DYNAMIC LINKAGES BETWEEN GOLD, OIL, EXCHANGE RATE AND STOCK MARKET: EVIDENCE FROM INDONESIA

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ABSTRACT

This study examines the interdependence and linkages among international gold price, international crude oil price, exchange rate, and stock market index in the Indonesian context employing the Nonlinear Autoregressive Distributed Lag (NARDL) approach on monthly data from January 2000 to December 2022. The findings of the study provide empirical evidence for the presence of both short- and long-term asymmetries among these selected asset classes. Results suggest that co-integration exists among all the variables. The exchange rate impacts oil prices, gold prices, and the stock market in the long run, and also shows an asymmetric effect on the stock market and international crude oil in the short run. However, its influence on gold was not evident in the short run. Gold prices affect the exchange rate in the long run as well as in the short run. Fluctuations in stock prices influence gold prices and exchange rates. However, stock market shocks influence oil prices in the short run. This is a preliminary study in the Indonesian context, representing the dynamic simultaneous nexus among these selected asset markets. The findings provide valuable insights into fiscal and economic policies. Therefore, the study has significant implications for regulators, academicians, and investors in making effective financial decisions.

Keywords: *Crude Oil Prices; Gold Prices; Jakarta Stock Market Index; NARDL Co-Integration Test.*

INTRODUCTION

This paper explores the dynamic relationship and causal nexus between the stock market, gold, crude oil, and exchange rate for a selected emerging economy of the ASEAN region, i.e.,

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Indonesia. Indonesia, the world's fourth most populous country, is classified as one of the world's largest emerging economies, ranked 16th by nominal GDP and 10th largest by purchasing power parity (PPP) with an annual growth rate of 5.3% in 2022.

Emerging equity markets have undergone remarkable growth in terms of volume and value, receiving sizable capital inflows from developed economies (Beckmann et al., 2016). However, these emerging markets are susceptible to uncertainty and volatility. Variations in crude oil prices influence the trade balance and current account of the country; therefore, the rise in oil prices is a significant factor that influences the profitability of the firms in the economy by raising the cost of production and transportation expenses. Changes in the cost of production and profitability lead to changes in stock prices as well.

Besides importing oil, Indonesia is among the largest suppliers of gold to the world which is a major component of its GDP. Over the past five years, Indonesian jewelry exports to the world have increased at an annual rate of 16.6%, achieving a value of USD 3.78 billion in 2022. Indonesia is ranked seventh with a 4.7% export share. It then follows that the changes in gold prices have a sizeable impact on the Indonesian economy as well. Higher gold prices can benefit Indonesian gold mining companies and potentially boost their stock prices. Moreover, gold is often an international commodity traded in international markets either as a haven or hedge for investors, and during times of economic uncertainty, major investments are undertaken in gold which affects stock market sentiments.

The exchange rate, intermediating the international transactions of the balance of payments, is another crucial variable in the economy as its level and stability have a direct impact on investment (Oriavwote & Eriemo, 2012). It also serves as a barometer for economic and financial progress (Bakhsh & Khan, 2019). A good number of studies suggest a significant relationship between exchange rates and oil prices (Buetzer et al., 2012; Jain and Biswal, 2016; Fratzscher et al., 2014). Furthermore, soaring oil prices put upward pressure on the general price level within an economy which causes the exchange rate to sink in countries with high oil imports (Fratzscher et al., 2014; Jain and Biswal, 2016). In contrast, oil-exporting countries experienced exchange rate appreciation (Buetzer et al., 2012).

This paper attempts to extend the extant literature on the causal linkages between the stock market, gold, exchange rate, and crude oil markets in the ASEAN region from the Indonesian perspective. Indonesia is among the most important emerging economies, and it can be, to a greater extent, classified as an oil/gas-rich economy (Kuboniwa, 2014). Research that explores the interconnections and linkages among the prices of gold, oil, the stock market, and the exchange rate is rare in the context of Indonesia. Moreover, most of the studies have used linear approaches for analyzing the linkages among these four selected markets (Akbar et al., 2019; Jain and Biswal, 2016; Singhal et al; 2019; Sheikh et al; 2020). Nonetheless, it is recognized that most financial time series have non-normality, long tails, and high kurtosis. Normally, this occurs due to structural breaks, regime shifts, and the existence of intrinsic non-linearity. Hence, the linear framework is no longer a good fit for investigating this instance. Most importantly, the price movement of one asset class, such as energy, can have varying effects on other asset classes, such as stocks, and currency rates. In this regard, the current study intends to fill this gap in the literature by examining non-linear relations and interactions that happen among the gold, oil, exchange rate, and stock market about diverse investment horizons.

Our study offers valuable contributions to the literature in numerous ways. First, this study attempts to uncover the nexus between gold, crude oil, stock market index, and exchange rate from the perspective of Indonesia, one of the important emerging economies of the ASEAN region. Secondly, this study extends the findings of the existing literature by using a non-linear autoregressive distributed lag model (NARDL) to discover the response of a variable to the movements of other variables in the long run and short run. The NARDL approach has the advantage compared to other nonlinear switching approaches in its ability to simultaneously address asymmetry and complex cointegration dynamics among the sampled time series (Apergis and Cooray, 2015). Thirdly, this study evaluates whether the causal relationship among the selected markets is asymmetric or symmetric. Lastly, our study investigates the nexus and dynamic linkages among the four markets simultaneously as it is important to comprehend the interdependence of multiple variables interacting at the same time rather than in isolation (Aloui & Ben, 2016).

Our paper is structured as follows. Section 2 reviews the previous literature. The sample and the empirical models are described in Section 3. Empirical findings and discussion are presented in Section 4. Section 5 concludes the study with a discussion of the implications of empirical findings.

LITERATURE REVIEW

The dynamic relationship between gold, oil price, stock market, and exchange rates has been widely studied in the literature. In this section, we review this literature. The section is divided into two parts. The initial part of the review included studies that mainly examined two of the variables under consideration. The review of studies that simultaneously examined more than two variables is covered in the second part.

The literature contains numerous studies that examine the linkage between stock and oil prices, holding the convention that changes in stock prices reflect the overall soundness of the economy and thus serve as a pulse of economic performance (Ghosh & Kanjilal, 2016). Oil prices are viewed as a crucial factor in several studies that have sought to explain changes in stock prices/returns (Alqahtani et al., 2020). While movements in oil prices are considered to be a significant factor determining volatility in stock returns, the results are mixed and ambiguous. The prevailing ambiguity in the empirical evidence has motivated researchers to investigate the relationship in depth.

