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Asymmetric reactions of the crude oil and natural gas markets on Vietnamese stock markets

Jassim Aladwani
Department of Business Studies, Box Hill College Kuwait, Kuwait City, Kuwait

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Abstract

Purpose – The purpose of studying the impact of crude oil and natural gas prices on the Vietnamese stock market is to understand the relationship between energy prices and the overall performance of the financial markets. As Vietnam is an energy-dependent country, fluctuations in crude oil and natural gas prices can significantly affect various industries, including manufacturing, inflation, transportation, energy production and economic growth. These sectors are often sensitive to changes in energy costs, which can lead to shifts in corporate profitability and investor sentiment. By analyzing how crude oil and natural gas prices influence the Vietnamese stock market, policymakers and investors can provide deeper insights into the economic risks and opportunities related to energy price volatility. This paper can also provide valuable information for decision-making in sectors such as economic forecasting, risk management and investment strategies.

Design/methodology/approach – Using monthly data from January 2006 to March 2024, data were collected from the Vietnamese stock market and the OPEC organization for oil prices, while data on natural gas were obtained from the EIA. The data were analyzed using vector error correction (VEC) model, impulse response function, variance decomposition test and asymmetric reactions method; the study tries to ascertain the short-term and long-term dynamic relationships between the shocks of the crude oil price and natural gas prices and their effects on the movement of the stock price. In addition, the GARCH model is applied to measure the volatility of crude oil and natural gas prices.

Findings – Crude oil price shocks have a statistically significant impact on most Vietnamese real stock market indices, except for the utility and consumer indices and some energy companies. Conversely, natural gas price shocks do not significantly affect on Vietnamese stock market indices, except for the energy index and some energy companies. Some "important" of both crude oil price and natural gas price shocks tend to depress the stock returns of energy companies. An increase in both crude oil and natural gas volatility can lead to heightened speculation in certain indices, particularly the energy and industrial indices, as well as in some energy companies. This heightened speculation often results in elevated of their stock returns.

Originality/value – This study provides valuable insights into the field of study examining how fluctuations in the prices of oil and gas, particularly during major crisis periods such as global financial crisis, COVID-19 pandemic and the Russo-Ukrainian War, affect financial markets.

Keywords Crude oil price volatility, Natural gas price volatility, Vector auto-regressive model, Vietnamese stock market

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1. Introduction

The objective of this study is to examine the dynamic interactions between the stock market and shocks originating from both crude oil and natural gas prices. Unlike the majority of existing studies that predominantly focus on Canada, the US, China, European nations or India, this study investigates the effects of shocks originating from both crude oil and natural gas prices on the Vietnamese stock markets. The choice of Vietnam as a case study is particularly relevant for several reasons. Firstly, Vietnam's position as a crucial player in the global commodities market has gained increasing attention, particularly concerning the volatility of crude oil and natural gas prices. As one of the world's leading oil importers and a significant natural gas producer, the instabilities in both commodity prices have profound implications for the country's financial markets. As one of the leading oil importers globally, Vietnam has experienced a substantial rise in its import activities recently. According to the Organization for Economic Co-operation and Development (OECD, 2023), Vietnam imported $9.7 billion worth of refined petroleum, positioning itself as the 30th largest importer of refined petroleum globally. During that year, refined petroleum was the third most-imported product in Vietnam. The primary sources of Vietnam's refined petroleum imports included South Korea, contributing $3.7 billion; Singapore, providing $1.7 billion; Malaysia, with $1.4 billion; Thailand, accounting for $1.2 billion; and China, which supplied $1.1 billion. Regarding the natural gas, in 2023, Vietnam exported $116 million worth of liquefied natural gas, ranking it as the 35th largest exporter of these products globally (Ha, 2010; OECD, 2023). The primary destination for Vietnam exports of liquefied natural gas was Cambodia, which received $116 million worth. On the other hand, Vietnam imported $12,300 worth of liquefied natural gas, making it the 98th largest importer of these products worldwide. The main supplier of liquefied natural gas to Vietnam was China, providing $12,300 worth (AMRO Annual Consultation Report, 2023).

Second, the relationship between the global oil market and Vietnam has increasingly strengthened. Since 1997, Vietnam has emerged as a net importer of crude oil. By 2013, its reliance on oil imports had surpassed 38%. Consequently, Vietnam is now significantly influenced by fluctuations in the global oil market (Husain, 2015). Since 2005, international crude oil prices have experienced a significant upward trend. In mid-2007, during the global financial crisis (GFC), the prices of OPEC crude oil surged beyond $145.31 per barrel (Hagen *et al*., 2011). Additionally, the COVID-19 pandemic and the ongoing WAR in Russia contributed to further price increases, with prices reaching approximately $115 per barrel from $49 per barrel (Milov, 2024). These fluctuations in the international market led to substantial volatility, which in turn caused Vietnam's domestic crude oil market to rise. This increase in the oil subsequently drove up energy prices, impacting motor, diesel, gasoline, and liquified petroleum gas, coal and electricity costs.

Consequently, Vietnam's nationwide commodity price index also experienced an increase. In the meantime, due to the appreciation of the Vietnamese Dong (VND) against the US dollar and expectations of economic expansion following the Vietnamese government's reforms, the Vietnamese stock market has shown steady growth since 2010. The encouraging economic conditions, with the economy expanding at a rate of approximately 6.7%, have attracted investors from around the globe to the Vietnamese market (IMF, 2010). As a result, monitoring whether fluctuations in energy prices, especially oil and natural gas prices, are transmitted to the stock market in Vietnam will garner significant attention from investors and policymakers. This focus is due to the potential implications these price shocks may have on economic stability, inflation and market dynamics in the country. Although it is widely acknowledged that increasing crude oil prices negatively impact the stock markets of oil-importing countries, and that decreasing natural gas prices are detrimental to gas-exporting countries, there have been relatively little empirical studies focused on these dynamics within Vietnam. Given that Vietnam is a major exporter of natural gas and a major importer of crude oil, the lack of in-depth analysis on how these factors interplay in the Vietnamese stock market context represents a significant gap in the literature. This calls for further investigation into how fluctuations in crude oil prices, along with changes in natural gas prices, affect Vietnam's stock market. It could be suggested that this connection partly reflects the informational efficiency of the Vietnamese stock market. An informationally efficient

market incorporates all available current information, including data on natural gas price shocks and crude oil price shocks. Therefore, the observed dynamics might be indicative of how well these markets integrate and respond to such economic information. This indicates that the efficiency of the Vietnamese stock market in processing and reacting to various economic signals could play a significant role in shaping their behavior.

