# Market risk spillover and the asymmetric effects of macroeconomic fundamentals on market risk across Vietnamese sectors 

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#### Abstract

Global economic downturns and multiple extreme events threaten Vietnam's economy, leading to a surge in stock market risk and significant spillovers. This study investigates market risk spillovers and explores the asymmetric effects of macroeconomic indicators on market risk across 24 sectors in Vietnam from 2012 to 2022. We use the value-at-risk (VaR) technique and a vector autoregression (VAR) model to estimate market risks and their spillovers across Vietnamese sectors. We then examine the asymmetric effects of macroeconomic indicators on market risk using a panel nonlinear autoregressive distribution lag (NARDL) model. Our results confirm that Vietnam's market risk increases rapidly in response to extreme events. Additionally, market risks exhibit substantial inter-connectedness across the Vietnamese sectors. The Building Materials, Technology, and Securities sectors are primary risk transmitters, whereas the Minerals, Development Investment, and Education sectors are major risk absorbers. Our results also confirm that market risk responds asymmetrically to changes in interest rates, exchange rates (USD/NND), trade openness, financial development, and economic growth in the short and long run. Minerals, Oil \& Gas, and Rubber are the sectors that are most affected by macroeconomic indicators in the long run. Based on these important findings, implications focused on limiting market risks and their spillovers, along with sustainable investing, have emerged.


Keywords: Market risks, Spillovers, Asymmetric effects, Macroeconomic indicators, Vietnam

## Introduction

Since 2020, the world has faced many unprecedented events that primarily pertain to economic, geopolitical, and ecological turmoil. Specifically, inflation at multi-decade highs prompts rapid monetary policy tightening and squeezes household budgets. The lingering COVID-19 pandemic continues to disrupt global economic activities. The Russo-Ukrainian conflict heightens the likelihood of major geopolitical disruption. Worldwide record-breaking temperatures and droughts indicate an exacerbated state of global climate change. As such, the International Monetary Fund (2022) projects that global economic growth will slow from 6.0 per cent in 2021 to 3.2 per cent in 2022 and

[^0]2.7 per cent in 2023, which is the weakest economic growth estimation over the last two decades, excluding the Global Financial Crisis (GFC) and COVID-19 pandemic.
The gloomy economic outlook and these combined extreme events pose particular dangers to emerging markets and developing economies (EMDEs), including Vietnam, a new economic force in the Asia-Pacific region. The considerable slowdown in major economies, including the US and China, will reduce external demand for goods and services in several EMDEs, of which Vietnam may suffer the most because the US and China are the country's largest trading partners. In addition, a slowdown occurs when many EMDEs' governments cannot curb these emerging extreme events due to budget deficits (World Bank, 2022).
These multiple layers of extreme events and pessimistic economic prospects signal the probable occurrence of extreme market downturns (Long et al. 2019). The probability of a severe market downturn is the systematic tail risk of the stock market and can be considered a market risk. Therefore, measuring and managing market risk is an urgent issue to be addressed in current studies. Previous studies have shown that market risk increases significantly during extreme events (see Bui et al. 2022a, 2022b, 2021; Kourouma et al. 2010; Li et al. 2021; Rout et al. 2020; Powell et al. 2017, among others). Prior studies also documented significant market risk spillovers across different countries (see Abduraimova 2022; Aloui et al. 2022; Cao 2022; Jian et al., 2021; Nguyen and Lambe 2021) and at the sector level within a country (see Adams et al. 2014; Chiu et al. 2015; Zhang et al. 2020). However, no study has examined market risk spillovers across Vietnamese sectors.
In addition, macroeconomic indicators have significant effects on stock returns (Dellas and Hess 2005; Lim and Kim 2011; Lim and Sek 2014; Rizwan and Khan 2007). However, only one recent study investigates the impact of macroeconomic indicators on stock market risk across Vietnamese sectors (see Bui et al. 2022a, b). Our study differs from that of Bui et al. (2022a, b) as we include trade openness, financial development, and economic growth in addition to interest and exchange rates to better capture the effects of macroeconomic indicators. Furthermore, we focus on the asymmetric effects of these indicators, not their total effects, on market risks across sectors to highlight appropriate policy responses to the current challenging political and economic environments.
Our study addresses these research problems by examining market risk spillover and the asymmetric effects of macroeconomic indicators on market risk across 24 Vietnamese sectors from 2012 to 2022 . We address the following research questions: (i) To what extent does market risk vary across Vietnamese sectors during extreme events? (ii) How does market risk spill over across Vietnamese sectors-transmitters and recipients? and (iii) How do macroeconomic indicators asymmetrically affect market risk across Vietnamese sectors in the short and long run?
This study contributes to the existing literature in three ways. First, we enrich the literature on market risk at the sectoral level using a widely used technique. Second, we explore the market risk spillover across sectors in Vietnam, which has been largely ignored in previous studies. Third, to the best of our knowledge, this is the first analysis of the asymmetric effects of macroeconomic indicators on market risk across Vietnamese sectors in the short and long run. Finally, we examine the extent to which market risk across the Vietnamese sectors responds separately to the rise and fall of macroeconomic
indicators in the short and long run. Our findings provide insightful implications for Vietnamese policymakers, practitioners, and investors in mitigating market risks and their spillovers and in promoting sustainable investing to achieve long-term financial goals.
The remainder of this paper is organized as follows. Sect. "Literature review" discusses and synthesizes relevant empirical studies on the topic. Sect. "Data and research methodology " presents the study's data and research methodology. The empirical results are reported and discussed in Sect. "Empirical results", followed by concluding remarks and policy implications in Sect. "Discussions".

