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Asymmetric Effects of Uncertainty and Commodity Markets on Sustainable Stock in Seven Emerging Markets

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Abstract: The increase in global economic policy uncertainty (EPU), volatility or stock market uncertainty (VIX), and geopolitical risk (GPR) has affected gold prices (GD), crude oil prices (WTI), and stock markets, which present challenges for investors. Sustainable stock investments in emerging markets may minimize and diversify investor risk. We applied the non-linear autoregressive distributed lag (NARDL) model to examine the effects of EPU, VIX, GPR, GD, and WTI on sustainable stocks in seven emerging markets (Thailand, Malaysia, Indonesia, Brazil, South Africa, Taiwan, and South Korea) from January 2012 to June 2023. EPU, VIX, GPR, GD, and WTI showed non-linear cointegration with sustainable stocks in seven emerging markets and possessed different asymmetric effects in the short and long run. Change in EPU increases the return of Thailand's sustainable stock in the long run. The long-run GPR only affects the return of Indonesian sustainable stock. All sustainable stocks are negatively affected by the VIX and positively affected by GD in the short and long run. Additionally, long-run WTI negatively affects the return of Indonesia's sustainable stocks. Our findings contribute to rational investment decisions on sustainable stocks, including gold and crude oil prices, to hedge the asymmetric effect of uncertainty.

Keywords: geopolitical risk; global economic policy uncertainty; sustainable stock; asymmetric; NARDL

JEL Classification: C50; D81; G10; Q40

1. Introduction

Economic policy shifts are regarded as uncertainties of a dynamic nature that may have an impact on businesses (Pástor and Veronesi 2012). Uncertainties are also known as systematic risks, which cannot be avoided and disturb investors. During times of high uncertainty, investors would seek higher returns to risk premium when holding financial assets, which collides with the financial economics theory that explains the positive relationship between risk and returns (Prukumpai et al. 2022). Baker et al. (2016) calculated the economic policy uncertainty index using a newspaper-based approach that reflected economic risks in the United States and pointed out that economic policy uncertainty has a high significant impact on the entire economy. Thus, economic policy uncertainty affects the stock market more than geopolitical risks (GPRs) and financial stress (Das et al. 2019; Kamal et al. 2022; Tran and Vo 2023). The study on economic policy uncertainty were applied to investigate the relationship between stock markets in many countries (see, e.g., Erdoğan et al. 2022; Nusair and Al-Khasawneh 2023). This principle has been applied across many countries, and based on this, Davis (2016) created a global economic policy uncertainty (EPU) index.

The EPU quantifies the influence on stock markets, and relevant research has revealed the relationship between stock markets and commodity markets, such as gold and crude oil, across different countries (see, e.g., Raza et al. 2016; Hoque et al. 2019; Atri et al. 2023).

The Chicago Board of Options Exchange (CBOE) volatility index reflects investor fears of US stock market uncertainty (VIX) (Ghumro et al. 2022) and is commonly employed as a benchmark for assessing uncertainty in the stock market (see, e.g., Prukumpai et al. 2022; Tran and Vo 2023). Black Swan events, such as the financial crisis in 2008, the European sovereign debt crisis in 2009, and the oil crisis in 2014, created uncertainty in global stock markets. These effects have drawn considerable attention to a global society confronted with unprecedented COVID-19, which has resulted in the most uncertain crude oil price volatility since the 1970s (Chancharat and Sinlapates 2023). Oil prices have fallen owing to the fall in demand for oil, global stock markets, and the economic and industrial activities of oil-importing countries. Hence, with gold being a safe haven, prices should increase (Baur and Lucey 2010). However, Kamal et al. (2022) found that gold was not affected by the EPU, VIX, or GPR during the COVID-19 pandemic.

The Russia–Ukraine war on 24 February 2022 added to GPR and damaged the economy, as well as affecting global financial markets, while rendering it difficult to recover from the COVID-19 effect. The evidence of the Russia–Ukraine war encourages an increase in energy costs that may occur both in the short run and in the long run (Umar et al. 2022; Wang et al. 2022). Stock markets are sensitive to uncertainty and highly influence investor sentiment. As a result, investors would seek safe-haven assets within a store of value such as gold (Baur and Smales 2020; Lei et al. 2023; Taera et al. 2023). Owing to high uncertainty in previous years, investments in companies with environmental, social, and governance (ESG), known as sustainable stock, have grown in popularity worldwide in the markets because sustainable stock will assist in diversifying risk in the long run (Andersson et al. 2022). By 2022, the investment value of ESG reached USD 41 trillion, exceeding the COVID-19 period in 2020, reaching USD 35 trillion, and is expected to rise to USD 50 trillion by 2025 (Diab 2022). The increase in sustainable stock investment is caused by a shift in demand toward socially responsible investing, which places a greater emphasis on social, environmental, and ethical benefits (Garel and Petit-Romec 2021), as well as the desire to lower risks, especially during a crisis and uncertainty (Mousa et al. 2022).

In addition to an increase in sustainable stock investments, investors should be aware of portfolio management risks. GPR, VIX, EPU, and commodity price changes in recent years have anticipated consequences with a negative effect on the stock market because they are risky assets that are sensitive to uncertainty and dependent on commodity prices (Kamal et al. 2022; Atri et al. 2023). Sustainable stocks are negatively affected by EPU and VIX (Shaikh 2022; Naeem et al. 2023), while they are positively affected by gold and crude oil prices (Darsono et al. 2022). Besides the limited studies on the effect of GPR on sustainable stocks, Taera et al. (2023) indicate that sustainable stock bears a lower risk during high GPR and acted as a safe haven during COVID-19 (Rubbaniy et al. 2022), while Piserà and Chiappini (2024) explained that sustainable stocks are not safe havens, as they have a positive relationship with the stock market. A study by Tang et al. (2023) on financial assets, which is similar to sustainable stocks, concluded that GPR has a negative effect on green bonds. Likewise, GPR and VIX also negatively affect clean energy stocks (Ghosh 2022). Sarker et al. (2023) explained that GPR positively affects clean energy stocks in the long run.

Therefore, uncertainties could unequally or asymmetrically affect sustainable stocks, both positively and negatively. Investors should employ sufficient knowledge for decision making. Thus, under these uncertainties (EPU, GPR, and VIX), investing in emerging markets is a suitable risk diversification strategy, as they bear a lower response than developed countries (Bossman and Gubareva 2023; Tran and Vo 2023). Investing in sustainable stocks is more flexible against environmental issues than investing in capital markets (Shaikh 2022). Studies on sustainable stocks in emerging markets have received little attention. Naeem et al. (2023) pointed out that changes in the VIX are bad news for sustainable stocks in emerging Asian markets. Darsono et al. (2022) explained that investing in Chinese and Brazilian sustainable stocks could only diversify gold and crude oil. In contrast, Cagli et al. (2023) emphasized that investing in sustainable stock in emerging markets could effectively

hedge against crude oil. Bhattacherjee et al. (2023) reported that studies on sustainable stocks in each emerging market usually lack concern for GPR and do not provide a comprehensive understanding of the effects of uncertainties, including gold and crude oil prices, on emerging markets.