The study is structured as follows: First, Section 2 outlines the literature review. Next, Section 3 provides a detailed discussion on the methodology and introduces the VAR model. Sections 4 then presents the empirical results. Section 5 concludes the study with a focus on recommendations for future research directions.

2. Literature review

Theoretically, the energy sources such as crude oil and natural gas play critical roles in shaping the production costs within industries and serve as fundamental determinants of the value of final output products. Sun *et al*. (2022), Mübariz (2024) and Aladwani (2025) observed that elevated prices for crude oil and natural gas are often indicative of increased fuel costs. This escalation in fuel expenses can, in turn, lead to higher transportation costs and inflated product and service prices. Such dynamics may raise concerns about broader economic impacts, including potential increases in the inflation, as businesses face challenges in maintaining profitability while managing rising production costs.

A reduction in consumer spending often leads to a decline in demand for products or services, which can subsequently impact firm profits, especially when production output is reduced. This dynamic directly influences the value of shares in firms, triggering changes in the stock market. Consequently, it is commonly understood that an increase in the crude oil and natural gas prices tends to pressure stakeholders within the country to allocate more resources toward energy consumption. This shift can reduce profit margins and have an adverse effect on the broader stock market.

Fluctuations in crude oil and natural gas prices, driven by demand shocks, can significantly alter their impact on the stock market. Recent studies by Hailemariam and Smyth (2019), Prabheesh *et al*. (2020) and Aladwani (2024) highlight a positive correlation between energy prices and stock market returns. The alignment of stock market prices with global energy prices trends is particularly surprising in economies like Sri Lanka, Bangladesh, Pakistan and India, which are net importers of crude oil and natural gas. This synchronization indicates that external factors heavily influence these economies, affecting their domestic stock market dynamics.

Gupta (2016) and Musa *et al*. (2022) explain that energy prices and stock market returns are influenced by shifts in worldwide aggregate demand. For instance, a decline in aggregate demand typically reduces the demand for crude oil and natural gas, alleviating the pressure on the energy prices. Simultaneously, a drop in aggregate demand can impact firm revenues, further contributing to a decline in stock prices. This indicates that the behavior of stock traders in response to fluctuations in crude oil and natural gas prices reflects their reactions to a broader set of interconnected factors driving these price changes. These dynamics emphasize the complex interplay between aggregate demand, stock market conditions and energy pricing strategies.

Although studies such as Basher *et al*. (2018), Musa *et al*. (2022) and Aladwani (2024) have provided evidence on the impact of crude oil and natural gas price shocks on stock markets, significant research gaps remain in this area. While these studies have demonstrated the influence of crude oil and natural gas price shocks across various economies worldwide, they frequently overlook a critical aspect: the diverse nature of energy source export and import activities in different economies, especially in the Asia. This omission is significant because the effects of energy price shocks are likely to vary depending on an economy's trade structure and dependence on exports or imports. Therefore, understanding these variations requires further exploration to capture the nuanced impact of energy price shocks on stock markets across economies with distinct dynamics.

Existing studies have taken a comprehensive approach to analyzing the relationships between major energy sources, such as the crude oil price and natura gas price, and a country's macroeconomic performance. These analyses delve into how major energy market conditions, including crude oil prices and natural gas dynamics, interact with broader economic indicators like fiscal and government policies, GNI, GDP and inflation (Brown and Yucel, 2002; Nakov and Pescatori, 2010; Holm-Hadulla and Hubrich, 2017; Mukhtarov *et al*., 2019; Seyed *et al*., 2023). Earlier studies predominantly found an inverse association between energy prices, such as crude oil price and natural gas price, and gross domestic product (GDP) in certain developed economies, including the UK, Germany, Canada, France and USA. These findings suggested that rising crude oil prices and natural gas prices would negatively impact GDP (Taghizadeh-Hesary and Yoshino, 2015; Galadima and Aminu, 2019; Rizwan *et al*., 2023). However, by the early 1980s, this linear inverse association became less apparent. Numerous scholars have begun exploring the asymmetric association between the volatility of crude oil prices and natural gas prices in relation to macroeconomic activities. Notable examples include the work of Sandrine and Valérie (2008) and Herrera *et al*. (2019) on US economy and Galadima and Aminu (2019), who examined similar dynamics in Nigeria. In the latter context, it is commonly assumed that both crude oil and natural gas prices significantly influence the macroeconomy, affecting both supply and demand dynamics. On the demand side, Wei *et al*. (2017) and Muhammad *et al*. (2021) observed that an increase in crude oil prices and natural gas prices could trigger economic challenges such as inflation in certain South Asian economies. Van de Ven and Fouquet (2017) and Khalid (2018) found that shocks of crude oil and natural gas prices significantly hindered consumption patterns and investment activities in the US and UK. On the other hand, an increase in crude oil and natural gas prices may facilitate a transfer of wealth from countries that import oil and natural gas to those that are net exporters of these resources (Sławomir *et al*., 2021; Walid *et al*., 2021a, b).

At the supply level, crude oil and natural gas are essential inputs for production; therefore, an increase in their prices will elevate production costs. This rise may compel industries to either scale down operations or transition to less energy-intensive alternatives. Consequently, such adjustments could adversely affect overall production and contribute to unemployment pressures. This relationship has been examined in the research conducted by Yanfeng and Xiaoying (2016) on China, as well as by Salah (2020) in the context of Canada and the US Therefore, the increase in crude oil and natural gas prices exerts a multifaceted impact on various industries. Solarin and Shahbaz (2015) and Yanfeng and Xiaoying (2016) examined the effects of increasing crude oil prices and natural gas prices on China and Malaysia's gross domestic product (GDP), trade openness, inflation, foreign direct investment, imports, exports, consumption and other key macroeconomic indicators. Extensive studies have been conducted by scholars to examine the impact shocks of the crude oil and natural gas prices on a nation's macroeconomic performance. However, since fluctuations in crude oil and natural gas prices are not the sole factors influencing stock prices, and because both crude oil and natural gas price shocks affect stock prices in different industries in varying ways, the relationship between these shocks and financial markets remains complex and often unclear, particularly in developing countries.

There are relatively limited studies examining the shocks of the crude oil price and natural gas price on stock markets, with most studies focusing on developed economies such as the European countries, the United Kingdom and the United States. In contrast, research on this topic in other regions, particularly in emerging or developing economies, remains sparse. This gap in the literature leaves room for further investigation into how these crude oil price and natural gas price shocks influence stock market behavior across different economic contexts. For instance, Ewing *et al*. (2018), along with Yanfeng *et al*. (2023), applied a standard cash-flow dividend valuation model to analyze the stock market in the United States. Their research revealed that fluctuations in crude oil price and natural gas price shocks significantly impacted real stock price returns.