The positive linkage between stock returns and oil prices has been evidenced in numerous studies such as Arouri and Rault (2012), Brown and Sarkozy (2009), Chisholm (2014), Froggatt and Lahn (2010); Yousaf and Hassan (2019). Some studies have also found a negative relationship (see for example, Ghorbel and Boujelbene, 2013; Park and Ratti, 2008; Jones and Kaul, 1996; Singhal et al., 2019). One of the common observations in this literature is that most of these studies were conducted in the backdrop of oil and equity price shocks in the developed economies of Australia, Canada, the UK, the US, and other European markets (Am & Shanmugasundaram, 2017; Broadstock & Filis, 2014; Salisu & Isah, 2017). Towards this end, Diaz et al. (2016) studied the connection between changes in oil prices and returns in stock markets of the G7 economies. Their findings show a negative connection between oil price volatility and stock market returns in the G7 countries, indicating the importance of global oil prices in the context of the stock market. During the 1970s and 1980s, researchers found a negative impact of oil price fluctuations on the US stock market (Kaul & Seyhun, 1990; Sadorsky, 1999; Papapetrou, 2001). Many studies reveal that surging energy costs result in higher production costs that have a negative influence on stock returns and influence the stock prices in the countries that import oil (Aloui & Jammazi, 2009; Basher & Sadorsky, 2006; Ciner, 2001; Ghouri, 2006; Hammoudeh & Choi, 2007).

Meanwhile, Basher and Sadorsky (2006) reported the influence of oil price fluctuations on stock prices and confirmed that oil price risk is a significant driver of stock returns in emerging economies. Using the same methodology, Chung-Rou, and Shih-Yi (2014) reached similar findings about China, Russia, and India. Yanfeng and Xiaoying (2017) examined the relationship between shocks in oil prices and the stock market of China. According to them, stock volatility's response to oil shocks is nearly insignificant, however, stock return's responses to oil shocks differ and are closely related to the causes that produce changes in oil prices.

Various approaches have been used to investigate the relationship between oil and the stock market. Using ARCH and GARCH methodology, Oberndorfer (2009) revealed that an increase in oil prices influenced the stock returns adversely in Europe from 2002 to 2007. Miller and Ratti (2009) employed a VECM and reported that the stock market reacted adversely in the long run to shocks in oil prices for the period 1971-2008, however, this negative relationship broke down after September 1999. Their findings confirm that this relation has a structural breakdown. Arouri (2011) applied the Granger causality test to confirm a significant relationship between changes in oil prices and European stock markets. Chebbi and Derbali (2015) applied the DCC GARCH model to determine the linkages between commodities and the stock market. Moreover, Chang et al. (2020) determined the influence of oil prices on stock returns by applying a cointegration approach.

The relationship between crude oil prices and gold prices has been vastly investigated. In this regard, studies have found a strong linkage between these two markets. Cashin et al. (1999) found a significant link between oil and gold by taking the data from seven commodities. Narayan et al. (2010) examined whether gold serves as a hedge against inflation and found that the two markets can predict each other. The causal linkages between oil and gold price volatility were studied by Zhang and Wei (2010). Simakova (2011) observed a significant long-run relationship between oil and gold prices. Soytas et al. (2009) explored the relationship between the price of gold and the prices of oil in both the long run and short run, however, their findings confirmed that no causality exists between these two markets.

The price of oil has historically been viewed as a leading indicator of movements in exchange rates around the world (Amano and van Norden, 1998). Hence, numerous studies have confirmed a significant relationship between crude oil prices and exchange rates. A good number of studies, employing linear cointegration tests, showed a long-term association between prices of crude oil and the exchange rate. The literature, however, reveals mixed findings (Xu et al., 2019).

Amano and Van Norden (1998) investigated the relationship between oil prices and the exchange rate. Their results reported a strong relationship between the real oil price and the real effective exchange rates for Germany, Japan, and the United States. Basher et al. (2012) and Beckman et al. (2016) observed that a rise in the oil price puts downward pressure on the value of the US dollar in the short run. The analysis was performed on monthly data by using the structural VAR model. Yang et al. (2017) found a negative linkage between the price of crude oil and the value of the exchange rate for oil-exporting nations. In addition to this, the study revealed that this link remains ambiguous by employing wavelet coherence analysis. Moreover, Singhal et al. (2019) also found that the crude oil price had a negative influence on the exchange rate of the economy of Mexico. Mensah, Obi, and Bokpin (2017) observed the long-run dynamic linkages between the price of oil and the exchange rate besides the bilateral U.S. dollar exchange rates for oil-dependent countries including India, Russia, South Africa, Ghana, and Nigeria, before the financial crisis of 2008–2009. In more recent studies, Kumar (2019) observed considerable evidence of the existence of a bidirectional nonlinear relationship between oil and exchange rate. Employing wavelet analysis and NARDL methodology, Kharif et al. (2021) found an asymmetric impact of oil on the exchange rate in the long run from 1990 to 2019 for India.

Basher and Sadorsky (2006) evaluated the dynamic linkages among stock prices, oil prices, and exchange rates by taking a sample of emerging markets. The study employed structural VAR methodology and concluded that oil prices do influence equity returns. Basher et al. (2012) explored the relationship between oil prices, stock markets, and exchange rates and found that a rise in oil prices depressed the US dollar exchange rate and stock prices in emerging markets in the short run. Aloui and Assa (2016) indicated that the stock market, oil prices, and exchange rate have a symmetric and time-varying relation. Kayalar et al. (2017) considered the structural relationships among the prices of crude oil, currency rates, and stock market indices for oil importers and exporters. Aloui and Assa (2016) and Kayalar et al. (2017) employed the same econometric approach and found that most oil-exporting economies' stock indexes and exchange rates are more dependent on oil prices while emerging oil-importing economies are less sensitive to oil price variations. Sahu et al. (2014) also considered the relationship between crude oil prices, exchange rate, and stock market in India. They concluded that a cointegrating relationship exists among the three variables from the period 1993-2013. However, their findings also exhibited that the long-term relationship between oil prices and the Sensex was not adequately supported by statistical data. In a related study, Jain and Biswal (2016) found that a reduction in the price of gold and prices of crude oil triggered a fall in the value of the Indian rupee and Sensex index. Furthermore, Kumar (2019) confirmed a non-linear causal linkage between the price of oil and the exchange rate and prices of oil and stock prices in the context of India. In a more recent study for Norway, Singhal et al. (2022) suggested that there was a long-term relationship between crude oil price, exchange rate, and stock markets when crude oil prices were used as the dependent variable. This study also confirmed the bi-directional causal relationship between the stock market and exchange rate and the unidirectional causal relation between the crude oil market and the Norwegian stock market.

