	0.707986
3	0.074790	97.39566	0.050264	2.554073
4	0.084421	95.90292	0.043818	4.053259
5	0.090010	94.22160	0.039523	5.738872
6	0.092748	92.69685	0.042671	7.260476
7	0.094073	91.45283	0.073134	8.474032
8	0.094784	90.46108	0.167811	9.371110
9	0.095287	89.62924	0.352330	10.01843
10	0.095730	88.87880	0.620315	10.50089
Variance Decomposition of OIL:				
Period	S.E.	Stock	Oil	Exch
1	0.110563	6.173824	93.82618	0.000000
2	0.181476	23.74514	75.93973	0.315134
3	0.222759	32.42674	65.25792	2.315343
4	0.248983	36.72568	56.48315	6.791174
5	0.264457	37.99009	51.26065	10.74926
6	0.274718	37.77949	48.07723	14.14329
7	0.282187	37.17008	46.14699	16.68293
8	0.288526	36.59557	44.91701	18.48742
9	0.294774	36.16548	44.00997	19.82454
10	0.301397	35.95165	43.17452	20.87383
Variance Decomposition of EXCH:				
Period	S.E.	Stock	Oil	Exch
1	0.022975	43.33526	0.129253	56.53548
2	0.027558	55.34631	0.093863	44.55983
3	0.029934	60.84008	1.045216	38.11470
4	0.030975	59.73890	3.952352	36.30874
5	0.031653	57.21935	7.499743	35.28091
6	0.032701	55.89401	10.13627	33.96972
7	0.034214	55.97978	11.35234	32.66788
8	0.035923	56.65325	11.59261	31.75414
9	0.037556	57.14205	11.45484	31.40311
10	0.038985	57.21424	11.27648	31.50927