## Literature review

Extreme value theory (EVT) provides a comprehensive basis for constructing market risk estimators for extreme events. EVT is a branch of statistical theory that studies outliers in a distribution. This theory estimates the stochastic behavior of a process at abnormally large or small levels (Singh et al. 2013). EVT can be applied to extreme market downturns by modelling the tail behavior of a financial return distribution.
Based on EVT, several modern risk management techniques have been introduced and adopted to address market risk proactively. Among the various techniques, the Value-at-Risk (VaR) appears to be the most conventional tail risk measure in financial markets (Bui et al. 2022a, b; Ho et al. 2021; Jorion 2007; Kourouma et al. 2010; Kuester et al., 2005; Li et al. 2021; Powell et al. 2017; Rout et al. 2020; Terinte et al., 2015; Uyar and Kahraman 2019). The findings from these studies indicate that market risks increase significantly during tail events, such as the global financial crisis (GFC) (Kourouma et al. 2010; Powell et al. 2017) and the COVID-19 pandemic (Bui et al. 2022a, b; Ho et al. 2021; Li et al. 2021; Rout et al. 2020).
Market risk is an important price determinant that significantly affects stock returns at both the market and individual security levels (Bali et al. 2009; Bollerslev and Todorov 2011; Chabi-Yo et al., 2018; Harris et al. 2019; Huang et al., 2012; Kelly and Jiang, 2014). Meanwhile, empirical evidence shows particularly strong connectedness among returns on individual stocks (Ang and Chen 2002) and international stock markets (Kenourgios et al. 2011; Madaleno and Pinho, 2012) during tail events. Therefore, market risk is likely to have a spillover effect. Research on the spillover effect has led to the adoption of the Vector Autoregression (VAR) model and its variants (see Chatziantoniou et al. 2022; Belaid et al. 2021; Dagher and Hasanov 2023; Diebold and Yilmaz 2012, 2014, 2015; Urom et al. 2021, among others). The intuition behind the VAR model is that each variable is affected by its past values and the past values of other variables in the system. Therefore, a VAR model captures both static and dynamic interlinkages among variables and is particularly suitable for examining the spillover of idiosyncratic shocks across units and times.
The literature has documented market risk spillovers in various international stock markets. At the country level, Abduraimova (2022) examines the spillovers among international stock markets during the GFC. A subnetwork analysis of the contagion indicates that market risk propagated from advanced to emerging economies during the GFC. Cao (2022) investigates the mechanism of market risk spillovers among financial markets in the US, Europe, and Asia-Pacific. This study documents significant bidirectional market
risk spillovers with persistent impacts between the US and other markets, particularly during periods of market turbulence. This finding is complemented by Nguyen and Lambe (2021), who indicate that the US and Canada are major market risk transmitters, while Korea and Finland are primary receivers. Jian et al. (2021) investigate market risk spillovers between Chinese stock index futures and spot markets. Their findings confirm bidirectional market risk spillovers between China's stock index futures and spot markets. The downturn of one market exerts direct and indirect spillover effects, exacerbating the risk in other markets. Aloui et al. (2022) examine market risk spillovers from China to the G7 stock markets before and during the COVID-19 pandemic. This study documents significant market risk spillovers between China and the G7 countries, and these effects have become more pronounced during the pandemic.
At the sectoral level, empirical analyses of market risk spillovers mainly focus on the financial sector (Adams et al. 2014; Chiu et al. 2015). Adams et al. (2014) conclude that commercial banks and hedge funds are the primary risk transmitters among several financial institutions. In addition, the financial sector has a significant spillover effect on non-financial sectors in the US (Chiu et al. 2015) and Vietnam (Vo, 2022a, 2022b). Zhang et al. (2020) explore market risk spillovers across different sectors in China. The empirical analysis confirms a market risk spillover network that connects all sectors in the Chinese stock market. The utilities and financial sectors play important roles in several risk-event periods.
Given the current economic outlook, examining the effects of macroeconomic indicators on market risk can assist policymakers and investors. Previous studies find significant effects of macroeconomic indicators on stock returns, including interest rates (Rizwan and Khan 2007), exchange rates (Lim and Sek 2014), trade openness (Lim and Kim 2011), financial development (Dellas and Hess 2005), and economic growth (Nguyen et al. 2022). Thus, these macroeconomic indicators are likely to affect market risk to changes in market returns. Bui et al. (2022a, b) confirm that exchange and interest rates significantly affect market risks across sectors in Vietnam.
Based on the aforementioned studies, the literature appears to have largely ignored market risk spillovers across sectors. Furthermore, no analysis of market risk spillover has been conducted for Vietnam, which deserves more attention during the current difficult times. Bui et al. (2022a, b) only partially examine the effects of macroeconomic indicators on market risk. Their analysis primarily ignored other relevant and important macroeconomic factors such as trade openness, financial development, and economic growth. More importantly, their analysis does not address the short- and long-run asymmetric effects of macroeconomic indicators on market risk. As such, the literature review warrants our analysis to examine market risk spillovers and explore the asymmetric effects of macroeconomic indicators on market risk across the 24 Vietnamese sectors from 2012 to 2022.

## Data and research methodology

## Data

We obtain the daily indices of the 24 sectors in Vietnam to estimate the monthly market risk for each sector. Data are collected from the Ho Chi Minh City Stock Exchange (HOSE) and Hanoi Stock Exchange (HNX) from 03 January 2012 to July 31, 2022. The 24 Vietnamese

Table 1 Selected variables, descriptions, and sources

| Variables | Abbreviation | Descriptions | Sources |
| :---: | :---: | :---: | :---: |
| Dependent variable |  |  |  |
| Market risk | Market risk | Tail risk across 24 Vietnam sectors estimated from VaR | Authors' calculation |
| Independent variables |  |  |  |
| Interest rate | Interest | LIBOR—Swiss 3-month LIBOR Middle rate (SNB) | Thomson Reuters—Refinitiv |
| Exchange rate | Exchange | USD/VND exchange rate | Thomson Reuters—Refinitiv |
| Trade openness | Openness | Vietnam's total exports and imports as the percentage share of GDP | General Statistics Office of Vietnam |
| Financial development | $F D$ | Financial Development Index | International Monetary Fund |
| Economic growth | GDP | Vietnam's annual GDP per capita | The World Bank |
| Control variables |  |  |  |
| Gold price | Gold | Gold Futures Price | Thomson Reuters - Refinitiv |
| Oil price | Oil | Crude Oil WTI Futures |  |

sectors are Aquaculture, Aviation, Banking, Building Materials, Business, Construction Investment, Development Investment, Education, Energy, Fertilizers, Food, Minerals, Oil and Gas, Pharmaceuticals, Plastic, Public Services, Real Estate, Rubber, Securities, Services, Steel, Technology, Trade, and Transportation.
We use the interest rate (LIBOR), exchange rate (USD/VND), trade openness, financial development, and economic growth to capture the effects of macroeconomic indicators on market risks across the Vietnamese sectors. Trade openness is measured as the sum of Vietnam's exports and imports as a percentage of the GDP. We use the Financial Development Index provided by the International Monetary Fund to comprehensively capture the depth, access, and efficiency of Vietnam's financial institutions and markets. We developed the index using a standard three-step approach: (i) normalizing variables, (ii) aggregating normalized variables into sub-indices that represent a particular functional dimension, and (iii) aggregating the sub-indices into an overall index (Svirydzenka 2016). Finally, economic growth was captured using GDP per capita. Gold and oil prices were used as control variables in the regression analysis. All the variables are summarized in Table 1.