Many studies have combined and analyzed the linkages among international crude oil and gold prices, stock market indexes, and exchange rates. In this context, Arfaoui and Rejeb (2017) examined the linkages among international oil, the US dollar, gold, and stock prices. Research has also been conducted in developing countries. For instance, Sheikh et al., (2020) chose Pakistan to investigate the relationship between exchange rate, stock index, gold, and oil prices. Seyyedi (2017) and Jain and Biswal (2016) depicted the association between gold prices, crude oil, the rate of exchange, and the stock market in India. Delgado et al (2018) chose the Mexican market to depict the interrelation between oil, stocks, and exchange rates. Singhal et al (2019) applied the ARDL model to the Mexican economy to investigate dynamic linkages among the international oil prices, stock market index, exchange rate, and international gold prices. Their findings suggest that international gold prices have a positive impact on the stock prices in Mexico, whereas oil prices have a negative impact. Moreover, in the analysis for the long run, gold prices and exchange rates were unrelated, while oil prices drove the exchange rate negatively.

The interconnection between commodity and financial markets is a crucial and challenging problem for investors as stock prices are influenced by several macroeconomic variables, such as gold prices, prices of crude oil, volatilities of crude and gold prices, inflation rate, and exchange rate (Gokmenoglu & Fazlollahi, 2015). Therefore, it is much more complicated to understand the causal relationships and linkages among economic and financial variables for researchers, policymakers, investors, and portfolio managers (Akbar, Iqbal & Noor 2019). An in-depth review of existing literature reveals relationships and linkages among the listed variables. However, there is still no consensus among the studies about the direction and whether the relationship is symmetric or non-symmetric. Previously, most studies used linear approaches to examine this relationship. However, non-linear approaches are more suitable and informative. Additionally, to the best of our knowledge, studies exploring the nexus among the international crude oil price, international gold price, exchange rate, and the stock market are rare in the ASEAN region.

The review of current literature exhibits that studies concerning the effect of crude oil prices and gold prices on the Indonesian rupiah are narrow and inconclusive, whereas the relationship between the exchange rate and the stock market remains unexplored. Simultaneous empirical investigation of the association between the exchange rate, movements in the stock market, and shocks in oil and gold prices in the context of Indonesia is non-existent to the best of our knowledge. Hence, our objective in this study is to examine the dynamic linkages between international oil prices, exchange rates, international gold prices, and the stock market index in Indonesia.

DATA AND METHODOLOGY

Data

This study examines the interdependence and linkages among crude oil, gold, exchange rate, and the stock market index in Indonesia. The sample period of the study employs the time series monthly data ranging from January 2000 to December 2022. The justification for taking 2000 as the beginning year is based on the fact that the stock exchanges of ASEAN countries underwent reforms during the 1990s and became fully developed by the end of the 1990s.

For crude oil, denoted as OIL, we use the US WTI crude spot price benchmark as a proxy for oil price movements as the US is the leading trading partner with Indonesia in the energy sector. The price is quoted in U.S. dollars per barrel. The international gold spot price, denoted by GOLD, is used as a proxy for the gold price. It is priced in US dollars per ounce. Most of the trading in Indonesia is made in U.S. dollars as it is the most powerful currency that is used in worldwide trading activities. The Indonesian rupiah (IDR) and US dollar (US $) currency pairings are used to measure movements in exchange rates that are symbolized by ER. For the stock market, we use the IDX Composite index (also known as the Jakarta Stock Exchange index (JSX Composite)) which is the main index of the Jakarta Stock Exchange, Indonesia. Regarding data collection, WTI crude oil price and gold price (USD/ troy ounce) are extracted from the World Bank and the data for the Indonesia stock index are obtained from DataStream. Table 1 presents the details about the variables and the sources of data collection.

Table 1. List of Variables and Sources of Data Collection

Variables Name	Abbreviations	Sources	Units	Variables Name
International Crude Oil Prices	OIL	*WORLD BANK*	WTI Crude oil spot price	International Crude Oil Prices
International gold spot prices	GOLD	*WORLD BANK*	USD per troy ounce	International gold spot prices
Stock Market Price	SP	*DATASTREAM*	Index	Stock Market Price
Exchange rate	ER	*DATASTREAM*	USD / IDR	Exchange rate

Methodology

This study aims to investigate the dynamic and causal linkages in the long and short run between international gold prices, oil prices, exchange rates, and stock market returns in Indonesia employing the NARDL model (Shin et al., 2014). The NARDL bound test has numerous advantages over other models that were previously used for checking the linkages and relationships among the selected variables. This helps to avoid the endogeneity issue by using lagged variables as each testing equation may have different lags. According to Liu et al. (2017), the test guards against spurious regression problems and avoids problems of weak power in small samples in showing the co-integrating association (Romilly et al., 2001; Pesaran, 1997). Past studies (such as Singhal et al., 2019; Tursoy and Faisal, 2018; and Singhal et al., 2022) have applied the ARDL model, which is incapable of testing asymmetric relationships. To avoid this problem, we apply the NARDL model which efficiently tests asymmetric cointegration relationships in the short- and the long-run.