To address this gap, we consider the effects of EPU, VIX, GPR, and commodity markets such as gold and crude oil, since the effect of uncertainties and commodity markets occurs differently in positive and negative ways. We apply the non-linear autoregressive distributed lag (NARDL) model by Shin et al. (2014) to examine the asymmetric effects on sustainable stock in seven emerging markets, namely Thailand, Malaysia, Indonesia, Brazil, South Africa, Taiwan, and South Korea. Thus, we exclude other emerging markets due to a lack of sufficient data. The model analyzed monthly data from January 2012 to June 2023. Our study offers investors valuable insights into effective portfolio management in situations characterized by uncertainty. Investors can employ data on the effect of sustainable stocks in the short and long run to adjust their portfolios and expected returns. In addition, we offer valuable insights into minimizing the effect of uncertainties on maintaining the stability of a sustainable stock market.

The subsequent sections of the paper are as follows: in Section 2, we provide a literature review. In Section 3, we elaborate on data and methodology. Section 4 contains the result and discussion. Finally, Section 5 includes the conclusions, policy implications, and future recommendations.

2. Literature Review

Efficient market theory states that the prices of securities accurately reflect perfect information. Investors can expect returns according to their risk profiles. Sharpe (1964) categorized financial market risks into systemic and unsystematic risks. Investors can diversify their investments to avoid unsystematic risks specific to corporate risks. In contrast, systemic risk comes from markets and macroeconomic factors that are unavoidable (Prukumpai et al. 2022). The capital asset pricing model (CAPM) can be used to show systematic risk. However, changes in global markets are also a contributing factor to their influence on stock markets rather than domestic macroeconomics alone (Donadelli 2015). Global economic policy uncertainty (EPU), stock market uncertainty (VIX), and geopolitical risk (GPR) are global risk factors that significantly impact the performance of financial markets, including the co-movement between commodity prices and financial markets. In this study, we examined gold and crude oil prices as commodities. Gold is widely recognized as a safe haven, whereas crude oil plays a crucial role in driving economic activity. Thus, we summarized the literature review into two points: first, uncertainty effects on sustainable stocks, and second, the effects of gold and crude oil prices on sustainable stocks.

2.1. Uncertainty Effects on Sustainable Stock

Economic policy uncertainty causes significant challenges for investors and policymakers in pushing and pulling capital flow in financial markets, while negatively impacting economic activity in terms of demand, leading to a temporary halt in investments and supply, which affects employment and productivity (Bernanke 1983; Bloom 2009). This situation has a negative effect on the performance of stock markets and creates a dilemma among investors, prompting them to make reckless decisions that ultimately lead to a crash in the stock market (Pástor and Veronesi 2013). Additionally, the consequences of economic policy uncertainty can trigger spillover effects on stock markets and sustainable stocks. According to Lean and Nguyen (2014), the US economic policy uncertainty affects the return and volatility of Asia Pacific and North American sustainable stocks due to sustainable stocks being similar to stocks but with a socially responsible investment perspective. A study by Nusair and Al-Khasawneh (2023) discussed the economic policy uncertainty that negatively affects the G7, and the study by Shaikh (2022) discusses the effects on US sustainable stocks. By contrast, Darsono et al. (2022) found that economic

policy uncertainty has a positive effect on Russian sustainable stocks. Bhattacherjee et al. (2023) studied the effect of EPU on sustainable stocks in both developed and emerging markets in the long run. A similar study on sustainable stocks by Tang et al. (2023) stated that there are different positive and negative effects of the US economic policy uncertainty on green bonds.

The VIX, in addition to EPU, measures market expectations of uncertainty in the US stock market (S&P 500) over the next 30 days, and is inversely related to the stock prices. Therefore, when there is an increase in VIX, it signifies a corresponding rise in investors' fear during downside risks (Ghumro et al. 2022) and negatively affects the stock markets in Hong Kong, Australia, and Japan, asymmetrically, in the short and long run (Tran and Vo 2023), as well as sustainable stock in Asia Pacific countries since sustainable stocks are part of stock markets (Naeem et al. 2023). However, VIX has a positive effect on renewable and alternative energy stocks (Ghosh 2022). GPR emerges from political uncertainty in governments and social issues with the potential to affect international relations. The GPR index proposed by Caldara and Iacoviello (2022) employs the same underlying idea as the economic policy uncertainty presented by Baker et al. (2016). GPR is expected to negatively affect the Canadian stock market (Bossman and Gubareva 2023), with asymmetric effects on the Brazilian, South African, and Turkish stock markets (Hoque and Zaidi 2020), while Malaysian and US stocks remain unaffected (Hoque et al. 2019; Kamal et al. 2022).

Nevertheless, the increased GPR from the Russian–Ukrainian War has presented a challenging obstacle for investors in risk management (Umar et al. 2022). Mousa et al. (2022) suggested that investing in sustainable stock in the Arab region can minimize the risks associated with the outbreak of COVID-19, and be a safe haven (Rubbaniy et al. 2022), also exhibiting lower volatility compared to stock markets in the case of a Russia–Ukraine war (Taera et al. 2023). Sohag et al. (2022) found that GPR has a positive effect on green equity. On the other hand, Shaikh (2022) and Naeem et al. (2023) discovered that economic policy uncertainty and VIX have a negative effect on sustainable stocks, with similar results in the stock markets. The study of sustainable stock, given the current global uncertainty, has been under-examined while there is growing interest in the investment in sustainable stocks. Hence, investors should consider the pros and cons of investing in sustainable stocks with regard to the effects of uncertainty. Thus, we address this gap by analyzing the effects of uncertainty on sustainable stocks in seven emerging markets.

2.2. Gold and Crude Oil Prices Effects on Sustainable Stock

Past studies indicate a significant interest in the relationship between changes in gold and crude oil-price linkages to stock markets. However, a consensus on this relationship remains elusive. Baur and Lucey (2010) stated that gold is a safe haven for stock markets, as it exhibits a negative effect and can hedge stock markets in ten developed markets (Ali et al. 2020). Similarly, Lei et al. (2023) determined that gold prices negatively affected sustainable stock in the developed countries of the Asia–Pacific region and displayed a negative effect on the US stock market in the long run (Atri et al. 2023). Raza et al. (2016) employ the NARDL model to demonstrate that gold prices have an asymmetrically positive effect on the stock markets of India, Chile, South Africa, Indonesia, and Thailand. The Malaysian stock market (Hoque et al. 2019) and the BRCIS group (Raza et al. 2016) had a negative effect on crude oil prices, as well as Singapore, Japan, New Zealand, and the Philippines' sustainable stock in the long run (Bhattacherjee et al. 2023). Gheraia (2022) argues that crude oil prices have a long-run positive effect on the Saudi Arabian stock market. In addition, the NARDL model was employed to assess the effects of crude oil prices on the Turkish stock markets, as performed by Erdoğan et al. (2022), who found an asymmetric effect of crude oil prices in the short and long run.

Recently, an increase in GPR has affected commodity price volatility. In particular, the spillover effect of crude oil on gold (Wang et al. 2022) and stock markets (Umar et al. 2022), and investment in emerging markets, can contribute to risk reduction (Chancharat and Sinlapates 2023). The rise in awareness of environmental, social, and governance (ESG)

investments or sustainable stocks can be explained by increased volatility in commodity prices, particularly gold and crude oil, as well as the presence of uncertainty. According to Andersson et al. (2022), investing in a sustainable stock can help minimize the risks associated with investing in gold and crude oil, while also being a safe haven and hedging portfolio (Cagli et al. 2023). Darsono et al. (2022) proposed that gold and crude oil prices have a positive effect on Chinese, Brazilian, and US sustainable stocks, implying a positive movement. However, this relationship does not serve as a safe haven. Similarly, Piserà and Chiappini (2024) did not find sustainable stock to be a safe haven. In addition, crude oil prices positively affect clean energy stocks (Ghosh 2022). Sarker et al. (2023) discovered an asymmetrical effect of crude oil prices on clean energy stocks.