## Research methodology

Measuring the market risk level using Value-at-Risk
The returns on each sector index were calculated using the logarithmic returns on the daily closing prices of the sector indices. Consequently, we adopt the Value-at-Risk (VaR) as our risk measurement method. A parametric approach was used in this study. This parametric approach is a widely used method that assumes that returns follow a normal distribution. We then calculated the mean and standard deviation of all sectors' daily returns and used these values to estimate the monthly market risk across sectors. McNeil et al. (2015) developed this approach.

$$
V a R_{\alpha}=\mu+\sigma \cdot f_{(\alpha)}^{-1}
$$

where $\mu$ is the mean of all returns from one sector; $\sigma$ is the standard deviation; $f_{(\alpha)}^{-1}$ is the inverse of the normal distribution of the returns, and 1- $\alpha$ represents the confidence level.

## Estimating the market risk spillover across 24 Vietnamese sectors using the forecast error variance decomposition in a vector autoregression (VAR) model

After obtaining the market risk for each sector, we next analyze the market risk spillover among the 24 sectors in the Vietnamese stock market. We apply the connectedness/ spillover approach by Diebold and Yilmaz (2012, 2015) in our analysis of market risk spillovers. Under the approach of a spillover network analysis, the association structure among all sectors can be identified deeper. Additionally, the direction of each sector's transmission structure and node weight can be identified simultaneously (Diebold and Yilmaz, 2014).
The spillover index is calculated based on the forecast error variance decomposition in the vector autoregression (VAR) model constructed by Diebold and Yilmaz (2012, 2015). The procedure for applying this model is as follows. First, the VAR model of order p is fitted to the time series of market risk obtained from the VaR estimation. We then conduct an augmented Dickey (ADF) test to examine the stationarity of market risks among the 24 sectors and apply the VAR model. Second, we forecast the market risk for all sectors for $h$ periods. Using data up to time $t$, we obtain the error variance decomposition of each forecast corresponding to shocks arising from the same or other network components at time $t$. Third, based on the forecast error variance decomposition obtained from the previous step, we estimate the market risk spillover index for each sector and the total connectedness/spillover index for stock market risk in Vietnam.
The total spillover index for market risk in Vietnam is the percentage of the total variation in the spillover network. The total spillover index (TSI) was calculated as follows:

$$
T S I=\frac{1}{N} \sum_{\substack{i, j=1 \\ i \neq j}}^{N} d_{i j}
$$

where $N$ denotes the number of time series and $d_{i j}$ (for $i \neq j$ ) denotes the pairwise directional connectedness/spillover.

Our study examines market risk spillover by employing a VAR model with a lag length of one, forecast variance error of a 12-day-ahead period, and 60-day rolling-sample windows. The parameters for the VAR estimation were used in Diebold and Yilmaz (2015). A lag length of one in our model was selected based on the final prediction error (FPE) and Akaike's information criterion (AIC).

## The panel nonlinear autoregressive distribution lag (NARDL) model

Our panel data are considered to have a large T because the number of time points per cross section exceeds 30 (Pesaran and Smith 1995). We construct the Shin et al. (2013) nonlinear ARDL model in panel form, which is highly suitable for analyzing dynamic heterogeneous panel data with a large T. The panel's non-linear ARDL model offers three advantages. First, the NARDL model simultaneously captures asymmetries and nonlinearity, allowing us to address our research questions directly.

Second, it overcomes the inherent heterogeneity present in the data typically observed in stock prices. Third, it can handle panel data with unit roots or mixed-order integrations that do not exceed I(1).

The two techniques used to create a panel nonlinear ARDL model are the Pooled Mean Group (PMG) and Mean Group (MG) techniques. The MG technique relies on estimating N time-series regressions and averaging the coefficients, whereas the PMG estimator involves pooling and averaging the coefficients (Blackburne and Frank 2007). For the model specification, the Hausman test was employed to test whether there was any systematic difference between the two estimators. By design, in addition to the panel regression results, MG and PMG generate results for individual units. Both long- and short-term responses were evaluated.
The unrestricted error-correction model in the linear ARDL takes the following form:

$$
\begin{equation*}
\Delta \mathrm{y}_{i, t}=\alpha+\theta \mathrm{y}_{i, t-1}+\delta \mathrm{x}_{t-1}+\sum_{j=1}^{p-1} \vartheta_{j} \Delta \mathrm{y}_{i, t-j}+\sum_{j=1}^{p-1} \mu_{j} \Delta \mathrm{x}_{t-j}+\varepsilon_{i, t} \tag{1}
\end{equation*}
$$

where $\alpha$ is the intercept, $\theta$ and $\delta$ are the long-run coefficients while $\vartheta_{j}$ and $\mu_{j}$ are the short-run coefficients, and $\varepsilon_{t}$ denotes the error term. $i$ and $t$ represent the sector and month, respectively.
We then consider the nonlinear asymmetric long-run cointegrating regression in the NARDL model as follows:

$$
\begin{equation*}
\mathrm{y}_{i, t}=\sigma^{+} \mathrm{x}_{t}^{+}+\sigma^{-} \mathrm{x}_{t}^{-}+u_{i, t}, \tag{2}
\end{equation*}
$$

where $\sigma^{+}$and $\sigma^{-}$are the asymmetric long-run coefficients of the vector of regressors ( $\mathrm{x}_{t}$ ) that can be decomposed into its partial sum processes of positive changes $\left(\mathrm{x}_{t}^{+}\right)$and its partial sum processes of negative changes $\left(\mathrm{x}_{t}^{-}\right)$, and $u_{t}$ is an i.i.d. process with zero mean and finite variance. $i$ and $t$ represent the sector and month, respectively. The partial sum of the positive and negative changes in the independent variables was defined as:

$$
\begin{equation*}
\mathrm{x}_{t}^{+}=\sum_{j=1}^{t} \Delta \mathrm{x}_{j}^{+}=\sum_{j=1}^{t} \max \left(\Delta \mathrm{x}_{j}, 0\right) \text { and } \mathrm{x}_{t}^{-}=\sum_{j=1}^{t} \Delta \mathrm{x}_{j}^{-}=\sum_{j=1}^{t} \min \left(\Delta \mathrm{x}_{j}, 0\right), \tag{3}
\end{equation*}
$$