Model Specification

The long-run asymmetric regression model (Shin et al., 2014) is given as follows:

$$Yt = \delta + X+t + \delta^{-} X-t + \pi t \quad (1)$$

As Yt indicates dependent variables, δ+ and δ− represent related long-run parameters. X+ t and X− t denote the part sum of negative and positive changes in the exogenous variable such as:

$$Xt+ = \sum it=1 \quad \Delta xi+ = \sum ti+1 \max (\Delta Xi, 0) \quad (2)$$

$$Xt- = \sum it=1 \quad \Delta xi- = \sum ti+1 \min (\Delta Xi, 0) \quad (3)$$

The NARDL model is expressed as follows.

$$\Delta yt = \mu + \vartheta yyt\text{-}1 + \vartheta x\text{+}xt\text{-}1\text{+} + \vartheta x\text{-}xt\text{-}1\text{-} + \sum mi=1\ \delta i\Delta yt - I + \sum ni=0\ (\lambda + i \quad \Delta x+t - i + \lambda - i\ x - t - i) + \varepsilon 1t$$

Where Δ represents changes in the dependent variables. The coefficients for the long-run asymmetry are expressed as ϑ+ and ϑ and the coefficients for the short-run asymmetry are represented by λ+ and λ−. It is important to note that an analysis for the long term seeks to determine the timing and rate at which exogenous variables adjust to impact the dependent variable, whereas the short-term analysis attempts to assess the instantaneous effects of variations in explanatory variables over the dependent variable. In addition, the Wald test is used to test the long-run symmetry by testing the null hypothesis of equality of λ+ and λ−. Both the direct and indirect effects of explanatory variables on the dependent variable are estimated by changes in the long-run coefficient. These parameters calculate the nonlinear relationship when x and y are in their long-run equilibrium. Initially, applying a unit root test is crucial to ensure that the integration of the time series is not of order (2). For this purpose, we apply the Augmented Dickey-Fuller test (ADF) and Phillip Person (PP) at the levels and the first difference. Next, to determine the proper lag length, the Akaike information criterion (AIC) is used. Bounds testing is then performed to test whether a co-integrating relationship exists between the dependent and independent variables.

For the unrestricted error correction model, the asymmetric NARDL equations are presented as follows:

$\Delta OILt = \alpha o + \alpha 1\ OILt\text{-}1 + \alpha 2\ GOLD\text{+}t\text{-}1\text{+}\ \alpha 3\ GOLD\text{-}t\text{-}1\text{+}\alpha 4\ ER\text{+}t\text{-}1 + \alpha 5\ ER\text{-}t\text{-}1\text{+}\ \alpha 6\ SP\text{+}t\text{-}1\text{+}\ \alpha 7\ SP\text{-}t\text{-}1\text{+}$ $\Sigma nt\text{=}1\alpha 1\Delta OILt\text{-}1\text{+}\Sigma nt\text{=}1\alpha 2\Delta GOLD\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\alpha 3\Delta GOLD\text{-}t\text{-}1\text{+}\Sigma nt\text{=}1\alpha 4\ \Delta ER\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\alpha 5\ \Delta ER\text{-}t\text{-}1 +$

$\Sigma nt\text{=}1\alpha 6\Delta SP\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\alpha 7\Delta SP\text{-}t\text{-}1\text{+}\ \varepsilon 1t$

$\Delta GOLDt = \beta o + \beta 1\ GOLDt\text{-}1\text{+}\ \beta 2\ OIL\text{+}t\text{-}1 + \beta 3\ OIL\text{-}t\text{-}1 + \beta 4\ ER\text{+}t\text{-}1 + \beta 5\ ER\text{-}t\text{-}1\text{+}\ \beta 6\ SP\text{+}t\text{-}1\text{+}\ \beta 7\ SP\text{-}t\text{-}1\text{+}\Sigma nt\text{=}1$ $\beta 1\ \Delta GOLDt\text{-}1\text{+}\Sigma nt\text{-}1\ \beta 2\ \Delta OIL\text{+}t\text{-}1\text{+}\Sigma nt\text{-}1\ \beta 3\ \Delta OIL\text{-}t\text{-}1\text{+}\ \Sigma nt\text{-}1\ \beta 4\ \Delta ER\text{+}t\text{-}1\text{+}\ \Sigma nt\text{-}1\ \beta 5\Delta ER\text{-}t\text{-}1\text{+}\Sigma nt\text{-}1\beta 6\Delta SP\text{+}t\text{-}1$ $\text{+}\Sigma nt\text{-}1\beta 7\Delta SP\text{-}t\text{-}1\text{+}\ \varepsilon 2t$

$\Delta SPt = \gamma o + \gamma 1\ SPt\text{-}1 + \gamma 2OIL\text{+}t\text{-}1\text{+}\ \gamma 3OIL\text{-}t\text{-}1\text{+}\gamma 4\ GOLD\text{+}t\text{-}1\text{+}\gamma 5GOLD\text{-}t\text{-}1\text{+}\gamma 6ER\text{+}t\text{-}1\text{+}\gamma 7ER\text{-}t\text{-}$ $1\text{+}\Sigma nt\text{=}1\gamma 1\Delta SP\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\gamma 2\Delta SP\text{-}t\text{-}1\text{+}\Sigma nt\text{=}1\gamma 3\Delta OIL\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\gamma 4\Delta OIL\text{-}t\text{-}1\text{+}\Sigma nt\text{=}1\gamma 5\Delta GOLD\text{+}t\text{-}$ $1\text{+}\Sigma nt\text{=}1\gamma 6\Delta GOLD\text{-}t\text{-}1\text{+}\Sigma nt\text{=}1\gamma 7\Delta ER\text{+}t\text{-}1\ \text{+}\Sigma nt\text{=}1\gamma 8\Delta ER\_t\text{-}1 + \varepsilon 3t$

$\Delta ERt = \mu o + \mu 1ERt\text{-}1\ \text{+}\mu 2OIL\text{+}t\text{-}1\text{+}\ \mu 3OIL\text{-}t\text{-}1\text{+}\ \mu 4GOLD\text{++}\ \mu 5GOLD\text{-}t\text{-}1\text{+}\ \mu 6SP\text{+}t\text{-}1\text{+}\ \mu 7SP\text{-}t\text{-}$ $1\text{+}\Sigma nt\text{=}1\mu 1\Delta ERt\text{-}1\text{+}\Sigma nt\text{=}1\mu 2\Delta OIL\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\mu 3\Delta OIL\text{-}t\text{-}1\text{+}\Sigma nt\text{=}1\Delta\mu 4\Delta GOLD\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\Delta\mu 5\Delta GOLD\text{-}t\text{-}$ $1\text{+}\Sigma nt\text{=}1\mu 6\Delta SP\text{+}t\text{-}1\text{+}\Sigma nt\text{=}1\mu 7\Delta SP\text{-}t\text{-}1\text{+}\varepsilon 4t$

Where OIL denotes international crude oil prices, GOLD denotes international gold spot prices, ER denotes the IND/USD exchange rate, and SP denotes the Indonesia Stock Market Index (IDX).