Past literature reviews have examined phenomena in stock markets with regard to the effects of EPU, VIX, GPR, gold, and crude oil on sustainable stocks, particularly in emerging markets that have been assessed throughout the entire region (see, e.g., Naeem et al. 2023; Lei et al. 2023). However, there has been a lack of focus on the specific details of each country, as well as empirical studies. Moreover, the outbreak of the Russia–Ukraine war, which is unlikely to end, has had wide effects globally. To capture the short- and long-run consequences, we employ the NARDL model to examine the asymmetric effects of uncertainty and commodity markets on sustainable stocks in seven emerging markets.

3. Data and Methodology

3.1. Data

This study examines the asymmetric effects of uncertainty and commodity markets on sustainable stocks in seven emerging markets: Thailand, Malaysia, Indonesia, Brazil, South Africa, Taiwan, and South Korea. The monthly data during January 2012 to June 2023 were employed. The sustainable stocks data were acquired from the official website of Morgan Stanley Capital International, via www.msci.com (accessed on 4 November 2023). Global economic policy uncertainties (EPUs) and geopolitical risk (GPR) were obtained from www.policyuncertainty.com (accessed on 4 November 2023). Stock market uncertainty (VIX) was obtained from the official website of CBOE via www.cboe.com (accessed on 4 November 2023). Gold and crude oil prices were gathered from www.investing.com (accessed on 4 November 2023). Thus, the variable descriptions are shown in Table 1.

Table 1. Variable descriptions.

Variables	Abbreviation	Description
Sustainable stock	THA	Thailand MSCI ESG leaders standard (USD)
	MYS	Malaysia MSCI ESG leaders standard (USD)
	IDN	Indonesia MSCI ESG leaders standard (USD)
	BRA	Brazil MSCI ESG leaders standard (USD)
	AFR	South Africa MSCI ESG leaders standard (USD)
	TAI	Taiwan MSCI ESG leaders standard (USD)
	KOR	South Korea ESG leaders standard (USD)
Uncertainty	EPU	Global economic policy uncertainty index
	VIX	CBOE volatility index
	GPR	Geopolitical risk index
Commodity	GD	Gold: Gold price (USD per troy ounce)
	WTI	Crude oil: West Texas intermediate crude oil price (USD per barrel)

However, we exclude other emerging markets due to lack of sufficient data. Gold prices, crude oil prices, and sustainable stocks are returns. EPU, VIX, and GPR are change. This can be put into an equation, thus, $r_t = \ln(P_t/P_{t-1})$, when r_t is return (sustainable stocks, gold, and crude oil) and changes (EPU, VIX, and GPR) in the month t, while P_t is price or the index of month t, and ln is a natural logarithm.

3.2. Methodology

We applied the nonlinear autoregressive distributed lag (NARDL) model developed by Shin et al. (2014) to demonstrate the magnitude of reaction asymmetry of response variables in the returns (sustainable stocks) due to changes in the explanatory variables (EPU, VIX, GPR, GD, and WTI) in both the short and long run. NARDL can capture both the short- and long-run asymmetric effects by developing a model of asymmetric cointegration into a single equation. Thus, NARDL possesses advantageous characteristics compared to alternative linear econometric models for examining cointegration (Sarker et al. 2023) and has been widely studied with other financial assets (see, e.g., Gheraia 2022; Ghumro et al. 2022; Atri et al. 2023; Tang et al. 2023).

The NARDL equation (Shin et al. 2014) is expressed as follows:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t \tag{1}$$

When y_t is the response variable, β^+ and β^- are asymmetric long-run parameters; u_t is an error term; and x_t is an explanatory variable vector with the decomposed partial sum of a positive change (x_t^+) and negative change (x_t^-) for x_t, and can thus be presented as

$$x_t = x_0 + x_t^+ + x_t^- \tag{2}$$

When x_0 is the initial value, the process of change in the partial sum of the positive and negative changes can be presented as

$$x_t^+ = \sum_{i=1}^{t} \Delta x_i^+ = \sum_{i=1}^{t} \max(\Delta x_i, 0) \tag{3}$$

$$x_t^- = \sum_{i=1}^{t} \Delta x_i^- = \sum_{i=1}^{t} \min(\Delta x_i, 0) \tag{4}$$

Referring to the NARDL in Equations (1) and (2), the asymmetric error-correction model (AECM) can be rewritten as

$$\Delta y_t = \rho \xi_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{q} \left(\theta_j^+ \Delta x_{t-j}^+ + \theta_j^- \Delta x_{t-j}^- \right) + \varepsilon_t \tag{5}$$

When $\xi_t = y_t - \beta^+ x_t^+ - \beta^- x_t^-$ is a non-linear error-correction term. The speed of adjustment analysis using AECM is based on ρ, and the equation can be rewritten as:

$$\Delta y_t = \alpha + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{q} \left(\theta_j^+ \Delta x_{t-j}^+ + \theta_j^- \Delta x_{t-j}^- \right) + \rho y_{t-1} + \lambda^+ x_{t-1}^+ + \lambda^- x_{t-1}^- + \varepsilon_t \tag{6}$$

$\beta^+ = -\lambda^+ / \rho$ and $\beta^- = -\lambda^- / \rho$, where λ^+ and λ^- are positive and negative long-run coefficients, respectively, while θ_j^+ and θ_j^- are positive and negative short-run coefficients, α is constant, γ is a coefficient, and ε_t is an error term (white noise).

Equation (6) represents the short- and long-run asymmetric effects of the explanatory variable on the response variable; thus, the cointegration by NARDL, by Shin et al. (2014), in the bound test, according to Pesaran et al. (2001), using the F statistic (F_{PSS}). The null hypothesis of cointegration is $H_0 : \rho = \lambda_1^+ = \lambda_1^- = 0$ and the alternative hypothesis of cointegration is $H_1 : \rho \neq \lambda_1^+ \neq \lambda_1^- \neq 0$. The Wald test is used to examine the asymmetric effect in the short run when $\sum_{j=0}^{q} \theta_j^+ \neq \sum_{j=0}^{q} \theta_j^-$ and in the long run when $\lambda_1^+ \neq \lambda_1^-$. NARDL can be expressed as follows:

$$\Delta y_{it} = \alpha + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{q_1^+} \theta_{1j}^+ \Delta EPU_{t-j} + \sum_{j=0}^{q_1^-} \theta_{1j}^- \Delta EPU_{t-j} + \sum_{j=0}^{q_2^+} \theta_{2j}^+ \Delta VIX_{t-j} + \sum_{j=0}^{q_2^-} \theta_{2j}^- \Delta VIX_{t-j}$$

$$+ \sum_{j=0}^{q_3^+} \theta_{3j}^+ \Delta GPR_{t-j} + \sum_{j=0}^{q_3^-} \theta_{3j}^- \Delta GPR_{t-j} + \sum_{j=0}^{q_4^+} \theta_{4j}^+ \Delta GD_{t-j} + \sum_{j=0}^{q_4^-} \theta_{4j}^- \Delta GD_{t-j} + \sum_{j=0}^{q_5^+} \theta_{5j}^+ \Delta WTI_{t-j} \quad (7)$$

$$+ \sum_{j=0}^{q_5^-} \theta_{5j}^- \Delta WTI_{t-j} + \rho y_{it-1} + \lambda_1^+ EPU_{t-1}^+ + \lambda_1^- EPU_{t-1}^- + \lambda_2^+ VIX_{t-1}^+ + \lambda_2^- VIX_{t-1}^-$$

$$+ \lambda_3^+ GPR_{t-1}^+ + \lambda_3^- GPR_{t-1}^- + \lambda_4^+ GD_{t-1}^+ + \lambda_4^- GD_{t-1}^- + \lambda_5^+ WTI_{t-1}^+ + \lambda_5^- WTI_{t-1}^- + \varepsilon_t$$