Additionally, Sadorsky (1999) found that WTI crude oil price shocks and their volatility were significant factors in explaining real stock returns in the United States. His study demonstrated that fluctuations in the WTI crude oil price dynamics contributed more to

forecasting error variance in stock returns than to interest rates. Liu (2017) and Mübariz (2024) conducted research on the stock market of the UK, uncovering similar findings. Their study revealed that the volatility of both crude oil and natural gas prices was a key factor in explaining stock price fluctuations. They also observed that positive shocks in crude oil and natural gas prices had a dampening effect on real stock price returns. Ahmed *et al*. (2014) argued that there was a statistically significant relationship between real stock price returns and both crude oil price and natural gas price futures. However, they found that this relationship was nonlinear, indicating that the interaction between these variables is complex and does not follow a straightforward pattern. Their results indicate that fluctuations in crude oil price and natural gas price futures can have a varying impact on real stock returns.

In addition, Hoang (2021) used a combination of SVAR and nonlinear ARDL models to analyze the short-term and long-term asymmetric effects of crude oil price structural shocks on the Ho Chi Minh stock exchange index. Results from the SVAR model suggest that demand shocks exert significant long-term effects on Vietnamese stock markets, whereas supply shocks do not exhibit a similar impact. The nonlinear ARDL analysis reveals that both negative and positive aggregate demand shocks strongly influence Vietnamese stock indices in the long run. These results highlight the need for market regulators to accelerate the development of the local oil market and underscore the importance for investors to closely monitor demand-related information.

Ewing and Thompson (2007) investigated the cyclical relationships between macroeconomic factors such as real stock returns, industrial production index, unemployment rates and consumer price index by employing time-series filtering approaches. Their analysis found that, while these factors exhibited cyclical patterns, crude oil prices lagged behind stock market performance in the United States.

In contrast, Juncal and Fernando (2003) and Jungwook and Ronald (2008), in their analysis of the United States and selected European countries, found differing effects of crude oil price shocks on stock markets depending on the countries' trade roles. For oil-importing countries, an increase in crude oil price shocks had a negative impact on stock market performance, likely due to rising costs and inflationary pressures. Conversely, for oil-exporting countries, the effect was positive, possibly due to boosted liquidity and increased export revenues, which could increase purchasing power and investment returns.

Numerous scholars have confirmed that shocks related to crude oil and natural gas prices impact the real stock returns of various industries in distinct ways. A widely accepted perspective is that these shocks tend to benefit upstream companies in the oil and gas sectors, as they often rely on crude oil and natural gas as essential energy sources. However, these shocks can negatively impact downstream companies and other industries, which may face increased costs or disruptions in supply chains.

For instance, Huang *et al.* (1996) and more recent studies, such as Syed *et al*. (2022) conducted a study utilizing a correlative method alongside a Vector autoregression (VAR) model analysis, focusing on the US stock market index, stock price indices of various industries, and the stock prices of the number of oil and gas companies' stock returns. Their results indicated that returns from the crude oil price and natural gas price futures significantly explained the stock returns of oil and gas companies, suggesting that these returns could serve as a leading indicator for this sector.

However, the crude oil and natural gas prices had minimal impact on the overall US stock market. Ali *et al*. (2012) and Magazzino *et al*. (2023) utilized an expanded market model to analyze the stock returns of various industries in selected European stock returns. The authors revealed that both crude oil price and natural gas price shocks significantly impacted stock prices across industries.

Notably, the oil and gas sectors, along with the diversified resource industry, exhibited positive sensitivities to these shocks. In a unique study utilizing Johansen co-integration test analysis, Hammoudeh *et al*. (2003) discovered that WTI crude oil price future shocks over a 1-month to 4-month period played a significant role in explaining the stock price movements

of petroleum refining companies, petroleum extracting companies and petroleum marketing companies. Their study highlighted the sensitivity of these sectors to short-term fluctuations in bond markets, suggesting that changes in WTI oil prices could be a critical factor influencing stock performance within these industries.

Sourav and Killins (2021) and Goncharuk *et al.* (2021) conducted a study focusing on Canadian firms as case examples. By using stock market index, and other macroeconomic factors as explanatory variables, their studies revealed that increases in crude oil and natural gas prices positively influenced the returns of firm stock prices. Lanza *et al.* (2005) and Sebastian and Stefan (2014) utilized a distinct method, differing from previous studies by employing VAR and VECM models, to examine the relationships among large oil and gas firms and various stock markets. Their analysis revealed that a greater of both the crude oil price and natural gas price spread was associated with higher stock prices for these firms.

A notable study addressing this issue is that of Hoang (2021), which examines the relationship between crude oil prices and stock price returns within the context of Vietnam's economy. The findings reveal that crude oil price shocks negatively influence stock prices in countries. This indicates that economies with significant import volumes of crude oil are likely to experience a decline in their stock markets as a result of such price fluctuations.

However, it is significant to emphasize a gap in the existing literature: to date, no studies have extensively investigated the influence of natural gas prices on the Vietnamese stock market. This signifies an essential area for further research to understand how natural gas prices intersect with stock market dynamics, especially in economies with varying trade structures like Vietnam.

3. Data and methodology

3.1 Data description

This study investigates the impact of shocks of the oil price and natural gas price on Vietnam's real stock returns, spanning from January 2006 to March 2024. The analysis covers significant crises such as the global financial crisis (GFC), the COVID-19 pandemic, Russia-Urania war I and II and the Russia-OPEC oil price war, all of which have had a direct influence on oil and natural gas prices. The analysis also includes economic activity measures like industrial production, long-term interest rate and consumer price index to explore their influence on the relationship between shocks of crude oil price and natural gas price on the stock market. For crude oil price, the OPEC crude oil price is chosen as a representative of the world crude oil price while the natural gas price, Natural Gas (Henry Hub) Price, is used as a representative of the world real natural gas price. The exchange rate is used to adjust the nominal (USD) prices of the natural gas and crude oil to find Vietnam's crude oil prices and real natural gas prices. Regarding the long-term interest rates, the Vietnam 10-year bond yield is selected as a representative measure. Additionally, for the stock market analysis, the Ho Chi Minh Stock Exchange is selected as the study subject. The study utilizes 1 composite index, five classification indices and the stock prices of 12 major energy companies to conduct a comprehensive examination of the Vietnamese stock market. Supplementary Table 1 shows the definitions of the variables under consideration along with their respective abbreviations.