For all the above equations, the null hypothesis is as follows:

OIL Equation: $\alpha 1= \alpha 2= \alpha 3= \alpha 4 = 0$

Gold Equation: $\beta 1=\beta 2= \beta 3= \beta 4 = 0$

SP Equation: $\gamma 1= \gamma 2= \gamma 3= \gamma 4 = 0$

ER Equation: $\mu 1= \mu 2\ \mu 3= \mu 4 = 0$

We perform the Wald F-test to test the above equations with the null hypothesis stating that no long-term relationship exists among the time series. In the long run, cointegration is evident if the F-statistic falls above the upper critical value and vice versa. Results are inconclusive if F-statistics is in between the critical values. As a next step, an error correction model (ECM) is developed to scrutinize the behavior of the error correction term (ECT) that is the residuals from the long-run regression. The ECT is also instrumental in determining the speed of the adjustment towards the long-run equilibrium or the long-run stability of the co-integrating relationship.

$\Delta OILt = \alpha o + \Sigma nt=1\alpha 1\Delta OILt-1+\Sigma nt=1\alpha 2\Delta GOLD+t-1+\Sigma nt=1\alpha 3\Delta GOLD-t-1+\Sigma nt=1\alpha 4\ \Delta ER+t-1+\Sigma nt=1\alpha 5\ \Delta ER-t-1 +$

$\Sigma nt=1\alpha 6\Delta SP+t-1+\Sigma nt=1\alpha 7\Delta SP-t-1 + \Sigma nt=1\alpha 8\Delta ECTt-1 + \varepsilon 1t$

$\Delta GOLDt =\beta o + \Sigma nt=1\ \beta 1\ \Delta GOLDt-1+\Sigma nt-1\ \beta 2\ \Delta OIL+t-1+\Sigma nt-1\ \beta 3\ \Delta OIL-t-1+ \Sigma nt-1\ \beta 4\ \Delta ER+t-1+ \Sigma nt-1\ \beta 5\Delta ER-t-1+\Sigma nt-1\beta 6\Delta SP+t-1 +\Sigma nt-1\beta 7\Delta SP-t-1+ \Sigma nt=1\ \beta 8\Delta ECTt-1 + \varepsilon 2t$

$\Delta SPt=\gamma o+\Sigma nt=1\gamma 1\Delta SPt-1+\Sigma nt=1\gamma 2\Delta OIL+t-1+\Sigma nt=1\gamma 3\Delta OIL-t-1+\Sigma nt=1\gamma 4\Delta GOLD+t-1+\Sigma nt=1\gamma 5\Delta GOLD-t-1+\Sigma nt=1\gamma 6\Delta ER+t-1 +\Sigma nt=1\gamma 7\Delta ER\_t-1 +\Sigma nt=1\gamma 8\Delta ECT\_t-1 +\varepsilon 3t$

$\Delta ERt=\mu o+\Sigma nt=1\mu 1\Delta ERt-1+\Sigma nt=1\mu 2\Delta OIL+t-1+\Sigma nt=1\mu 3\Delta OIL-t-1+\Sigma nt=1\Delta\mu 4\Delta GOLD+t-1+\Sigma nt=1\Delta\mu 5\Delta GOLD-t-1+\Sigma nt=1\mu 6\Delta SP+t-1+\Sigma nt=1\mu 7\Delta SP-t-1+\Sigma nt=1\mu 8\Delta ECT\_t-1 +\varepsilon 4t$

The ECTt-1 term depicts the rate of adjustment to the long-run equilibrium following shocks in the short-run. Additional diagnostic tests consisting of non-normality, serial correlation, and heteroscedasticity are performed to assess the model's goodness of fit. The stability tests, Cumulative sum (CUSUM), were employed, and the findings indicate the stability of the regression equation.

RESULTS AND DISCUSSIONS

To conduct the econometric analysis, the variables have been transformed into log-returns series. Table 2 presents the summary statistics for all the variables. It is found that among all variables, GOLD exhibits the highest mean value that is 0.0066 and mean of ER shows the lowest mean value that is 0.0028. However, the highest standard deviation is 0.1050 for the OIL price which suggests that oil is more volatile than the other variables in the system. Exchange rate (ER) series returns with the lowest standard deviation (0.0317), depicting the lowest volatility among all the selected variables. All variables tend to be negatively skewed except GOLD. OIL has the greatest kurtosis. The JB statistic indicates deviation from normality for all variables except GOLD.

Table 2. Descriptive Statistics

	Mean	Std. Dev	Max	Min	Skewness	Kurtosis	JB stat
OIL	0.0039	0.1050	0.5474	-0.5926	-0.9557	10.8299	747.05
GOLD	0.0066	0.0363	0.1119	-0.1248	0.0089	3.5124	3.0236
SP	0.0060	0.0840	0.2606	-0.4315	-0.9890	6.9967	228.70
ER	0.0028	0.0317	0.1448	0.1814	0.1408	9.6768	513.59

Note: The table reports the summary statistics of the international Crude oil Price (OIL), International Gold Price (Gold), Stock price index (SP), Exchange rate (ER).

Table 3. Correlation Matrix

	1	2	3	4
OIL	1			
GOLD	0.092	1		
SP	0.344***	0.210***	1	
ER	-0.132**	-0.195***	-0.247***	1

*Note: ***, ** represent the statistical significance of correlation at 1% and 5% respectively*

Table 3 reports the correlation among the variables. The correlation between oil prices and exchange rate is negative, indicating diversification opportunities for the investors. In contrast, the correlation between gold and stocks is positive, while the correlation between stock prices and exchange rate is negative.

NARDL-based testing is applicable only to time series of the order I(0) or I(1) variables. Therefore, the confirmation that none of the variables is I(2) in the case of NARDL is important to avoid spurious regression. We do this by applying the unit root tests, Augmented Dicky Fuller (ADF) and Phillips-Peron (PP) tests, the results of which are reported in Table 4. Results confirm that all variables in our sample are stationary at the level. Table 5 reports the estimates for Brock Dechert Scheinkman (BDS) test that the distributions of the series are not identical and independent. This implies that the null hypothesis for the BDS stands rejected. Hence an asymmetric approach is required to capture the non-linearity in the relationship among the selected variables except gold which shows linearity at 1ST dimension. The results in Table 5 support the fact that the actual relationship between the variables is non-linear.