When y_{it} is the sustainable stock monthly return of emerging market *i* at time *t*. We referred to the hedging definition of Baur and Lucey (2010) and Baur and Smales (2020) to analyze the response of sustainable stocks to EPU, VIX, GPR, GD, and WTI. The sustainable stocks can be a strong (weak) hedge when there is a positive correlation (uncorrelation) against EPU, VIX, and GPR. Sustainable stocks can be a strong (weak) hedge when there is negative correlation (uncorrelation) against GD and WTI. Thus, the hypotheses are tested.

4. Result and Discussion

4.1. Descriptive Statistics

Table 2, Panel A, presents a report of descriptive statistics. Except for Taiwan sustainable stock (TAI), all sustainable stocks show lower average returns than gold (GD), while the return of crude oil (WTI) shows a lower average return than all sustainable stocks except the Malaysian sustainable stock (MYS) and the Brazilian sustainable stock (BRA). The TAI exhibits the highest average return, while GPR has the largest average change. All data do not follow a normal distribution, hence the Jarque–Bera statistical test is significant except for GD, which indicates a 0.01 stationary level, or I(0), which is statistically significant, according to the augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests. As a result, the data are suitable for applying NARDL, as it is stated by Shin et al. (2014) that data should not indicate stationary at second difference or I(2) (see, e.g., Raza et al. 2016; Gheraia 2022; Sarker et al. 2023).

Table 2, Panel B, displays the correlation matrix, and all sustainable stocks maintain a positive relationship with GD and WTI but a negative relationship with global economic policy uncertainty (EPU), stock market uncertainty (VIX), and geopolitical risk (GPR), except MYS and BRA, which bear a positive relationship with GPR. Furthermore, EPU, VIX, GPR, GD, and WTI showed no multicollinearity, due to variance inflation factor (VIF) < 10. Figure 1 shows the movement pattern of prices and returns on sustainable stocks, gold, and crude oil, including index and change of EPU, VIX, and GPR in the data series over the study period.

4.2. Asymmetric Effects of EPU, VIX, GPR, GD, and WTI on Sustainable Stock

We applied non-linear autoregressive distributed lag (NARDL) to our study. As a result of non-linear cointegration for seven emerging markets reported in Table 3, we analyze the cointegration using the F_{PSS} test and use the Akaike information criterion (AIC) to select the optimal lag length. Table 4 shows the short- and long-run asymmetrical effects of global economic policy uncertainty (EPU), stock market uncertainty (VIX), geopolitical risk (GPR), gold prices (GD), and crude oil prices (WTI) on the sustainable stocks of Thailand (THA), Malaysia (MYS), Indonesia (IDN), Brazil (BRA), South Africa (AFR), Taiwan (TAI), and South Korea (KOR). Our analysis found that EPU, VIX, GPR, GD, and WTI affect sustainable stock change in an asymmetric manner. We observed a significant statistic for the speed of adjustment (ECM), and all sustainable stocks except THA and IDN show more than −1. Narayan and Smyth (2006) suggest that an ECM coefficient between −1 and −2 implies that equilibrium exists and there is dampened fluctuation. However, the error correction process appears rapidly, and thus the long-run consideration is recommended.

Table 2. Descriptive summary.

Variables	THA	MYS	IDN	BRA	AFR	TAI	KOR	EPU	VIX	GPR	GD	WTI
Panel A: Descriptive statistics and unit root tests												
Average (%)	0.050	−0.426	0.037	−0.426	−0.078	0.858	−0.122	0.237	−0.261	0.301	0.072	−0.244
S.D. (%)	5.778	4.247	6.600	9.877	7.174	5.670	6.356	18.395	24.656	18.471	4.170	14.794
Max (%)	21.245	10.800	14.277	24.742	17.851	22.169	16.136	62.525	85.259	72.449	10.342	41.334
Min (%)	−17.999	−15.883	−37.498	−48.520	−28.766	−18.689	−22.040	−49.540	−61.428	−50.856	−11.715	−84.414
Skewness	−0.087	−0.439	−1.581	−0.744	−0.518	0.011	−0.490	0.414	0.439	0.307	0.148	−2.209
Kurtosis	4.448	4.020	9.800	6.090	3.963	5.646	4.071	4.363	3.759	3.789	2.851	15.860
J-B	12.151 [a]	10.344 [a]	321.05 [a]	67.153 [a]	11.420 [a]	39.969 [a]	12.042 [a]	14.521 [a]	7.689 [b]	5.708 [c]	0.624	1055.5 [a]
ADF	−11.555 [a]	−11.447 [a]	−11.124 [a]	−11.361 [a]	−12.414 [a]	−13.011 [a]	−12.083 [a]	−15.476 [a]	−16.484 [a]	−16.480 [a]	−11.933 [a]	−8.558 [a]
PP	−11.790 [a]	−11.587 [a]	−11.468 [a]	−11.990 [a]	−12.508 [a]	−12.941 [a]	−12.074 [a]	−20.488 [a]	−26.302 [a]	−25.470 [a]	−12.007 [a]	−8.198 [a]
Panel B: Correlation matrix and multicollinearity												
THA	1.000											
MYS	0.583 [a]	1.000										
IDN	0.620 [a]	0.525 [a]	1.000									
BRA	0.507 [a]	0.553 [a]	0.514 [a]	1.000								
AFR	0.632 [a]	0.638 [a]	0.556 [a]	0.639 [a]	1.000							
TAI	0.512 [a]	0.616 [a]	0.414 [a]	0.422 [a]	0.587 [a]	1.000						
KOR	0.580 [a]	0.640 [a]	0.425 [a]	0.471 [a]	0.674 [a]	0.722 [a]	1.000					
EPU	−0.039	−0.114	−0.180 [b]	−0.045	−0.074	−0.083	−0.118	1.000				
VIX	−0.481 [a]	−0.442 [a]	−0.274 [a]	−0.327 [a]	−0.481 [a]	−0.414 [a]	−0.509 [a]	−0.055	1.000			
GPR	−0.096	0.029	−0.088	0.048	−0.057	−0.148 [c]	−0.141 [c]	0.040	0.079	1.000		
GD	0.188 [b]	0.241 [a]	0.247 [a]	0.253 [a]	0.272 [a]	0.250 [a]	0.261 [a]	0.084	−0.034	0.005	1.000	
WTI	0.159 [c]	0.206 [b]	0.197 [b]	0.325 [a]	0.317 [a]	0.168 [b]	0.276 [a]	−0.204 [b]	−0.170 [b]	−0.084	−0.012	1.000
VIF								1.060	1.012	1.045	1.008	1.085