3.2 Nonlinear transformations of crude oil and natural gas variables

The crude oil and natural gas prices are marked by significant price increases and high volatility. The observed asymmetric response of economic activity to oil price and gas price shocks has prompted researchers to investigate various oil and gas specifications to test associations between variables from different perspectives (see, for example, Hamilton, 1996). Building on this study, two nonlinear transformations are defined as follows:

First: COP_t^+: real crude oil price increases - $COP_t^+ = \max(0, COP_t)$

$$NGP_t^+: \text{real natural gas price increases} - NGP_t^+ = \max(0, NGP_t)$$

In this context, changes in crude oil price and natural gas price are separated into positive and negative changes based on the belief that increases in both oil and gas prices may significantly impact the Vietnamese stock market, whereas decreases might not have the same effect.

Second: $NCOP_t^n$ net real crude oil price increases

$$NCOP_t^n = \max\left(0, \log\left(COP_t\right) - \max\left(\log\left(COP_{t-1}\right) - \log\left(COP_{t-n}\right)\right)\right)$$

$NNGP_t^n$: net real natural gas price increases- $NGP_t^+ = \max\left(0, NGP_t\right)$

$$NNGP_t^n = \max\left(0, \log\left(NGP_t\right) - \max\left(\log\left(NGP_{t-1}\right) - \log\left(COP_{t-n}\right)\right)\right)$$

The monthly percentage change of the crude oil price and natural gas price in log level from the past n months is defined as positive if the change is positive and zero otherwise. This transformation, proposed by Hamilton (1996), suggests that to gauge how unsettling an increase in the oil and gas price might be for consumer and firm spending decisions, it is more appropriate to compare the current price with its values over several previous months rather than just the previous month. He proposed using the difference between the log crude oil price and log natural gas price in month t and its maximum value over the previous n months. If the difference is negative, no oil price or natural gas price change is considered to have occurred. This variable allows for examining the relationship between "important" crude oil price and natural gas price increases and Vietnamese stock market activities.

When $n = 1, NCOP_t^n$ is equivalent *to* COP_t and $NNGP_t^n$ is equivalent *to* NGP_t

3.3 Oil and gas prices volatility

The GARCH model is widely used to measure the volatility of commodity price time series data, including oil and natural gas prices. Developed by Bollerslev (1986), the GARCH model extends the ARCH model introduced by Engle (1982) by allowing for a more flexible lag structure in the conditional variance equation. The basic GARCH model is defined as follows:

$$y_t = \mu + \varepsilon_t \tag{1}$$

$$VOL_t^2 = \beta_0 + \sum_{i=1}^{p} \beta_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \alpha_j VOL_{i-j}^2 \tag{2}$$

where VOL_t^2 stands the conditional variance at time t, β_0 indicates a constant, ε_{t-i}^2 is are past squared errors, and the parameters β_i *and* $\alpha_j > 0$ and $\beta_i + \alpha_j < 1$ to ensure stationarity.

3.4 The VAR models

If a four-dimensional column vector y_t is defined to include $VLIR_t$, COP_t (NGP_t), $VIPI_t$ and VNX_t, the VAR model can be established as follows:

$$y_t = \Omega_1 y_{t-1} + \Omega_2 y_{t-2} + \ldots + \Omega_p y_{t-p} + \varepsilon_t, t = 1, 2, \ldots, T \tag{3}$$

p represents the lag orders, specified by both the Akaike information criterion (AIC) and Schwarz information criterion (SIC). T denotes the sample size of VAR model. $\Omega_1, \Omega_2, \ldots, \Omega_p$ are called parameter matrices, ε_t denotes a column vector of error terms of model, characterized by an expected value of zero for each element for all t and no serial correlation for all t.

The variable VNE_t can be determined by

$$VNE_t = y_{4t} = \sum_{j=1}^{4} \left(\mathbb{C}_{4j}^{(0)} \epsilon_{jt} + \mathbb{C}_{4j}^{(0)} \epsilon_{j,t-1} + \dots \right) \tag{4}$$

where $\mathbb{C}_{4j}^{(0)} = \frac{\partial VNE_{t+q}}{\partial \epsilon_{j,t}}$, which is considered as a fourth vector element and j^{th} line element of $\mathbb{C}_q$

Since the variance of VNE_t can be decomposed into fourth row uncorrelated effects, the criterion can be defined as follows to determine the contribution of numerous disturbances to the variance of VNE_t:

$$RCV_{j->4}(\infty) = \frac{\sum_{p=0}^{\infty} \left(\mathbb{C}_{4j}^{(p)} \right)^2 VOL_{jj}}{VOL(VNE_t)} = \frac{\sum_{p=0}^{\infty} \left(\mathbb{C}_{4j}^{(p)} \right)^2 VOL_{jj}}{\sum_{j=1}^{4} \sum_{q=0}^{\infty} \left(\mathbb{C}_{4j}^{(p)} \right)^2 VOL_{jj}} \tag{5}$$

Relative contributions of variance (RCV) measure the impact of the *jth* variable on VNE_t at time *t*.

4. Empirical results

4.1 Unit root test results

Before applying the application of VAR approach, it is crucial to examine the properties of the time series using unit root tests (Sims, 1980). To ensure robust results, the PP test was selected for this purpose. The empirical results of the PP test are illustrated in Supplementary Table 2. According to these results, the null hypotheses that all-time series under investigation contain a unit root are not rejected at the 5% level. However, the null hypothesis that the first difference in each time series has a unit root is rejected at the 1% significance level.

Since that all-time series in their log levels—each includes a unit root, the Johansen test co-integration test is performed to investigate the presence of common stochastic trends among them. The findings are found in Supplementary Table 3, demonstrating that no co-integration is present among the time series under investigation. It has been observed that the unrestricted VAR model outperforms the restricted VECM model in terms of forecast variance at short horizons when the restriction is valid. Additionally, the performances of the unrestricted VECM and VAR models for orthogonalized impulse response analysis over the short-term are almost identical. Therefore, the VAR model has been selected for further analysis.

4.2 World real crude oil price and real natural gas price shocks

The main objective of this section is to evaluate the impact shocks of the world oil and gas prices on the Vietnamese stock market by analyzing orthogonalized impulse responses. Based on the analysis by Sadorsky (1999) on the impact of crude oil price shocks on United States stock returns, the variables in the VAR model are ordered as follows: $VLIR_t$, $WCOP_t$, $VIPI_t$, and VSE_t. On the other hand, the COP_t variable is replaced with $WNGP_t$ to assess the natural gas price shocks impact on the real stock returns. This ordering presumes that shocks to the long-term interest rate are independent of contemporaneous disturbances affecting the other variables. By establishing this sequence, it is assumed that shocks to the $VLIR_t$, COP_t (NGP_t) and $VIPI_t$ can have immediate effects on real stock returns. However, real stock returns are not expected to have contemporaneous effects on these variables. Supplementary Figures 1 and 2 display the curve of the impulse–response function (IRFs) simulated using the analytical approach. These simulations are based on the VAR model, which includes the variables $VLIR_t$, $WCOP_t$, $VIPI_t$ and VNI_t for crude oil price shocks. Additionally, a VAR model replacing $WCOP_t$ with $WNGP_t$ is used for natural gas price shocks. Supplementary Figures 1 and 2 show that the IRFs return to zero within ten months for crude oil price shocks and IRFs for natural

gas price shocks revert to zero within three months, indicating that the effects of both crude oil price shocks and natural gas price shocks are temporary.