One issue arising from Eq. (3) is that if variable $x$ has a missing value in month $t$, its decomposed variables, $\mathrm{x}_{t}^{+}$or $\mathrm{x}_{t}^{-}$still retain the observation from the previous month $t-1$. In other words, even when the original variable (pre-decomposition) $x$ has a missing value in month $t$, the decomposed variables $x_{t}^{+}$and $x_{t}^{-}$still contain observations for that month. These characteristics result in an increased number of observations for the decomposed variables $\mathrm{x}_{t}^{+}$or $\mathrm{x}_{t}^{-}$compared with the number of observations for the original variable x . Therefore, we apply the following data-cleaning constraint to address this issue:

$$
\mathrm{x}_{t}^{+}=\emptyset i f x_{t}=\emptyset \text { or } \mathrm{x}_{t}^{-}=\emptyset i f x_{t}=\emptyset .
$$

By associating Eqs. (3) and (1), the panel NARDL model can be expressed as follows:

$$
\Delta \mathrm{y}_{i, t}=\alpha+\theta \mathrm{y}_{i, t-1}+\delta^{+} \mathrm{x}_{t-1}^{+}+\delta^{-} \mathrm{x}_{t-1}^{-}+\sum_{j=1}^{p-1} \vartheta_{j} \Delta \mathrm{y}_{i, t-j}+\sum_{j=1}^{p-1}\left(\mu_{j}^{+} \Delta \mathrm{x}_{t-j}^{+}+\mu_{j}^{-} \Delta \mathrm{x}_{t-j}^{-}\right)+\varepsilon_{i, t},
$$

where $\delta^{+}=-\theta \sigma^{+}$and $\delta^{-}=-\theta \sigma^{-}$while $\mu_{j}^{+}$and $\mu_{j}^{-}$are positive and negative short-run adjustments to changes in the regressor $\mathrm{x}_{t}$, respectively. $i$ and $t$ represent the sector and month, respectively.
In this context, the variable " $y$ " represents market risk, while the variable " $x$ " represents a vector of independent and control variables. These independent and control variables include the interest rate, exchange rate, trade openness, financial development, gold price, and oil price. It is important to note that each of these six variables is decomposed into positive changes $(+)$ and negative changes $(-)$. For instance, the positive changes $(+)$ and negative changes $(-)$ of the interest rate are denoted as Interest ${ }^{+}$and Interest ${ }^{-}$respectively. $\Delta x$ and $\Delta y$ represent short-run estimates, while the variables x and y (without the $\Delta$ sign) represent long-run estimates. GDP per capita is not decomposed because it has increased over the years, with no instance of a year's value decreasing compared to the previous year.
The entire data analysis process, which includes seven major steps, is shown in Fig. 1.


Fig. 1 Data analysis process

## Empirical results

Understanding the market risk characteristics in each sector can assist policymakers in formulating adaptive policies, avoiding stock market crashes, and abating the destructive impact of tail events on the financial market. We discuss the market risk spillovers across sectors in Sect. "The market risk spillovers across 24 Vietnamese sectors". Sect. "The effects of macroeconomic indicators on market risk across Vietnamese sectors" presents the asymmetric effects of macroeconomic indicators on market risk. The robustness analysis is discussed in Sect. "Robustness analysis".
Figure 2 illustrates the level of market risk across the Vietnamese sectors from 2012 to 2022. On average, the Public Services sector experienced the most significant market risk, whereas the Business sector witnessed the lowest risk level over the years. The market risk in most sectors soared in 2016, 2018, and 2020, coinciding with Brexit, the China-United States trade war, and the COVID-19 pandemic, which are global tail (extreme) events. These findings indicate that Vietnam's stock market responds significantly to tail events. The Public Services, Minerals, Aviation, Services, and Rubber sectors exhibited the highest risk levels in 2016, whereas the Minerals, Development Investment, Oil and Gas, and Banking sectors faced the most significant market risk in 2018. The COVID-19 pandemic in 2020 and 2021 magnified market risk in almost all Vietnamese sectors. However, Development Investment was the only sector that withstood the pandemic's adverse effects. We also observe an upward movement of market risk among the sectors in 2022 as the Russo-Ukraine conflict escalates. As expected, the Oil $\mathcal{E}$ Gas sector will be exposed to the greatest potential losses during the first seven months of 2022.


Fig. 2 Market risk across sectors in Vietnam, 2012-2022

## The market risk spillovers across 24 Vietnamese sectors

Table 2 presents the market risk spillover network for the 24 Vietnamese sectors. The total spillover index (TSI) represents the aggregate spillover effect across all Vietnamese sectors. The TSI of all 24 Vietnamese sectors is 85.13 per cent for the entire period, signifying that market risk spillovers across Vietnamese sectors are significant, and that the interconnectedness among sectors is paramount. This finding confirms that extreme risk in Vietnam's stock market tends to spread rapidly across all sectors within the market.
In addition, the results of the net spillover effect of each sector in Table 2 show that the Building Materials, Technology, and Securities sectors are the most significant risk transmitters in the Vietnamese stock market. These three sectors have the highest "NET" values of $27.13,24.97$, and 23.53 percent in the market risk spillover network, respectively. Therefore, these three sectors are deemed the major sources of extreme risk transmission, suggesting that once significant market risk emerges in these sectors, the risk spreads quickly to the others. In contrast, the Minerals, Development Investment, and Education sectors are the top three significant risk absorbers with the lowest "NET" values of $-39.32,-32.64$, and -30.24 percent, respectively. Figure 3 shows the results obtained from Table 1 in the spillover network.