Notes: Superscripts "a", "b", and "c" indicate significance at 1%, 5%, and 10% levels, respectively. The augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are used to check the unit root tests, including the intercept and trend of all the return series. The variance inflation factor (VIF) is used for the multicollinearity test.
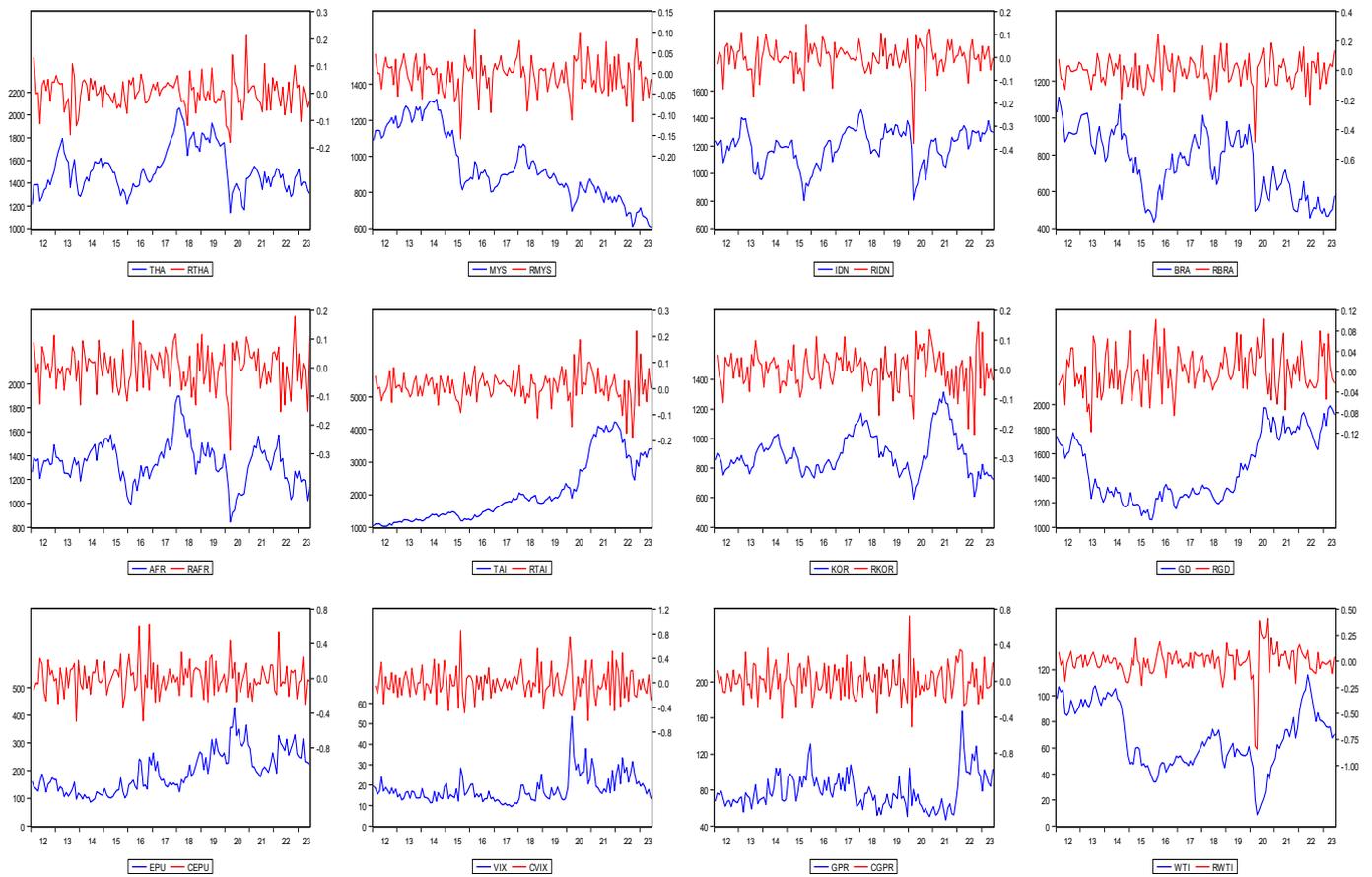
Figure 1. Prices and returns of sustainable stocks, gold, and crude oil, including index and change of EPU, VIX, and GPR.

Table 3. Bounds test for non-linear cointegration.

Variables	Lag Structure	F_{PSS}	Conclusion
THA	1, 0, 1, 2, 2, 0, 0, 1, 0, 2, 0	13.100 [a]	Cointegration
MYS	1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	11.830 [a]	Cointegration
IDN	1, 0, 0, 2, 1, 3, 0, 0, 0, 0, 3	12.220 [a]	Cointegration
BRA	1, 0, 1, 4, 0, 3, 3, 0, 0, 3, 0	11.371 [a]	Cointegration
AFR	1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 2	16.013 [a]	Cointegration
TAI	1, 0, 2, 3, 3, 0, 1, 0, 1, 0, 0	12.528 [a]	Cointegration
KOR	1, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0	13.304 [a]	Cointegration

Notes: Superscript "a" indicates significance at the 1% level and is based on the Akaike information criterion (AIC) selection model. The lower and upper bounds are 2.54 and 3.86, 2.06 and 3.24, and 1.83 and 2.94 for 1%, 5%, and 10%, respectively.

Furthermore, the diagnostic tests conducted on sustainable stocks revealed no serial correlation except for the AFR and no heteroskedasticity except for IDN, TAI, and KOR. The residual series were found to be normal except for TAI (Table 4, Panel C). The stability test for the cumulative sum of recursive residuals (CUSUM) and the CUSUM of squares (CUSUMSQ) indicates the stability of the coefficients and variances (Figures A1 and A2).

Table 4. Result from NARDL model.