To measure the statistically significant impact of real stock returns on the real crude oil price and real natural gas price shocks within three months, an impulse response analysis is conducted. The results, represented in Table 1, indicate that for the majority of indices, the effects of a world real crude oil price shock are statistically significant positive responses at a 5% level within three months. Exceptions include stock returns for two industry indices (utilities and consumer indices) and one energy company (PVC), which are not statistically significant in the subsequent months. To further explore the impact of nonlinear transformations method, Table 1 shows the effects of the world oil price ($WCOP_t^+$ or $WNCOP_t$) on the stock market dynamics of Vietnam. The empirical results indicate that, for most stock returns, an increase of one standard deviations in $WCOP_t^+$ are a statistically significant positive impact at a 5% level. However, there are exceptions: the effects are not statistically significant for three indices (materials, utilities and consumer indices) and three energy companies (MVB, PVS and PVC). On the other hand, regarding to the effect of a one standard deviation increase in net crude oil price $WNCOP_t$, Table 1 shows that all stock returns under investigation are a statistically insignificant impact on real stock returns, except for the energy index and three energy companies (PLX, PVP and CNG). Conversely, while world natural gas price shocks generally exert minimal influence on most stock indices, as evidenced by their statistical insignificance at the 5% level, specific sectors and companies have experienced notable exceptions. The energy and industrials indices, along with three energy companies (PLX, PGC, and CNG), exhibited statistically significant positive responses to these shocks at the 5% level over a three-month period. Regarding the results for nonlinear transformations of the world natural gas price shocks reveal that a one standard deviation increases in $WNGP_t^+$ generally does not have a statistically significant effect on most stock returns. However, there are exceptions: the impact is statistically significant at 5% level for the energy index and four energy companies, including PLX, PGC, PSH and CNG. This indicates that while the overall influence on real stock returns is limited, the energy index and some of the energy companies experience notable effects from changes in the natural gas price. Finally, concerning to the impact of a one standard deviation increase in $WNNGP_t$, the results presented in Supplementary Table 3 reveal that the responses of Vietnamese real stock returns are not statistically significant.

4.3 Vietnam real oil and natural gas price shocks

This section analyzes the effects of shocks to Vietnam's real crude oil price and real natural gas price on the stock returns, with consideration given to fluctuations in the exchange rate (dong per US Dollar). All empirical results are displayed in Table 2.

Firstly, the shocks to Vietnam's real crude oil price, as analyzed using a VAR model with five variables—$VLIR_t$, $VCOP_t$, $VIPI_t$ and VSE_t—reveals patterns similar to those observed with world crude oil price shocks, as represented in Supplementary Table 4. The impact on most real stock returns is statistically significant, with the exception of PSH company, stock prices become statistically insignificant when compared to the results for $WCOP_t$. Unlike world oil price shocks, Vietnamese oil price shocks specifically depress the industrial index and two energy company's stock returns (PVD and MVB). On the other hand, two nonlinear transformations of Vietnamese real crude oil price shocks ($VCOP_t^+$ and $VNCOP_t$) display the similar findings as world crude oil price shocks. As observed from Table 4, the shocks of $VCOP_t^+$ produce findings similar to those of the shocks of $WCOP_t^+$, as shown in Supplementary Table 4. Additionally, the shocks of $VNCOP_t$ show similar findings to those observed for the shocks of $VNCOP_t$, as illustrated in Supplementary Table 4, with a few differences. The main differences are that an increase in $VNCOP_t$ negatively impacts the industrial index, as well as the stock returns of two companies (PLX and CNG). Unexpectedly,

Table 1. Impulse responses of Vietnam real stock returns to shocks of the world oil and gas price results

Variables	Market indices						Oil and gas companies stock price returns											
	VNI	VEA	VII	VMI	VUI	VCI	PVS	PVT	PVD	PLX	MVB	PVP	CNG	PVC	JVPC	PGC	PVB	PSH
World crude oil price																		
Shock to *WCOP*	(+)	(+)	(+)	(+)	(NO)	(NO)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(NO)	(NO)	(+)	(+)	(+)
Shock to $WCOP^{+}$	(+)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(+)	(+)	(+)	(NO)	(+)	(+)	(NO)	(NO)	(+)	(+)	(+)
Shock to *WNCOP*	(NO)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)
World natural gas price																		
Shock to *WNGP*	(NO)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)
Shock to $WNGP^{+}$	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(+)
Shock to *WNNGP*	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)

Note(s): (+) indicates statistically significant positive at 5% level, (−) indicates statistically significant negative at 5% level, while (NO) indicates not statistically significant at 5% level

Source(s): Author's own work

Table 2. Impulse responses of Vietnam real stock returns to shocks of the Vietnam oil and gas price results

Variables	Market indices						Oil and gas companies stock price returns											
	VNI	VEA	VII	VMI	VUI	VCI	PVS	PVT	PVD	PLX	MVB	PVP	CNG	PVC	JVPC	PGC	PVB	PSH
Vietnam real oil price																		
Shock to *VCOP*	(+)	(+)	(−)	(+)	(NO)	(NO)	(+)	(+)	(−)	(+)	(−)	(+)	(+)	(NO)	(NO)	(+)	(+)	(NO)
Shock to $VCOP^{+}$	(+)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(+)	(+)	(+)	(NO)	(+)	(+)	(NO)	(NO)	(+)	(+)	(+)
Shock to *VNCOP*	(NO)	(+)	(−)	(NO)	(NO)	(NO)	(NO)	(NO)	(−)	(−)	(NO)	(+)	(−)	(−)	(NO)	(−)	(NO)	(NO)
Vietnam real natural gas price																		
Shock to *VNGP*	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)	(−)	(NO)	(NO)
Shock to $VNGP^{+}$	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)
Shock to *VNNGP*	(NO)	(−)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(−)	(NO)	(NO)

Note(s): (+) indicates statistically significant positive at 5% level, (−) indicates statistically significant negative at 5% level, while (NO) indicates not statistically significant at 5% level

Source(s): Author's own work

stock returns of the three energy companies (PVD, PVC and PGC) become statistically significant with negative responses when compared to the shocks of $WNCOP_t$ results.