## The effects of macroeconomic indicators on market risk across Vietnamese sectors

Table 3 presents the descriptive statistics of the variables. We then report the original data of our variables (before transformation) to provide a genuine sample and justify the rationale for taking natural logarithms for some of the variables. Market risk has a mean and standard deviation of 0.024 and 0.015 , respectively. Meanwhile, the mean values of exchange rate, trade openness, GDP (economic growth), gold price, and oil price are significantly different from those of market risk, which is the dependent variable in our empirical analysis. Thus, we used the natural logarithm of these variables to strengthen the normal distribution of our panel and avoid model misspecification.
In Table 4, we examine the order of the integration of our variables as a prerequisite for our empirical analysis. We perform the panel unit root tests proposed by Im et al. (2003) and Maddala and Wu (1999), with the null hypothesis that all panels consist of a unit root. The test statistics verify that market risk and financial development are integrated into order zero, $\mathrm{I}(0)$, whereas the remaining variables are integrated into order one, $\mathrm{I}(1)$. Thus, the panel possesses a mixed order of integration, signifying that our variables are either stationary at the level or first difference. None of the variables was stationary at the second difference. These unit root test results confirm the validity of applying the panel NARDL model to our empirical analysis.
We interpret the effects of macroeconomic fundamentals on market risk in Vietnam's sectors. Our empirical results address the asymmetric short- and long-run effects in two scenarios: (i) when all sectors are examined together and (ii) when each examining each sector separately. We used the PMG technique for both scenarios in the short run and the MG technique for the second scenario in the long run. Our model specification is based on the test statistics from Hausman's (1978) and Pesaran and Yamagata's (2008) slope homogeneity tests, as presented in Table 5. The Hausman test statistics support the use of PMG for the empirical analysis. However, the PMG technique assumes
Table 2 Market risk spillovers across 24 sectors in Vietnam

|  | AC | Av | вк | вм | ви | c | DI | ED | en | FE | Fo | MI |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Aquaculture (AC) | 14.27 | 2.9 | 5.03 | 4.79 | 6.11 | 3.23 | 3.1 | 0.89 | 2.13 | 3.71 | 4.16 | 0.99 |
| Aviation (AV) | 3.55 | 15.3 | 3.99 | 4.27 | 28 | 1.79 | 2.61 | 2.26 | 2.13 | 3.24 | 6.98 | 1.85 |
| Banking (BK) | 4.06 | 3.07 | 9.75 | 6.71 | 4.31 | 2.19 | 1.29 | 0.64 | 2.57 | 3.4 | 5.36 | 0.97 |
| Building Materials (BM) | 3.69 | 2.74 | 6.38 | 8.72 | 4.34 | 2.82 | 1.17 | 1.12 | 3.32 | 4.24 | 4.52 | 0.9 |
| Business (BU) | 4.53 | 2.24 | 4.96 | 4.97 | 11.28 | 3.04 | 1.94 | 0.95 | 3.32 | 4.3 | 4.75 | 1.68 |
| Construction Investment (Cl) | 4.37 | 2.29 | 3.86 | 4.97 | 4.96 | 15.81 | 3.81 | 1.91 | 3.17 | 3.78 | 3.16 | 2.87 |
| Development Investment (D) | 7.91 | 3.39 | 2.68 | 3.08 | 3.74 | 4.54 | 23.97 | 4.26 | 2.34 | 1.95 | 2.44 | 2.68 |
| Education (ED) | 1.46 | 1.83 | 2.27 | 4.13 | 3.82 | 3.39 | 2.13 | 37.56 | 2.08 | 1.82 | 1.9 | 0.98 |
| Energy (EN) | 2.37 | 1.7 | 4.08 | 5.71 | 4.51 | 3.08 | 1.03 | 0.78 | 17.84 | 4.07 | 5.17 | 1.11 |
| Fertilizer (FE) | 4.18 | 3.08 | 4.05 | 5.06 | 4.44 | 2.65 | 3.3 | 1.66 | 3.3 | 10.13 | 4.53 | 1.16 |
| Food (FO) | 3.39 | 4.65 | 6.02 | 5.37 | 4.31 | 1.81 | 0.92 | 0.68 | 3.72 | 3.56 | 11.55 | 0.94 |
| Minerals (M) | 2.1 | 3.13 | 2.37 | 232 | 4.46 | 4.31 | 2.98 | 1.98 | 3.92 | 2.02 | 2.89 | 27.39 |
| Oil and Gas (OG) | 4.76 | 3.21 | 7.66 | 6.27 | 3.95 | 2.14 | 1.97 | 0.6 | 2.66 | 3.27 | 5.31 | 1.28 |
| Pharmaceutical (PH) | 4.06 | 3.72 | 3.9 | 6.04 | 5.01 | 3.57 | 1.83 | 0.99 | 3.54 | 4.43 | 4.51 | 1.58 |
| Plastic (PL) | 3.79 | 2.39 | 5.44 | 5.43 | 5.07 | 2.07 | 1.08 | 0.4 | 2.61 | 4.9 | 5.43 | 1.25 |
| Public Services (PS) | 2.16 | 8 | 2.9 | 1.89 | 2.18 | 1.68 | 3.92 | 4.03 | 4.19 | 1.35 | 2.62 | 2.47 |
| Real Estate (RE) | 3.26 | 2.55 | 5.79 | 5.82 | 5.47 | 2.72 | 0.63 | 0.83 | 3.22 | 4.78 | 4.6 | 1.59 |
| Rubber (RU) | 4.5 | 1.34 | 3.97 | 3.99 | 5.64 | 2.57 | 1.95 | 1.74 | 3.13 | 4.14 | 3.9 | 1.56 |
| Securities (SE) | 4.1 | 1.66 | 6.91 | 6.49 | 5.48 | 3.32 | 1.7 | 0.95 | 2.91 | 4.47 | 4.4 | 1.05 |
| Services (VV) | 2.86 | 3.72 | 4.26 | 5.01 | 3.21 | 2.55 | 0.96 | 1.37 | 4.88 | 2.79 | 6.39 | 1.59 |
| Steel (ST) | 3.44 | 2.62 | 5.92 | 8.6 | 3.93 | 2.13 | 0.97 | 1.1 | 3.09 | 4.44 | 4.42 | 1.03 |
| Technology (TE) | 3.46 | 2.69 | 6.5 | 5.76 | 4.66 | 2.69 | 1.49 | 0.71 | 3.18 | 4.56 | 5.71 | 1.34 |
| Trade (TR) | 4.17 | 3.6 | 6.71 | 6.28 | 4.44 | 1.51 | 0.98 | 1.08 | 2.13 | 4.1 | 4.76 | 0.71 |
| Transportation (TP) | 3.89 | 1.95 | 5.28 | 5.44 | 6.42 | 2.65 | 1.63 | 1.27 | 3.19 | 4.66 | 4.74 | 1.73 |
| To others | 86.05 | 68.48 | 110.93 | 118.41 | 103.27 | 62.44 | 43.39 | 32.2 | 70.75 | 83.97 | 102.65 | 33.29 |
| NET | 0.32 | -16.22 | 20.68 | 27.13 | 14.55 | -21.74 | -32.64 | -30.24 | - 11.41 | -5.91 | 14.2 | -39.32 |