Variables	THA	MYS	IDN	BRA	AFR	TAI	KOR
Panel A: Short-run asymmetric effects							
ΔEPU^+_t	−0.035	−0.027	−0.030	0.032	−0.058 [c]	−0.063 [c]	−0.045 [c]
ΔEPU^-_t	0.051	−0.035 [c]	−0.043	0.004	−0.001	−0.006	−0.056 [b]
ΔVIX^+_t	−0.087 [a]	−0.078 [a]	−0.063 [b]	−0.033	−0.125 [a]	−0.137 [a]	−0.125 [a]
ΔVIX^+_{t-1}	−	−	−0.059 [b]	−0.039	−	−	−
ΔVIX^+_{t-2}	−	−	0.037	0.143 [b]	−	−	−
ΔVIX^-_t	−0.083 [a]	−0.070 [a]	−0.064 [c]	−0.260 [a]	−0.105 [a]	−0.049 [b]	−0.108 [a]
ΔVIX^-_{t-1}	−	−	−	0.189 [b]	−	−	−
ΔVIX^-_{t-2}	−	−	−	0.072	−	−	−
ΔGPR^+_t	−0.079 [a]	0.013	−0.089 [b]	0.040	−0.030	−0.026	−0.057 [b]
ΔGPR^+_{t-1}	−0.033	−	−	0.164 [a]	−	−	−
ΔGPR^+_{t-2}	−	−	−	−0.101 [c]	−	−	−
ΔGPR^-_t	0.042	0.020	0.038	0.080	0.050	−0.014	0.011
ΔGPR^-_{t-1}	−	−	0.112 [a]	−	0.079 [b]	−	−
ΔGPR^-_{t-2}	−	−	0.070 [b]	−	−	−	−
ΔGD^+_t	0.343 [a]	0.275 [a]	0.335 [b]	0.813 [a]	0.494 [a]	0.493 [a]	0.625 [a]
ΔGD^-_t	0.099	0.262 [a]	0.259 [b]	0.391	0.390 [a]	−0.019	0.193
ΔGD^-_{t-1}	−	−	−	−	−	−0.188	−
ΔWTI^+_t	0.022	0.033	−0.082	0.199 [b]	0.099 [b]	−0.035	0.061 [c]
ΔWTI^+_{t-1}	0.077 [b]	−	0.086 [c]	0.011	−	−0.019	−
ΔWTI^+_{t-2}	−	−	−	0.167 [b]	−	0.075 [c]	−
ΔWTI^+_{t-3}	−	−	−	−0.164 [b]	−	−	−
ΔWTI^-_t	−0.024	0.021	0.011	0.133	0.083 [c]	0.011	0.047
ΔWTI^-_{t-1}	−0.141 [b]	−	−	−	−	−0.074	−
ΔWTI^-_{t-2}	−	−	−	−	−	−0.114 [b]	−
ECM_{t-1}	−0.951 [a]	−1.004 [a]	−0.947 [a]	−1.023 [a]	−1.143 [a]	−1.258 [a]	−1.105 [a]
Panel B: Long-run asymmetric effects							
C	−0.012	0.009	0.008	−0.014	0.021	0.002	0.007
EPU^+	0.086 [b]	−0.027	−0.032	0.031	0.001	−0.050 [c]	−0.041 [c]
EPU^-	0.054	−0.035 [c]	−0.045	0.004	−0.001	−0.061 [b]	−0.051 [b]
VIX^+	−0.091 [a]	−0.078 [a]	−0.083 [b]	−0.411 [a]	−0.109 [a]	−0.109 [a]	−0.114 [a]
VIX^-	−0.088 [a]	−0.070 [a]	−0.068 [c]	−0.420 [a]	−0.092 [a]	−0.099 [a]	−0.098 [c]
GPR^+	−0.011	0.013	−0.094 [b]	0.048	−0.026	−0.021	0.004
GPR^-	0.044	0.020	−0.077 [c]	0.078	−0.021	−0.011	0.010
GD^+	0.360 [a]	0.274 [a]	0.354 [b]	0.794 [a]	0.432 [a]	0.391 [a]	0.565 [a]
GD^-	0.293 [b]	0.261 [a]	0.273 [b]	0.821 [a]	0.341 [a]	0.351 [a]	0.520 [a]
WTI^+	−0.023	0.033	−0.152 [b]	0.124	0.087 [a]	0.048	0.055 [c]
WTI^-	−0.062	0.021	−0.171 [b]	0.130	0.072 [c]	0.039	0.042
Panel C: Diagnostic tests							
Serial correlation	0.871	1.289	0.029	1.078	5.352 [c]	0.352	1.725
Heteroskedasticity	25.307	11.401	35.321 [b]	21.573	9.459	39.559 [a]	31.562 [a]
Normality	1.015	0.322	1.428	1.824	0.349	9.203 [a]	0.777

Notes: Superscripts "a", "b", and "c" indicate significance at 1%, 5%, and 10% levels, respectively.

The details of the short run in Table 4, Panel A, show that returns on KOR, AFR, and TAI decline by 4.50%, 5.80%, and 6.30% when positive EPU shocks increase by 1%. The increase in negative EPU shocks by 1% will result in increased returns on MYS and KOR by 3.50% and 5.60%, respectively, which is consistent with Shaikh's (2022) study on US sustainable stocks. However, this effect was not observed for THA, IND, or BRA. Thus, investing in sustainable stocks serves as diversification and a weak hedge.

The positive (negative) VIX shocks increased (decreased) by 1%, leading to returns on sustainable stocks in all markets declining between 6.30% and 13.70% (increasing between 4.90% and 26.00%), a declining situation except for BRA. Thus, investors' fear of increasing

stock market volatility is reflected in the returns on sustainable stocks in seven emerging markets. Additionally, positive GPR shocks increased by 1%, resulting in returns on THA, IND, and KOR, which declined between 5.70% and 8.90%. Negative GPR shocks in the previous month increased by 1%, resulting in decreases of 7.80% and 11.20% in IND and AFR, respectively. This illustrates that short-run GPR will result in investors' fear and require longer investment decisions. Therefore, an increase in GPR affects sustainable and clean energy stocks (Ghosh 2022).

Additionally, positive GD shocks increasing by 1% will result in increased sustainable stock returns by 27.50% to 81.30%, while negative GD shocks will decrease returns on AFR, IND, and MYS by 39.00%, 26.20%, and 25.90%, respectively. Thus, sustainable stock investment in seven emerging markets can only serve as a diversifier for GD, given the short-run positive movement in GD. Similarly, Darsono et al. (2022) revealed a short-run positive relationship between gold prices and returns for Chinese and Indian sustainable stocks. A 1% increase in positive WTI shocks results in an increasing return on KOR, AFR, and BRA of 6.61%, 9.90%, and 19.90%, respectively. A 1% increase in negative WTI shocks results in a decreasing return on the AFR of 8.30%. Our study suggests that sustainable stocks can serve as diversifiers in the crisis of short-run energy prices caused by rising crude oil prices, leading to a higher demand for alternative energy. Sustainable stocks will benefit from this situation, in addition to decreasing returns when crude oil prices decline. This is consistent with Ghosh's (2022) finding that clean energy stocks have a positive relationship with crude oil. Similarly, Andersson et al. (2022) concluded that sustainable stock investment serves as a diversifier for crude oil.

Nevertheless, the long-run asymmetrical effect that captures positive (β^+) and negative (β^-) effects will not necessarily develop in the same fashion as in the short run, except for VIX and GD. Positive and negative shocks continue to affect sustainable stocks in the long run (Table 4, Panel B). According to Bhattacherjee et al. (2023), the VIX will continue to affect Australian and Canadian sustainable stocks, similar to the 12 sustainable stocks that are affected by gold prices in the long run (Darsono et al. 2022). An increase in positive (negative) EPU shocks results in an increased return on THA and a decreased return on TAI and KOR (an increased return on MYS, TAI, and KOR). However, Shaikh (2022) found a negative relationship between economic policy uncertainty and US sustainable stocks. Our findings explain why increased EPU causes markets to overreact. However, this behavior will be adapted in the long run, and sustainable stocks are socially responsible investments with the potential to grow (Diab 2022). Thus, increasing returns on sustainable stocks make THA a strong hedge under global economic policy uncertainty. According to Cagli et al. (2023), sustainable stocks could be hedged during the COVID-19 pandemic. The positive (negative) GPR shocks will decrease (increase) the returns on IND in the long run and likewise in the short run. Consequently, an increase in GPR is a trigger for investors' risk assessment and sell-off, resulting in a negative market reaction that is similar to the South African stock market (Hoque and Zaidi 2020). The long-run GPR has no effect on the remaining six sustainable stocks, such as the long-run EPU.