This disparity may be attributed to the uncertainty associated with "important" crude oil price shocks, as noted in earlier studies (Hamilton, 1983; Jiménez-Rodríguez and Sánchez, 2005; Kilian, 2009; Xuehong *et al*., 2021). Previous studies suggest that such uncertainty disrupts market expectations, leading to variability in economic outcomes. For example, Yu *et al*. (2024) and Aladwani (2024) highlighted that uncertainty in crude oil prices often results in delayed investment decisions and reduced consumer spending due to unpredictable costs. These results align with our observations, where significant crude oil price shocks contribute to uneven impacts across industries.

Secondly, Table 4 shows that the Vietnam real natural gas price shocks were totally found similar to those observed with world natural gas price shocks, as represented in Supplementary Table 4. The key difference is that shocks of $VNGP_t$ become statistically significant while the performance of the stock returns of the PGC company worsens. Furthermore, Table 4 illustrates that both nonlinear transformations of Vietnam's real natural gas shocks ($VNGP_t^+$; $VNNGP_t$) generally exhibit comparable performance to those observed with world natural gas price shocks ($WNGP_t^+$; $WNNGP_t$), with two notable exceptions. Contrary to this trend, increases in $VNNGP_t$ result in a depression stock return of the energy index and PGC company. This disparity may be attributed to the uncertainty related to "important" natural gas price shocks, a phenomenon extensively discussed in previous studies (Ramberg and Parsons, 2012; Jadidzadeh and Serletis, 2017). Uncertainty can disrupt market stability, as seen in energy-dependent economies, where price shocks impact investment flows and operational costs (Pindyck, 2004; Bogmans *et al*., 2024). Our empirical results indicate that this uncertainty disproportionately affects industries with high natural gas dependency, consistent with the observations of Stephanie (2020). In conclusion, both linear and nonlinear measures of Vietnam's oil and gas price shocks exhibit different impacts on some variables under investigation when compared to world oil and gas price shocks. These differences occurred because investors may take into account movements in the exchange rate, as these changes could influence their investment strategies and decisions. This result is consistent with the previous work of Shupei *et al*. (2020), who argued that exchange rate movements serve as a critical determinant for portfolio adjustments among investors. Likewise, Berthou *et al*. (2022) proposed that exchange rate volatility could lead investors to adopt more cautious investment strategies, particularly in emerging economies where currency stability is less predictable.

4.4 Alternative VAR specification

This section aims to test the reliability and robustness of the VAR model findings by including additional variables, such as the consumer price index (CPI). A five-variable VAR model is constructed, incorporating variables such as $VLTR_t$, $WCOP_t$ ($WNGP_t$), $VIFR_t$, $VIPI_t$ and VNE_t. This model aims to assess the impact of crude oil price shocks (natural gas price shocks) and their nonlinear transformations. The findings are displayed in Table 3.

First, the comparison between Table 3 and Table 1 reveals that the impact of world crude oil price shocks on the material index and one oil company stock price returns (PVD) is no longer statistically significant. In addition, the effect of real crude oil price shocks measured by $WCOP_t^+$ on PVC company stock price returns become statistically significant at 5% level. According to the *WNCOP* shocks indicate that industrial index and PVT company stock price returns also become statistically significant at 5% level while PGC company stock price returns is no longer statistically significant. On the other hand, the impact of the Vietnam real oil price shocks ($VCOP$) for PVC company stock price returns become statistically significant at 5% level. Furthermore, Vietnam real crude oil price shocks measured by $VCOP_t^+$ reveals that material index become statistically significant at 5% level. An interesting result presented in Table 3 reveals that Vietnam real oil price shocks, as measured by *VNCOP*, cause the material index to become statistically significant at the 5%

Table 3. Impulse responses of Vietnam real stock returns to crude oil price shocks and gas price shocks results

Variables	Market indices						Oil and gas companies stock price returns											
	VNI	VEA	VII	VMI	VUI	VCI	PVS	PVT	PVD	PLX	MVB	PVP	CNG	PVC	JVPC	PGC	PVB	PSH
World crude oil price																		
Shock to *WCOP*	(+)	(+)	(+)	(NO)	(NO)	(NO)	(+)	(+)	(NO)	(+)	(+)	(+)	(+)	(NO)	(NO)	(+)	(+)	(+)
Shock to $WCOP^{+}$	(+)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(+)	(+)	(+)	(NO)	(+)	(+)	(+)	(NO)	(+)	(+)	(+)
Shock to *WNCOP*	(NO)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(+)	(NO)	(+)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)
Vietnam real oil price																		
Shock to *VCOP*	(+)	(+)	(−)	(+)	(NO)	(NO)	(+)	(+)	(−)	(+)	(−)	(+)	(+)	(+)	(NO)	(+)	(+)	(NO)
Shock to $VCOP^{+}$	(+)	(+)	(+)	(+)	(NO)	(NO)	(NO)	(+)	(+)	(+)	(NO)	(+)	(+)	(NO)	(NO)	(+)	(+)	(+)
Shock to *VNCOP*	(−)	(+)	(−)	(+)	(NO)	(NO)	(NO)	(+)	(−)	(−)	(−)	(+)	(−)	(+)	(NO)	(+)	(+)	(−)
World natural gas price																		
Shock to *WNGP*	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)
Shock to $WNGP^{+}$	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(+)
Shock to *WNNGP*	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)
Vietnam real natural gas price																		
Shock to *VNGP*	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(−)	(NO)	(NO)	(+)	(NO)	(NO)	(−)	(NO)	(NO)
Shock to $VNGP^{+}$	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)
Shock to *VNNGP*	(NO)	(−)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(−)	(NO)	(NO)

Note(s): (+) indicates statistically significant positive at 5% level, (−) indicates statistically significant negative at 5% level, while (NO) indicates not statistically significant at 5% level

Source(s): Author's own work

Table 4. Orthogonalized impulse response of Vietnam real stock returns to the volatility of the crude oil and natural gas prices in different VAR model results