Table 2 (continued)

|  | OG | PH | PL | PS | RE | RU | SE | SV | ST | TE | TR | TP | FROM others |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Aquaculture (AC) | 5.95 | 4.53 | 4.96 | 1.05 | 3.25 | 4.31 | 5.52 | 2.16 | 3.65 | 4.35 | 4.25 | 4.71 | 85.73 |
| Aviation (AV) | 5.05 | 5.43 | 4.42 | 5.9 | 2.8 | 4.33 | 2.49 | 3.38 | 4.07 | 4.28 | 4.91 | 2.15 | 84.7 |
| Banking (BK) | 6.91 | 3.58 | 5.3 | 1.78 | 4.36 | 2.59 | 7.33 | 2.11 | 5.35 | 6.56 | 5.53 | 4.29 | 90.25 |
| Building Materials (BM) | 5.87 | 4.69 | 4.78 | 1.16 | 4.22 | 3.04 | 6.45 | 2.88 | 7.65 | 5.53 | 5.12 | 4.63 | 91.28 |
| Business (BU) | 3.81 | 4.6 | 5.2 | 0.69 | 4.73 | 4.33 | 6.44 | 2.35 | 4.11 | 4.96 | 4.25 | 6.57 | 88.72 |
| Construction (CO) | 3.76 | 5.1 | 3.22 | 1.77 | 3.2 | 3.78 | 5.86 | 3.17 | 3.31 | 4.93 | 3.01 | 3.94 | 84.19 |
| Construction Investment (CI) | 4.08 | 3.44 | 2.26 | 5.32 | 3.15 | 2.62 | 3.25 | 1.6 | 2.35 | 3.53 | 3.59 | 1.82 | 76.03 |
| Development Investment (DI) | 2.41 | 2.67 | 1.84 | 3.71 | 2.78 | 2.87 | 3.12 | 3.33 | 4.07 | 2.5 | 3.97 | 3.37 | 62.44 |
| Education (ED) | 4.15 | 5.24 | 3.61 | 1.22 | 4.16 | 3.52 | 4.58 | 4.47 | 4.62 | 5.11 | 3.05 | 4.81 | 82.16 |
| Energy (EN) | 3.85 | 4.41 | 5.19 | 2.52 | 4.47 | 4.5 | 5.12 | 2.12 | 4.55 | 6.03 | 5.01 | 4.69 | 89.87 |
| Fertilizer (FE) | 5.37 | 4.72 | 5.7 | 1.27 | 4.11 | 3.14 | 5.04 | 4.31 | 4.14 | 6.18 | 4.41 | 4.71 | 88.45 |
| Food (FO) | 3.13 | 3.7 | 3.3 | 3.77 | 3.52 | 4.98 | 2.51 | 3.22 | 2.41 | 3.29 | 2.56 | 3.75 | 72.61 |
| Minerals (MI) | 9.46 | 3.97 | 5.43 | 1.12 | 3.58 | 3.56 | 5.51 | 2.85 | 5.4 | 5.74 | 5.25 | 5.05 | 90.54 |
| Oil and Gas (OG) | 4.57 | 11.38 | 5.37 | 0.8 | 4.28 | 3.44 | 4.24 | 3.16 | 5.29 | 4.82 | 5.03 | 4.44 | 88.62 |
| Pharmaceutical (PH) | 5.43 | 4.92 | 9.99 | 0.65 | 4.33 | 4.66 | 5.64 | 2.86 | 4.76 | 6.03 | 5.46 | 5.4 | 90.01 |
| Plastic (PL) | 3.19 | 2.59 | 2.34 | 33.68 | 2.8 | 4.66 | 1.8 | 1.56 | 2.24 | 3.34 | 2.62 | 1.8 | 66.32 |
| Real Estate (RE) | 4.3 | 4.45 | 5.18 | 0.9 | 10.81 | 2.5 | 6 | 2.95 | 5.6 | 5.57 | 6.16 | 4.34 | 89.19 |
| Rubber (RU) | 5.13 | 3.71 | 5.98 | 1.77 | 2.95 | 14.02 | 5.21 | 2.84 | 4.52 | 5.3 | 4.88 | 5.27 | 85.98 |
| Securities (SE) | 4.92 | 3.4 | 5.05 | 0.99 | 4.62 | 3.9 | 9.45 | 2.1 | 5.47 | 6.79 | 5.16 | 4.7 | 90.55 |
| Services (SV) | 5.31 | 4.16 | 5.01 | 2.61 | 3.93 | 4.19 | 3.52 | 15.46 | 5.34 | 4.26 | 3.34 | 3.29 | 84.54 |
| Steel (ST) | 5.72 | 4.59 | 4.93 | 1.23 | 4.21 | 3.52 | 6.17 | 3.48 | 10.01 | 5.13 | 4.87 | 4.44 | 89.99 |
| Technology (TE) | 5.4 | 3.9 | 5.35 | 0.94 | 4.65 | 3.84 | 6.78 | 2.4 | 4.65 | 8.99 | 5.46 | 4.9 | 91.01 |
| Trade (TR) | 5.74 | 4.83 | 5.54 | 1.01 | 5.8 | 3.77 | 5.98 | 2.09 | 5.06 | 6.14 | 10.07 | 3.52 | 89.93 |
| Transportation (TP) | 5.44 | 4.08 | 5.39 | 1.03 | 4.2 | 4.69 | 5.54 | 2.65 | 4.73 | 5.6 | 3.86 | 9.96 | 90.04 |
| TO others | 109.49 | 96.69 | 105.33 | 43.18 | 90.11 | 86.74 | 114.08 | 64.03 | 103.33 | 115.97 | 101.76 | 96.61 | TSI |
| NET | 18.96 | 8.07 | 15.32 | -23.14 | 0.92 | 0.76 | 23.53 | -20.51 | 13.33 | 24.97 | 11.83 | 6.57 | 85.13 |

TSI stands for the total spillover index \& Gas, PH Pharmaceutical, PL Plastic, PS Public Services, RE Real Estate, RU Rubber, SE Securities, SV Services, ST Steel, TETechnology, TR Trade, TPTransportation