An increase in long-run positive WTI shocks increases the returns on AFR and KOR, whereas an increase in long-run negative WTI shocks decreases the returns on AFR. Hence, positive movements and increasing crude oil prices encourage the use of alternative energy sources. Consequently, this leads to an increasing return on sustainable stocks, whereas returns on IND exhibit a decrease (increase) with an increase in long-run positive (negative) WTI shocks. On the other hand, Darsono et al. (2022) observed a positive long-run effect of crude oil prices on sustainable stocks, as did a study on clean energy by Sarker et al. (2023). Our findings explain that Indonesia relies heavily on crude oil and fossil fuels and that Indonesian sustainable stock markets exhibit limited access and have demonstrated the highest volatility (S.D.[2]) among other sustainable stocks in Asia throughout the study (Table 2, Panel A). An increase in crude oil prices leads to long-run economic costs and, interestingly, appears as bad news for Indonesian sustainable stocks (Table 4, Panel B). Economic growth, interest rates, and exchange rates in each country may deter-

mine the magnitude of this effect. Thus, sustainable stocks in seven emerging markets can hedge against EPU, GPR, and WTI while only diversifying VIX and GD, which differ heterogeneously among countries.

Table 5 shows the Wald test evaluation of the asymmetrical effects of EPU, VIX, GPR, GD, and WTI on sustainable stocks in the seven emerging markets in the short and long run. The following are short- and long-run asymmetric relationships: EPU, GPR, and WTI on THA presented both short and long-run effects; GPR effects on IND and AFR were in the short run; VIX effects on BRA and TAI were in the short run; VIX effects on AFR and KOR were in the long run; WTI effects on TAI were in the short run; and GD effects on TAI and KOR were in the short run.

Table 5. Wald tests for long-run and short-run symmetry.

Variables	THA	MYS	IDN	BRA	AFR	TAI	KOR
Panel A: Short-run							
EPU	6.547 [b]	0.027	0.004	0.148	1.525	1.336	0.204
VIX	0.079	0.760	0.043	2.991 [c]	0.082	4.631 [b]	0.034
GPR	10.669 [a]	0.174	28.532 [a]	0.640	7.205 [a]	0.400	1.895
GD	0.545	0.006	0.066	0.260	0.227	6.664 [b]	3.407 [c]
WTI	9.271 [a]	0.011	0.001	0.549	0.355	13.713 [a]	0.035
Panel B: Long-run							
EPU	4.956 [b]	0.765	0.597	1.081	0.016	0.939	0.638
VIX	0.224	1.246	1.644	0.252	2.998 [c]	1.623	3.197 [c]
GPR	8.360 [a]	0.342	0.529	0.647	0.084	0.459	0.121
GD	1.319	0.088	1.243	0.072	2.385	0.782	0.723
WTI	3.696 [c]	0.775	0.630	0.028	0.555	0.286	0.566

Note: Superscripts "a", "b", and "c" indicate significance at 1%, 5%, and 10% levels, respectively.

5. Conclusions and Policy Implications

Uncertainty is a factor that affects every aspect of the economy, possibly affecting pricing and returns in stock markets, based on financial economics theory. The spillover effect in financial markets influences investors' behavior and portfolio risk-management decisions. Investing in emerging markets and sustainable stocks are diversification options. Similarly, sustainable stocks state a consensus on the importance of investing in low-carbon and global sustainability. However, both investment risk and hedging are uncertain in the financial spectrum. Moreover, the rise in geopolitical risk from the Russia–Ukraine war has impacted the financial and commodity markets, as well as investor sentiment. Therefore, we study the asymmetric effect of global economic policy uncertainty, stock market uncertainty, geopolitical risks, gold prices, and crude oil prices on sustainable stocks in seven markets: Thailand, Malaysia, Indonesia, Brazil, South Africa, Taiwan, and South Korea. We applied the NARDL model and examined the monthly data from January 2012 to June 2023. The empirical findings validate the non-linear cointegration between global economic policy uncertainty, stock market uncertainty, geopolitical risk, gold prices, and crude oil prices with sustainable stocks in seven emerging markets.

Fluctuations in global economic policy uncertainty, stock market uncertainty, geopolitical risks, gold prices, and crude oil prices impose short- and long-run asymmetric effects on sustainable stock in seven emerging markets. In the long run, a positive effect on global economic policy uncertainty will ultimately lead to an increase in the adjustment of Thailand's sustainable stocks. Thus, Thailand's sustainable stock is a strong hedge. Indonesian, Brazilian, and South African sustainable stocks are weak hedges because of their absence of positive and negative effects. In addition, during geopolitical risks, sustainable stocks in seven emerging markets are weak hedges, except for the Indonesian sustainable stock. Positive (negative) effects on stock market uncertainty or bad news (good news) result in a decrease (increase) in sustainable stocks in seven emerging markets, indicating investors'

fear in the short and long run. Furthermore, they show more responses towards bad news than to good news. Similarly, an increase in the positive (negative) effect of gold prices results in an increase (decrease) in sustainable stocks in the seven emerging markets. Thus, sustainable stocks in seven emerging markets lack the potential for direct hedging against gold prices in both the short and long run. Indonesian sustainable stocks can potentially be a direct hedge against crude oil prices due to their positive and negative effects in the long run. Therefore, it is advisable to invest in Thailand's sustainable stock during an increase in global economic policy uncertainty and invest in Indonesian sustainable stocks when crude oil prices increase. During periods of high geopolitical risk, it is recommended to invest in seven emerging markets, except for Indonesian sustainable stocks. Hence, investment in the sustainable stock of seven emerging markets is a diversifier under stock market uncertainty and changes in gold prices.

Our study finds that investors tend to overreact in the short run, which leads to flight safety. However, investors may adapt their behavior in the long run as they are unaffected by global economic policy uncertainty and geopolitical risk. Therefore, our findings would enable domestic and foreign investors to design their portfolios by selecting sustainable stocks in emerging markets to minimize risk from global economic policy uncertainty, geopolitical risk, and changes in crude oil prices. Policymakers may consider the asymmetry of uncertainty as a risk factor when implementing policies, particularly in the initial stages of global economic policy uncertainty and geopolitical risks that affect investor sentiment. Hence, prioritizing specific policies to capture investors' trust and advocate sustainable stock investments will contribute to the accomplishment of the United Nations Sustainability Goals (SDGs). Nevertheless, the limitations of our study include an absence of discussion at the corporate and industrial levels, providing an opportunity to analyze the effect of uncertainties on the return of sustainable business or environmental, social, and governance (ESG). The heterogeneous themes of macroeconomic risk factors include inflation, the world uncertainty index (WUI), the financial stress indicator, economic uncertainty-related queries (EURQs), and other financial assets such as currency and treasury bonds. Finally, further details on the bullish, bearish, and normal conditions of the market can be applied using quantile-on-quantile regression.