	Market indices							Oil companies stock price									
VNI	VEA	VII	VMI	VUI	VCI	PVS	PVT	PVD	PLX	MVB	PVP	CNG	PVC	JVPC	PGC	PVB	PSH
Panel A - Real crude oil price shocks																	
Sign parameter of statistically significant impact on Vietnam stock returns of volume in VAR model $(VLIR_t, VOL_t, VIPI_t, VSM_t)$																	
(+)	(+)	(+)	(+)	(NO)	(NO)	(+)	(NO)	(+)	(−)	(+)	(−)	(−)	(+)	(NO)	(NO)	(NO)	(+)
Sign parameter of statistically significant impact on Vietnam stock returns of volume in VAR model $(VLIR_t, VOL_t, COP_t, VIPI_t, VSM_t)$																	
(+)	(+)	(+)	(+)	(NO)	(NO)	(+)	(NO)	(+)	(−)	(+)	(−)	(−)	(+)	(NO)	(NO)	(NO)	(+)
Sign parameter of statistically significant impact on Vietnam stock returns of volume in VAR model $(VLIR_t, VOL_t, COP_t, VIPI_t, VSM_t, VIFR_t)$																	
(+)	(+)	(+)	(NO)	(NO)	(NO)	(+)	(NO)	(+)	(−)	(+)	(−)	(−)	(NO)	(NO)	(NO)	(NO)	(+)
Panel B- Real natural gas price shocks																	
Sign parameter of statistically significant impact on Vietnam stock returns of volume in VAR model $(VLIR_t, VOL_t, VIPI_t, VSM_t)$																	
(NO)	(+)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(+)	(NO)	(+)
Sign parameter of statistically significant impact on Vietnam stock returns of volume in VAR model $(VLIR_t, VOL_t, COP_t, VIPI_t, VSM_t)$																	
(NO)	(+)	(−)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(−)	(NO)	(NO)	(−)	(NO)	(NO)	(+)	(NO)	(+)
Sign parameter of statistically significant impact on Vietnam stock returns of volume in VAR model $(VLIR_t, VOL_t, COP_t, VIPI_t, VSM_t, VIFR_t)$																	
(NO)	(+)	(−)	(NO)	(NO)	(NO)	(NO)	(NO)	(NO)	(−)	(NO)	(NO)	(−)	(NO)	(NO)	(+)	(NO)	(+)

Note(s): (+) indicates statistically significant positive at 5% level, (−) indicates statistically significant negative at 5% level, while (NO) indicates not statistically significant
Source(s): Author's own work

level. Additionally, the stock returns of two energy companies (MVB and PSH) become statistically significant and negative at the 5% level. Second, a comparison between of Tables 2 and 3 reveals that the impact of world natural gas price shocks for material index and the impact of Vietnam real natural gas price shocks measured by $VNGP_t^+$ for PGC company stock price returns become no longer statistically significant. In addition, impact of world natural gas price shocks measured by $VNCOP_T$ for energy index and PGC company stock price returns become statistically significant at 5% level. In conclusion, our findings suggest that the results from the VAR model remain robust even when incorporating additional relevant variables. This indicates that the model's effectiveness is preserved across various scenarios, reinforcing the reliability of the initial results.

4.5 Asymmetric effects of crude oil price and natural gas price shocks

Since Mork (1989) argued that increases in the oil price and natural gas price had a more significant impact on a country's macroeconomy compared with decreases, a substantial body of literature has emerged exploring the asymmetric effects of oil price and natural gas price shocks. Notable studies in this area include those by Omar and David (2010), Wensheng *et al*. (2019), Lance and Benjamin (2023), which further investigate how such shocks differently affect economic variables, especially financial markets.

Given that the responses of most market indices and all energy company stock prices to crude oil price shocks are statistically significant at 5% level, the focus is solely on assessing the asymmetric impact of these shocks on them. Regarding natural price shocks, the responses of stock prices for all energy company stock prices and the energy index are statistically significant at 5% level. Therefore, the analysis focuses exclusively on evaluating the asymmetric impact of natural price shocks on these variables. This approach allows for a more detailed understanding of how crude oil price shocks and natural gas price shocks affect market dynamics and financial performance differently depending on the direction and magnitude of the shock.

First, the variable COP_t (or NGP_t) is divided into positive and negative changes in the crude oil price shocks, as detailed below:

$$COP_t^- = min(0, COP_t),\ COP_t^+ = max(0, COP_t),$$

While for natural gas price shocks as follows:

$$NGP_t^- = min(0, NGP_t),\ NGP_t^+ = max(0, NGP_t),$$

Next, a five-variable VAR model incorporating variables such as $VLIR_t$, COP_t^+ (NGP_t^+), COP_t^- (NGP_t^-), $VIPI_t$ and VSM_t is constructed. To assess the differential impact of positive and negative crude oil price shocks and natural gas price shocks, a Wald test was conducted.

An additional variable, the inflation rate (VIR_t), is included into the previous VAR model to further assess the reliability and robustness of the findings.

In the crude oil price model with five variables for Vietnamese stock market returns (VSM_t):

$$VSM_t = \theta_0 + \sum_{i=1}^{n} \theta_1 VLIR_{t-i} + \sum_{i=1}^{n} \theta_{1i} COP_{t-i}^+ + \sum_{i=1}^{n} \theta_{1i} COP_{t-i}^- + \sum_{i=1}^{n} \theta_{1i} VIPI_{t-i} + \sum_{i=1}^{n} \theta_{1i} VSM_{t-i} + \varepsilon_t \quad (6)$$

In the crude oil price model with six variables for Vietnamese stock market returns (VSM_t):

$$VSM_t = \delta_0 + \sum_{i=1}^{m} \delta_1 VLIR_{t-i} + \sum_{i=1}^{m} \delta_{1i} COP^{+}_{t-i} + \sum_{i=1}^{m} \delta_{1i} COP^{-}_{t-i} + \sum_{i=1}^{m} \delta_{1i} VIPI_{t-i} + \sum_{i=1}^{m} \delta_{1i} VSM_{t-i} + \sum_{i=1}^{m} \delta_{1i} Inf_{t-i} + \varepsilon_t \quad (7)$$

Regarding the natural gas price shocks, COP^{+}_{t-i} and COP^{-}_{t-i} are replaced with NGP^{+}_{t-i} and NGP^{-}_{t-i} respectively in both models.

The null hypothesis (H_0) can be defined as follows:

$$H_0: \theta_{2i} - \theta_{3i} = 0, i = 1, \ldots n$$

or

$$H_0: \delta_{2i} - \delta_{3i} = 0, i = 1, \ldots n$$

where $COP^{+}_{t}(NGP^{+}_{t})$ and COP^{-}_{t} (NGP^{-}_{t}) are positive and negative crude oil price shocks (natural gas price shocks), respectively, either world or specific to Vietnam, The parameters n and m denote the lag orders, which are determined using the AIC or SC criterion criteria to ensure appropriate model specification.