Table 4. Results of Unit Root Test

Variables	ADF (at Level)	PP Test (at level)
Oil	-11.3059 (0.0000)***	-9.4652 (0.0000)***
Gold	-11.7199 (0.0000)***	-14.7450 (0.0000)***
SP	-14.0408 (0.0000)***	-14.0676 (0.0000)***
ER	-12.5465 (0.0000)***	-14.7450 (0.0000)***
Variable	**ADF (at 1st difference)**	**PP Test (at 1st difference)**
Oil	--7.6010 (0.0000)***	-145.0805 (0.0001)***
Gold	-9.9275 (0.0000)***	-119.3641(0.0001)***
SP	-7.5742 (0.0000)***	-164.5719 (0.0001)***
ER	-9.4652 (0.0000)***	-119.3641(0.0001)***

*Note: *** shows unit root at the 1% significance level. ADF and PP represent Augmented Dickey-Fuller and Phillips-Perron tests, respectively.*

Table 5. BDS Test Results

Series	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6
OIL	0.0310***	0.0484***	0.0567***	0.0568***	0.0545***
GOLD	0.0064	0.0147**	0.0229***	0.0250***	0.0267***
SP	0.0129***	0.0359***	0.0443***	0.0511***	0.0514***
ER	0.0298***	0.0680***	0.0953***	0.1080***	0.1194***

*Note: The BDS test is based on the residuals of a VAR for all chosen variables. ***, ** show the Significance level at 1% and 5%, respectively.*

Confirming both the order of integration and non-linearity in series, it is applicable to proceed NARDL model for further analysis. Estimates of NARDL co-integration are reported in Table 6. In all equations, the null hypothesis under scrutiny states that no long-run co-integration exists among the selected variables. Results of Table 6 indicate evidence of co-integration when OIL, GOLD, SP, and ER are used as the dependent variable. This reveals that movement in prices in four markets are dependent on each other in the long run. Consistent to our findings, Kumar et al. (2021) also found evidence of co-integration when oil was used as a dependent variable. Likewise, Zhu et al. (2011) reported the co-integration between oil and stock markets using multivariate techniques for the countries belonging to OECD and non-OECD. This is also similar with the findings of Singhal et al. (2022) who reported co-integration among exchange rate and gold when oil was used as dependent variables. However, contrary to this study, Singhal et al. (2019) reported no evidence of co-integration in these variables for Mexico when Oil and Gold were taken as dependent variables. Moreover, cointegration was not evident in the exchange rate and gold equations.

Table 7 reports the NARDL coefficients of the four equations for the long run. The results for stock market and gold prices are statistically insignificant to oil price in long run, whereas movements in the exchange rate affect oil prices significantly. Our results are parallel to those of Singhal et al. (2022), Akram (2009), Blomberg and Harris (1995), and Jammazi et al. (2015). Contrary to this, Kumar et al. (2021) observed that exchange rate shocks have no influence on oil prices in long-run. The long-term coefficient of GOLD equation indicate that only negative shocks of stock market prices and the exchange rate have a significant influence on gold prices in long-term. Additionally, positive shocks to the stock prices have drawn influence on gold prices at the 10% significance level. The estimates of the SP equation report that gold prices do not influence stock prices either positively or negatively. Contrary and this, some other studies (Singhal et al., 2019, Jain and Biswal, 2016) also confirmed the connectedness between gold prices to the stock prices. Furthermore, oil prices also leave no influence on stock prices neither positively nor negatively, while Singhal et al. (2021) favors the negative connectedness of oil price on prices of stocks. On the other hand, shocks in the exchange rate affect the stock price profoundly at a 1% significance level. This observation confirms that exchange rate appreciation and depreciation are connected to movements in stock market prices, showing congruence with the findings of Delgado et al. (2018). Whereas, contrary to our results, Singhal et al. (2019) reported no linkage of exchange rate at all with stock prices in context of Mexico. Furthermore, ARDL coefficients signify that the exchange rate has stronger influence on stock market prices. The estimates of the ER equation report that both positive and negative shocks of gold and stock prices are statically significant with the exchange rate in long-run at 1% significant level. On the other hand, variation in oil prices does not affect the exchange rate (IND/USD) in the long run. Contrary to these findings, Singhal et al. (2019) reported the insignificant connectedness of stock prices and gold prices towards exchange rate and suggested a negative significant connection to oil prices with exchange rate in long-run. However, (Jain and Biswal, 2016; Jain and Ghosh, 2013; Sjaastad, 2008) results are similar to this finding. Moreover, it is necessary to highlight that oil and gold prices are used to move in a similar direction (Melvin and Sultan, 1990).

Table 6. NARDL Bound Co-Integration Test

Variables	Null hypothesis	Lag structure	F-statistics	Outcome
Oil	$\alpha_{1=}\ \alpha_{2=}\ \alpha_{3=}\ \alpha_4 = 0$	(3,0,2,1)	18.5940***	Cointegration
Gold	$\beta_{1=}\beta_{2=}\ \beta_{3=}\ \beta_4 = 0$	(2,0,0,0)	25.6979***	Cointegration
ER	$\gamma_{1=}\ \gamma_{2=}\ \gamma_{3=}\ \gamma_4 = 0$	(1,0,0,3)	48.9589***	Cointegration
SP	$\mu_{1=}\ \mu_2\ \mu_{3=}\ \mu_4 = 0$	(3,0,3,0)	23.8375***	Cointegration

*Note: Model selection criteria are based on the Akaike information criterion (AIC). The maximum lag length was found to be 4. Superscript *** indicates a significant level at 1 %.*