Appendix A

The graphics of the stability test for the cumulative sum of recursive residuals (CUSUM) is shown in Figure A1 and the CUSUM of squares (CUSUMSQ) is shown in Figure A2.
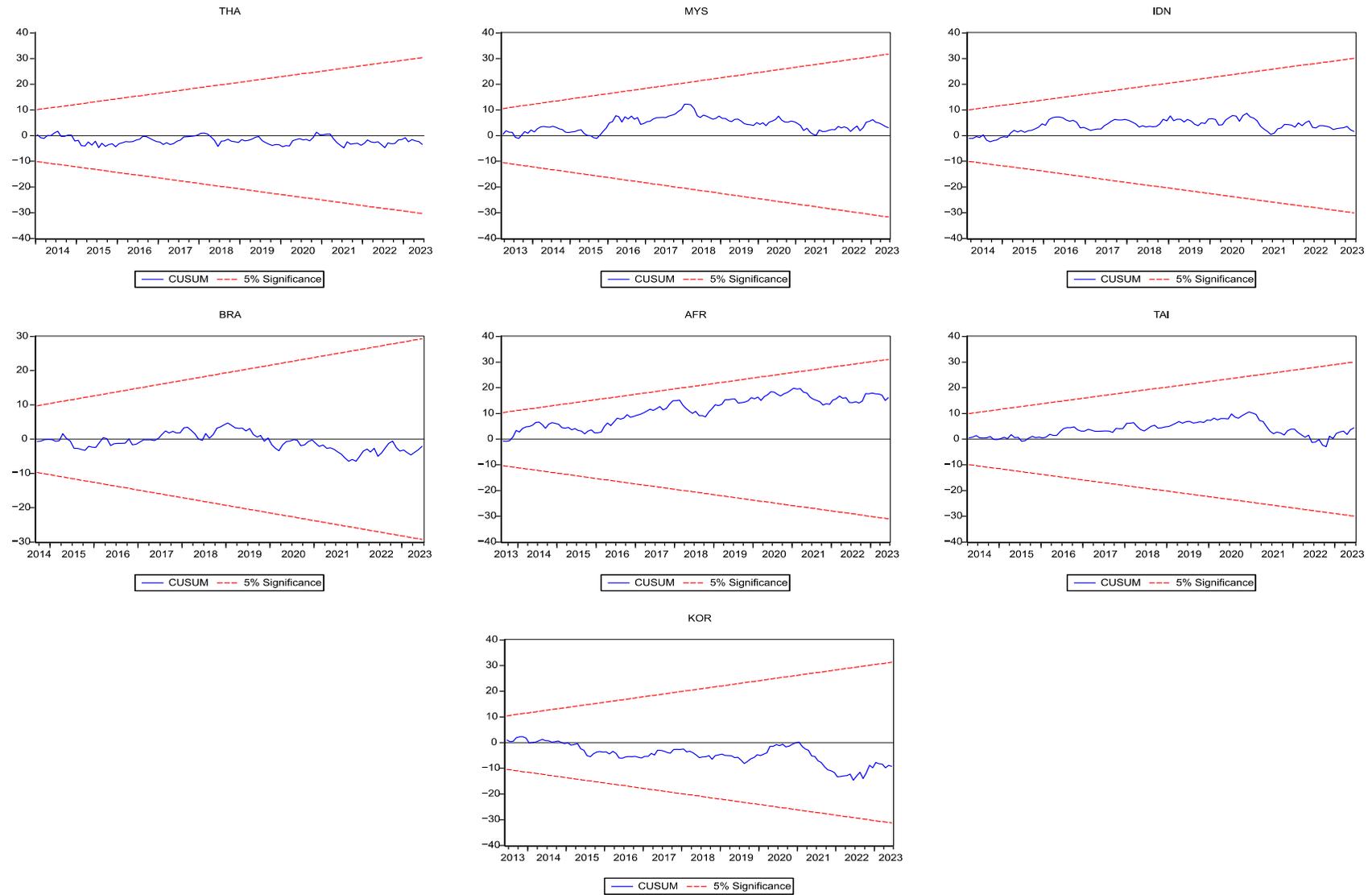
Figure A1. Cumulative Sum of Recursive Residuals (CUSUM).
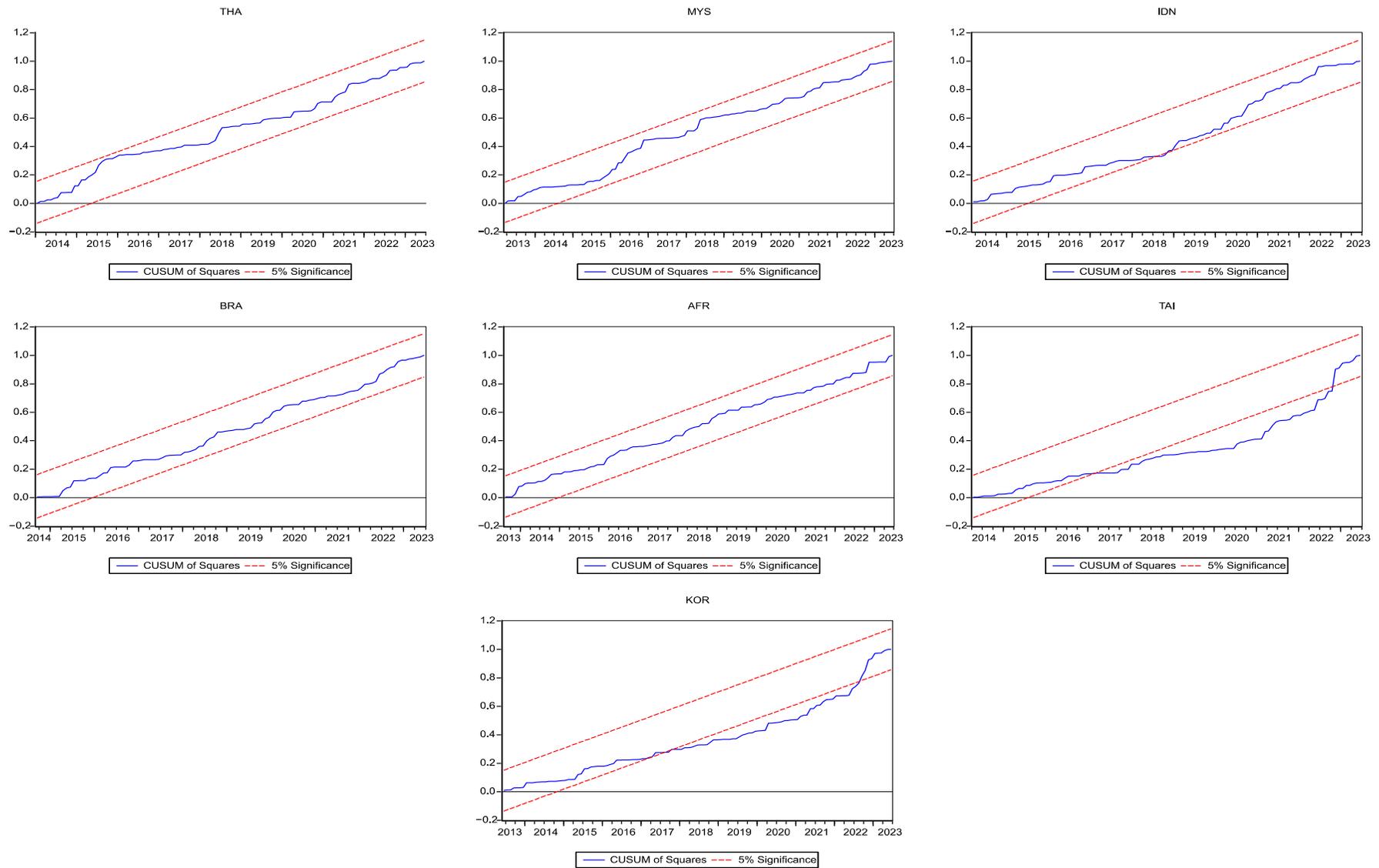
**Figure A2.** CUSUM of Squares (CUSUMSQ).

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