The empirical results of the Chi-square test are presented in Supplementary Table 4. These results, obtained from a Wald analysis of the coefficients for positive and negative of the crude oil price shocks, indicate that the null hypothesis of symmetry is generally rejected for most cases of crude oil price shocks. The exception is the material index and some energy company stock price returns (PVT, PVD, MVB, PVP and PGC). While in the most cases of natural gas price shocks, the null hypothesis of symmetry cannot be rejected except for the energy index at 5% level. Overall, statistical evidence supports the presence of asymmetric effects of crude oil price shocks on specific market indices and some of energy companies' stock returns. However, there are notable exceptions: the material index and some energy company stock price returns demonstrate asymmetric responses to Vietnam's crude oil price shocks, with significance observed at the 1% level. In contrast, the asymmetric effect of natural gas price shocks on energy companies' stock returns is not supported by the statistical evidence, although there is only one exception–energy index and PGC company stock return show asymmetric responses for Vietnam natural gas price shocks at 5% level. The results align with previous studies, including the research conducted by Hoang (2021), particularly in relation to the influence of crude oil prices. This consistency reinforces the validity of the findings and supports a broader understanding of how fluctuations in crude oil price volatility can affect financial market variables in Vietnam.

4.6 Effects of crude oil price and natural gas price volatility

The primary goal of this section is to evaluate whether the uncertainty resulting from real crude oil price volatility and real natural gas price volatility affects the stock market in Vietnam. In the beginning, the real crude oil price (real natural gas price) shocks are replaced with their volatility measures to construct a four-variable in the VAR model, including variables such as $VLIR_t$, VOL_t, $VIPI_t$ and VSM_t. This model focuses exclusively on world real crude oil price (world real natural gas price) shocks.

Next, the volatility (VOL_t) variable is incorporated alongside real crude oil price (real natural gas price) shocks to develop a five-variable VAR model. Finally, the VIR_t is added to the model to assess the reliability and robustness of the findings from the VAR model. Table 4 – Panel A presents a summary of the orthogonalized impulse response results for Vietnam real stock price returns. It is observed that crude oil price volatility generally exhibits a statistically

significant impact on most stock returns. However, there are notable exceptions: the utilities index, consumer staples index and four energy companies stock price returns (PVT, JVPC, PGC and PVB).

The crude oil price volatility may have a depressive effect on the real stock price returns of the three energy companies, namely, PLX, PVP and CNG. In contrast, it tends to drive up the stock prices of most market indices and other energy companies' stock price returns. Finally, when both crude oil price shocks and inflation rate are included in the analysis, it is observed that the responses of the material index, as well as PVC company stock price returns, become statistically insignificant. This outcome supports the conclusion that the results of the VAR model are reliable and robust, as the inclusion of additional variables does not alter the overall findings. Regarding balance of payment volatility, Table 4 – Panel B provides a summary of the orthogonalized impulse response findings for real stock returns. Analysis of the data reveals that real natural gas price volatility generally does not have a statistically significant impact on most real stock returns, expect energy index and two companies, namely PGC and PSH.

In the context of real natural gas price volatility, the industrial index and two energy companies stock price returns (PLX and CNG) show statistically significant negative responses at the 5% level. This indicates that fluctuations in the real natural gas price volatility may exert a depressive effect on these variables. When accounting for real natural gas price shocks and inflation in the VAR model, the empirical results remain consistent with those observed when only real natural gas price volatility is considered. This consistency supports the robustness of the findings. In conclusion, crude oil price volatility impacts most stock returns, with the notable exceptions of two indices and four energy companies stock price returns. In contrast, real natural gas price volatility does not demonstrate statistically significant effects on the majority of stock returns, except for the energy index and two energy companies stock price returns. However, increases in both crude oil price volatility and natural gas price volatility appear to drive speculation in these indices and energy companies, thereby elevating their stock returns.

5. Conclusions and recommendations for future work

Stock markets are frequently regarded as indicators of a country's macroeconomic health, suggesting a significant connection between the two. However, this topic remains contentious in Vietnam. Vietnamese scholars typically have two main viewpoints. The first viewpoint suggests that the stock market exhibits a weak positive correlation with the macroeconomy. This perspective is backed by research from Bui and Vo (2007), Nguyen and Nguyen (2010) and Muhammad *et al*. (2020). Another perspective argued that the correlation between the stock market and the macroeconomy is either not significant or negative. This viewpoint is supported by studies conducted by Riadh *et al*. (2016) and Hoang (2021). Scholars who hold this view argue that the Vietnamese stock markets are primarily driven by speculation rather than long-term investment.

This study examines the relationships between the crude oil price and stock market, as well as the interactions between natural gas price and stock market, incorporating several macroeconomic variables, including the industrial production index, long-term interest and inflation. Analyzing the results and discussions allows for drawing several conclusions as follows:

(1) Regarding most stock market indices, world crude oil price shocks exhibit a statistically significant impact at 5% level except for the utilities index, consumer index and two energy companies stock prices (PVC and JVPC). The measure of crude oil price shocks, which is calculated specifically for Vietnam's real crude oil price shocks, has shown to have statistically significant impacts on real stock returns. But the stock returns of Vietnam stock market, energy and industrial indices and some energy

companies are increased due to real crude oil price shocks. In contrast, some significant real crude oil price shocks negatively affect the stock prices of energy companies, causing a decrease. This suggests that investors may take fluctuations in the exchange rate into account when making investment decisions. Furthermore, the findings remain consistent and reliable even when accounting for other relevant variables.

(2) Changes in the world natural gas price shocks do not exhibit a statistically significant impact for most stock market indices except for energy and industrial indices and three energy companies' stock returns. However, stock returns for the energy index and some energy companies increase in response to real natural gas price shocks. Conversely, certain "important" real natural gas price shocks negatively impact the stock returns of the energy index and PGC companies.

(3) Overall, the asymmetric effect of crude oil price shocks on energy companies' stock returns is supported by strong statistical evidence, indicating that changes in crude oil prices can have varying effects on most stock market indices and some energy companies" stock returns. In contrast, the asymmetric effect of natural gas price shocks on energy companies' stock returns is not supported by statistical evidence except for the energy index.

(4) A rise in crude oil price volatility can stimulate speculation within certain stock market indices and among specific energy companies, which increases their stock returns. In contrast, natural gas price volatility does not significantly affect most of the stock returns but may lead to increased speculation in the energy index and PGC companies, thereby boosting their stock returns.

This study explores the relationship between crude oil price and Vietnam stock market and between natural gas price and stock market at the macroeconomic level. While the precise mechanisms underlying these connections warrant further investigation, potential avenues for future studies include simulation-based policy analysis examining the impact of varying energy prices on economic activity and subsequent stock market performance.

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Supplementary material
The supplementary material for this article can be found online.

Corresponding author
Jassim Aladwani can be contacted at: j.aladwani@bhck.edu.kw