Fig. 3 Market risk spillover network with 60 rolling windows and 12 forecast horizons

Table 3 Descriptive statistics

| Variable | N | Mean | SD | Min | Max |
| :--- | :--- | ---: | :--- | :--- | :---: |
| Market risk | 2973 | 0.024 | 0.015 | 0 | 0.171 |
| Interest | 2973 | 0.009 | 0.008 | 0.001 | 0.028 |
| Exchange | 2973 | -10.011 | 0.041 | -10.07 | -9.942 |
| Openness | 2841 | 188.738 | 19.003 | 156.554 | 210.4 |
| FD | 2973 | 0.372 | 0.023 | 0.323 | 0.403 |
| GDP | 2841 | 2823.129 | 402.505 | 2216.944 | 3373.083 |
| Gold | 2973 | 1442.361 | 253.812 | 1060.5 | 1974.5 |
| Oil | 2973 |  | 27.296 |  | 18.84 |

Table 4 Unit root test results

| Variable | Im-Pesaran-Shin |  | ADF Fisher Chi-square |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Level | 1st difference | Level | 1st difference |
| Market risk | $-23.8876^{* * *}$ | $-63.3072^{* * *}$ | 699.822*** | 1730.0954*** |
| Interest | 7.2986 | $-23.1317^{* * *}$ | 5.2468 | 651.8265*** |
| InExchange | 0.8868 | -42.2743*** | 26.9681 | 1561.9031*** |
| InOpenness | -0.789 | $-54.2507^{* * *}$ | 38.7588 | $1722.376^{* * *}$ |
| FD | $-4.0479 * * *$ | -49.0877*** | 79.2795*** | $1712.4845^{* * *}$ |
| $\operatorname{lnGDP}$ | 3.6298 | $-56.972^{* * *}$ | 11.4995 | 1728.0931*** |
| InGold | 0.7018 | $-53.4998^{* * *}$ | 26.8205 | 1724.0422*** |
| InOil | $-2.512^{* * *}$ | -44.1501*** | 59.1774 | 1640.7509*** |

Superscripts *** denotes the significance level of 1 per cent
homogeneous long-run coefficients (Pesaran et al., 2012), implying that the market risk effects of macroeconomic indicators are identical across sectors. The results of the slope homogeneity test show that the panel consists of heterogeneous slopes. Thus, we use

Table 5 Model specification test results

| Hausman (1978) | Chi-square | $P$-value |
| :---: | :---: | :---: |
|  | 5.47 | 0.963 |
| Pesaran and Yamagata (2008) | $\bar{\Delta}$ | $\bar{\Delta}_{\text {adj }}$ |
| Interest | $2.717^{* * *}$ | $2.751^{* * *}$ |
| InExchange | 10.663*** | 10.795*** |
| InOpenness | 10.424*** | 10.558*** |
| FD | $1.823^{* * *}$ | 1.849*** |
| $\operatorname{lnGDP}$ | 9.858*** | 9.985*** |
| InGold | 8.945*** | 9.055*** |
| InOil | 9.967*** | 10.09*** |

Superscripts *, ${ }^{* *}$ and ${ }^{* * *}$ denote the significance at 10 per cent, 5 per cent, and 1 per cent confidence levels, respectively
the MG technique to address the heterogeneous slopes when estimating the long-term effects of macroeconomic indicators on each sector's market risk.
Table 6 reports the short-run effects of macroeconomic indicators on the market risks across sectors in Vietnam in two scenarios: (i) when all sectors are considered together, the results are presented in the first column; and (ii) when each sector is considered, results are presented in the remaining columns. Our results confirm that either a rise or a fall in interest rates significantly increases market risks in Vietnam in the short run. However, the market risk effect of the latter (a drop in the interest rate) has a greater magnitude than the former. This finding implies that short-run fluctuations of the LIBOR rate shall trigger market risks in Vietnam. In addition, a decline in financial development significantly magnifies market risk, implying that a short-run reduction in the depth, access, and efficiency of Vietnam's financial institutions and markets shall heighten market risks in Vietnam. Furthermore, economic growth is also associated with a significant rise in market risks, indicating that an increase in Vietnam's GDP per capita magnifies market risks in the short run.
In contrast, either an increase or decrease in trade openness mitigates market risk in Vietnam, in which the effect on market risk of the latter has a greater magnitude. This finding signifies that changes in Vietnam's total exports and imports reduce the market risk in the short run. In addition, a decrease in the exchange rate significantly abates market risks, indicating that short-run depreciation of the VND against the USD reduces market risks in Vietnam. Similarly, a decline in trade openness and increased financial development significantly mitigate market risk. In other words, an increase in the depth, access, and efficiency of Vietnam's financial institutions and markets reduces the country's market risk in the short run.
The short-run effects on market risk appear to be consistent when all sectors are considered together. A decrease in the exchange rate reduces market risk across many Vietnamese sectors. We find that 19 of the 24 sectors experienced a statistically significant reduction in market risk. A decline in trade openness also significantly reduces market risks in 15 of the 24 Vietnamese sectors in the short run. Market risks across the Vietnamese sectors respond significantly to both increases and decreases in financial development in the short run. As financial development improves, market risks decrease in 8 out of 24 sectors, including Aquaculture, Business, Construction Investment, Minerals,
Table 6 The short-run effects of macroeconomic indicators on market risk across 24 sectors in Vietnam, 2012-2022