Table 7. Estimated long-run coefficients using the NARDL approach

OIL Equation Variables	Coefficient	Std. Error	t-Statistic	LAG	**GOLD Equation Variables**	Coefficient	Std. Error	t-Statistic	LAG
GOLD+	-0.0170	0.1668	-0.1022	0	OIL+	-0.0011	0.0212	-0.0527	1
GOLD-	-0.0310	0.1640	-0.1892	0	OIL-	0.0038	0.0219	0.1770	1
SP+	0.2063	0.1562	1.3204	1	SP+	0.0514	0.0287	1.7928*	1
SP-	0.2134	0.1602	1.3319	1	SP-	0.0782	0.0281	2.7832***	1
ER+	-1.1730	0.3891	-3.0142***	1	ER+	-0.1109	0.0741	-1.4969	1
ER-	-1.1690	0.3785	-3.0886***	1	ER-	-0.2037	0.0690	-2.9515***	1
C	-0.0031	0.0495	-0.0642		C	-0.0165	0.0093	-1.7616*	
SP Equation Variables	Coefficient	Std. Error	t-Statistic	LAG	**ER Equation Variables**	Coefficient	Std. Error	t-Statistic	LAG
OIL+	0.0507	0.0299	1.6913	0	OIL+	-0.0084	0.0123	-0.6841	0
OIL-	0.0550	0.0311	1.7655	0	OIL-	-0.0088	0.0126	-0.7014	0
GOLD+	0.0705	0.0839	0.8401	0	GOLD+	-0.2358	0.0672	-3.5070***	1
GOLD-	0.0946	0.0812	1.1652	0	GOLD-	-0.2530	0.0653	-3.8738***	1
ER+	-1.9510	0.2162	-9.0237***	1	SP+	-0.0904	0.0203	-4.4337***	0
ER-	-1.9969	0.2019	-9.8878***	1	SP-	-0.0808	0.0218	-3.6960***	0
C	-0.1096	0.0190	-5.7727***		C	0.0150	0.0081	1.8585*	

*Note: ***, **, * shows significant level at 1%, 5% and 10%, respectively.*

Table 8. Error correction model representation for the NARDL cointegration models

OIL Equation		**GOLD Equation**		**SP Equation**		**ER Equation**	
ΔOIL t-1	0.1967 (0.0715)***	ΔGOLD t-1	0.1352 (0.0579)**	ΔER+	-0.4997 (0.1606)***	ΔER t-1	0.2873 (0.0749)***
ΔOIL t-2	0.0820 (0.0555)	ECT(-1)	-1.0518 (0.0775)***	ΔER-	-0.2267 (0.1193)**	ΔER t-2	0.1348 (0.0567)***
ΔSP +	0.1602 (0.1032)			ΔER+ t-1	-0.5135 (0.1866)***	ΔGOLD+	-0.2018 (0.0758)***
ΔSP-	0.0779 (0.1032)			ΔER- t-1	0.3120 (0.1755)	ΔGOLD-	-0.0583 (0.0715)

ΔSP+ t-1	0.0234 (0.0953)	ΔER+ t-2	-0.1335 (0.1484)	ΔGOLD+ t-1	0.3007 (0.0839)***
ΔSP- t-1	-0.3766 (0.1173)***	ΔER- t-2	-0.3169 (0.1331)***	ΔGOLD- t-1	0.2059 (0.0741)***
ΔER+	-1.1758 (0.2722)***	ECT(-1)	-1.0979 (-18.7265)***	ΔGOLD+ t-2	0.1606 (0.0781)**
ΔER-	0.3673 (0.2145)			ΔGOLD- t-2	0.0558 (0.0700)
ECT(-1)	-1.0175 (0.0881)***			ECT(-1)	-1.4877 (0.1138)***

*Note: ***, **, * shows significant level at 1%, 5% and 10%, respectively.*

The results from the error correction model (ECM) are presented in Table 8. The model is applied to observe the dynamic relationship among the selected markets in the short term. The error correction term (ECT) returns negative and significant in the OIL (-1.0175), SP (-1.0979) and ER (-1.4877) equations. This indicates that stock prices, crude oil prices, gold prices, and exchange rates tend towards equilibrium after the systems experience any shock. However, the low value of the coefficient indicates the slower speed of adjustment. A noticeable finding is that movements in gold prices do not influence oil prices in the short run. Therefore, gold does not make a substitute for crude oil in the short run. However, the stock market and exchange rate fluctuations have a significant impact on oil prices in the short run. Our analysis indicates that negative stock price movements (lag 1) exhibit a negative price adjustment in Oil (0.3766), while positive movement in exchange rate causes a simultaneous negative adjustment (-1.1758) towards Oil.

The present analysis specifies that changes in oil and gold prices do not influence the stock market in the short run. On the other hand, there is a significant impact of the exchange rate over the stock market in the short-run as the Wald test (Table 9) also confirms the asymmetric short-run effect of the exchange rate on the stock market. It is found that stock price undertakes both positive and negative adjustments towards the negative movements (-0.4997, -0.2267). Moreover, positive movements in the exchange rate at lag (1) cause negative adjustment (-0.5135) in the stock market, and negative movements in the exchange rate at lag (2) also cause negative adjustment (-0.3169) in the stock market.

In the context of the ER equation, the present analysis indicates that upward movement in the gold price exhibits a simultaneous downward adjustment in the exchange rate (-0.2018). Exchange rate, on the other hand, experiences positive shifts towards positive movements in the gold market at lag 1 (0.3007, 0.2059). Furthermore, the exchange rate is perceived to indicate a positive adjustment in the direction of the positive movement in gold (0.0781) at lag 2. Meanwhile, according to the estimates of the GOLD equation, it is confirmed that the movement in all three assets, Oil, stock market, and exchange rate do not affect the gold market in the short run.

Table 9. Wald test results for short- and long-run symmetry

Variables	WLR	WSR
Panel A: Estimates of the OIL equation		
ER	0.0029	3.0597*
GOLD	0.0665	--
SP	0.0236	1.5716*
Panel B: Estimates of the GOLD equation		
ER	17.4035***	--
OIL	1.27943	--
SP	9.75432***	--
Panel C: Estimates of the SP equation		
ER	2.9701	8.3201***
GOLD	2.1182	--
OIL	0.5909	--
Panel D: Estimates of the ER equation		
GOLD	5.4037**	0.2010
OIL	0.0604	--
SP	4.7326**	--

*Notes: ***, **, and * show significant levels at 1%, 5%, and 10%, respectively.*

In Table 9, we report the estimates of the Wald test to test the long- and short-run symmetry. WLR represents the Wald estimates for long-run symmetry. WSR for long-term symmetry. Based on the estimates shown in column 1 of the table, we reject the null hypothesis of the long-run symmetric link in the GOLD equation for exchange rate and stock price. In the same vein, in the equation of exchange rate, the long-run symmetry for gold and stock prices is rejected. WSR represents the Wald estimates for short-run symmetry.

Results reported in Table 9 (second column), reject the null hypothesis of short-run symmetry for the stock price and exchange rate in the OIL equation, and the exchange rate in the SP equation. However, there is no information for the remaining variable.

Table 10. Diagnostic Tests for NARDL

TEST STATISTICS	RESULTS
Panel A: OIL Equation	
Heteroskedasticity	6.8837 (0.0000)
Serial correlation: LM statistics	0.4577 (0.6332)
Panel B: GOLD Equation	
Heteroskedasticity:	1.6618 (0.1079)
Serial correlation: LM statistics	0.1524 (0.8587)
Panel C: SP Equation	
Heteroskedasticity	4.5456 (0.0000)
Serial correlation: LM statistics	1.4395 (0.2389)
Panel D: ER Equation	
Heteroskedasticity	3.6817 (0.0000)
Serial correlation: LM statistics	1.8455 (0.1045)

There are a few assumptions that have to be met for applying the NARDL model to avoid spurious regression. The results of the diagnostic tests are reported in Table 10, which validates the application of the NARDL model. These tests are accompanied to determine the model's goodness of fit. However, there is a problem of heteroscedasticity in the regression equation of oil, SP, and ER. To solve these issues, we have used HAC covariance matrix modification to resolve this issue, as HAC can fix the value of any test statistics produced during the estimate. Furthermore, the Cumulative Sum (CUSUM) (Figures 1, 2, 3, and 4) are applied that are within the boundaries, specifying the stability of the regression model is stable.

CUSUM Plots

Figure 1. Oil Price

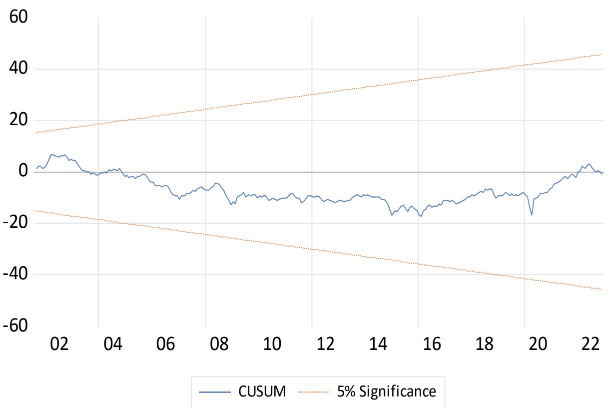


Figure 2. Gold Price

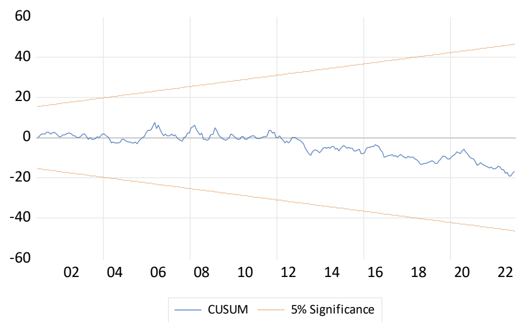


Figure 3: Stock Market

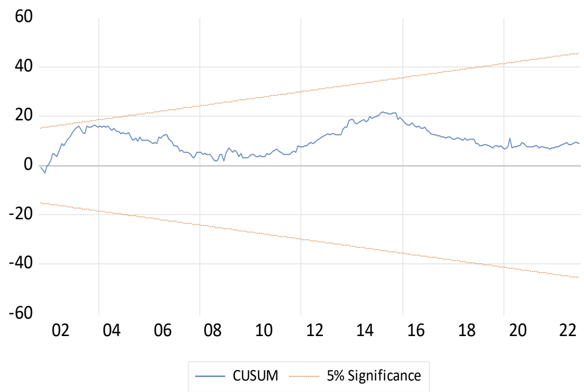
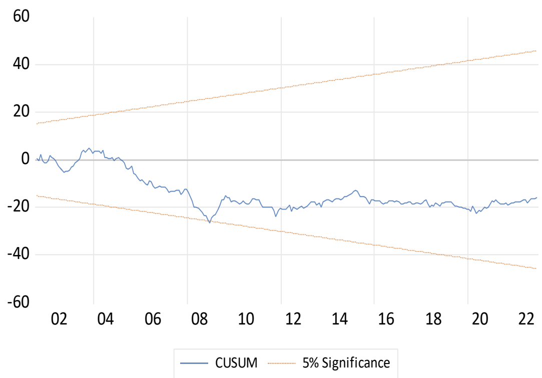


Figure 4: Exchange Rate



CONCLUSION AND IMPLICATIONS

This paper investigates empirically the dynamic and causal connection between gold, oil, exchange rate, and stock market in the Indonesian context using the NARDL approach and monthly data from January 2000 to December 2022. Our analysis reveals detailed information about the asymmetric linkages and causation between the four markets in the short and long run. The result from ARDL bound testing confirms the co-integration between the selected variables taken as the dependent variable. The analysis further uncovers a significant asymmetric causal effect of the exchange rate on the oil, gold, and stock markets in the long run. In the short run, in contrast, the causation is symmetric over oil and the stock market with no significant impact on gold. Current analysis also shows that, in the short run, variations in stock returns asymmetrically influence gold and the exchange rate. However, stock market shocks leave a significant and asymmetric impact on oil prices in the short run.

The current study has significant implications for academia, crude oil traders, investors, financial regulators, and Indonesian policymakers. As oil, gold, the exchange rate, and Indonesian stock market remain co-integrated, therefore, investors have to proceed with vigilance when considering the advantages of diversification for these selected assets. This research may also help investors, energy producers, traders, and portfolio managers in Indonesia in different asset categories to develop appropriate plans for constructing and modifying their portfolios. There are certain limitations in this study; this study has analyzed the linkages and nexus among selected assets Indonesian market perspective only but other economies of the ASEAN region that Thailand, Singapore, Malaysia, and the Philippines are still unexplored in this context. Furthermore, this study has considered the analysis of the whole sample but ignored the periods of crises like pre and post analysis in terms of Global financial crises.

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