| Short-run estimation |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Variables | All | AC | AV | BK | BM | BU | Cl | DI | ED | EN | FE | FO | MI |
| $\Delta$ Interest $^{+}$ | 1.945*** | 4.563*** | 1.297 | 3.695** | 1.686 | 2.169* | 0.103 | 1.02 | - 1.863 | 0.313 | -0.428 | 1.407 | 7.121** |
|  | (0.428) | (1.559) | (2.794) | (1.706) | (1.370) | (1.275) | (1.311) | (2.646) | (2.302) | (1.045) | (1.455) | (1.279) | (2.907) |
| $\Delta$ Interest $^{-}$ | 1.535*** | 0.905 | 2.251 | 1.656 | 1.027 | 0.945 | 1.700** | 2.968** | 1.486 | 1.433** | 1.286 | 0.917 | 2.383 |
|  | (0.129) | (0.854) | (1.607) | (1.014) | (0.815) | (0.713) | (0.755) | (1.509) | (1.361) | (0.602) | (0.841) | (0.761) | (1.557) |
| $\Delta \ln E x c h a n g e_{-1}^{+}$ | 0.154 | 0.195 | -0.236 | 0.661 | 0.354 | $-0.338$ | -0.114 | 0.103 | 0.005 | 0.02 | 0.133 | 0.307 | -0.119 |
|  | (0.110) | (0.407) | (0.878) | (0.466) | (0.377) | (0.338) | (0.361) | (0.724) | (0.645) | (0.287) | (0.400) | (0.351) | (0.744) |
| $\Delta / n E x c h a n g e_{-1}^{-}$ | $-0.630^{* * *}$ | $-0.704^{* * *}$ | -0.131 | $-1.081^{* * *}$ | $-0.762^{* * *}$ | $-0.421^{* * *}$ | $-0.372^{* *}$ | $-0.664^{* *}$ | -0.057 | $-0.611^{* * *}$ | -0.234 | $-0.764^{* * *}$ | -0.597* |
|  | (0.067) | (0.187) | (0.411) | (0.217) | (0.176) | (0.155) | (0.166) | (0.332) | (0.294) | (0.131) | (0.184) | (0.161) | (0.344) |
| $\Delta /{ }^{\text {O }}$ Openness ${ }^{+}$ | $-0.066^{* *}$ | -0.270* | -0.056 | -0.061 | -0.148 | -0.079 | - 0.048 | 0.016 | -0.098 | -0.105 | 0.09 | -0.101 | 0.004 |
|  | (0.030) | (0.140) | (0.358) | (0.162) | (0.130) | (0.116) | (0.123) | (0.248) | (0.222) | (0.098) | (0.137) | (0.121) | (0.257) |
| $\Delta /{ }^{\text {O }}$ Openness ${ }^{-}$ | $-0.431^{* * *}$ | - 0.082 | -0.679* | $-0.693^{* *}$ | $-0.608^{* * *}$ | $-0.483^{* * *}$ | -0.192 | 0.061 | 0.521 | $-0.436^{* * *}$ | $-0.548^{* * *}$ | $-0.624^{* * *}$ | $-0.865^{* *}$ |
|  | (0.065) | (0.216) | (0.402) | (0.248) | (0.199) | (0.180) | (0.189) | (0.382) | (0.333) | (0.151) | (0.211) | (0.188) | (0.389) |
| $\triangle F D^{+}$ | $-0.187^{* * *}$ | $-0.324^{* *}$ | 0.555 | -0.211 | -0.119 | $-0.495^{* *}$ | -0.235** | -0.085 | 0.081 | $-0.157^{*}$ | -0.112 | -0.113 | $-0.480^{* *}$ |
|  | (0.044) | (0.129) | (0.574) | (0.148) | (0.119) | (0.107) | (0.113) | (0.225) | (0.201) | (0.091) | (0.128) | (0.113) | (0.234) |
| $\triangle F D^{-}$ | $0.140^{* * *}$ | 0.185 | 0.117 | 0.099 | 0.051 | 0.642*** | -0.145 | -0.082 | $-0.246$ | 0.025 | 0.075 | -0.023 | 0.298 |
|  | (0.045) | (0.227) | (0.673) | (0.260) | (0.211) | (0.189) | (0.201) | (0.400) | (0.353) | (0.159) | (0.223) | (0.197) | (0.414) |
| $\Delta / n G D P$ | 0.095*** | 0.316** | 0.061 | 0.127 | 0.115 | 0.386*** | -0.034 | 0.058 | 0.009 | 0.021 | -0.046 | 0.057 | 0.138 |
|  | (0.035) | (0.161) | (0.382) | (0.186) | (0.149) | (0.134) | (0.143) | (0.285) | (0.253) | (0.113) | (0.159) | (0.139) | (0.296) |
| $\Delta / n$ Gold ${ }^{+}$ | 0.001 | 0.016 | 0.014 | 0.017 | 0 | 0.003 | 0.039 | -0.042 | 0.008 | 0.016 | -0.023 | - 0.013 | -0.053 |
|  | (0.006) | (0.035) | (0.073) | (0.040) | (0.032) | (0.029) | (0.031) | (0.063) | (0.057) | (0.024) | (0.035) | (0.030) | (0.064) |
| $\Delta /{ }^{\text {GGold }}$ - | $-0.022^{* *}$ | 0.021 | 0.074 | -0.041 | -0.048 | -0.044 | -0.054* | 0.027 | -0.104* | -0.01 | -0.008 | 0.019 | 0.045 |
|  | (0.010) | (0.035) | (0.080) | (0.041) | (0.034) | (0.030) | (0.031) | (0.061) | (0.054) | (0.024) | (0.035) | (0.030) | (0.063) |
| $\Delta / \mathrm{nOil}^{+}$ | $-0.014^{* * *}$ | -0.013 | 0.033 | $-0.027^{* * *}$ | $-0.019^{* *}$ | $-0.014^{* *}$ | -0.008 | 0.002 | -0.011 | $-0.018^{* * *}$ | $-0.014^{*}$ | $-0.013^{*}$ | -0.021 |
|  | (0.003) | (0.008) | (0.031) | (0.010) | (0.008) | (0.007) | (0.008) | (0.015) | (0.013) | (0.006) | (0.008) | (0.007) | (0.016) |
| $\Delta / \mathrm{nOil}^{-}$ | -0.004 | - 0.005 | -0.074* | 0.007 | -0.002 | -0.005 | -0.016* | -0.027 | 0.014 | 0.009 | -0.005 | -0.001 | 0.009 |
|  | (0.004) | (0.010) | (0.043) | (0.012) | (0.010) | (0.009) | (0.009) | (0.019) | (0.016) | (0.007) | (0.010) | (0.009) | (0.019) |

Table 6 (continued)

| Short-run estimation |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Variables | All | AC | AV | BK | BM | BU | Cl | DI | ED | EN | FE | FO | MI |
| Constant | $-1.031^{* * *}$ | - 1.045*** | $-0.577^{* * *}$ | $-1.002^{* * *}$ | -1.209*** | $-1.140^{* * *}$ | $-1.167^{* *}$ | $-0.746^{* * *}$ | $-0.933^{* *}$ | $-1.096^{* *}$ | - 1.130*** | -1.082*** | $-0.967^{* *}$ |
|  | (0.043) | -0.288 | -0.19 | -0.277 | -0.328 | -0.312 | -0.317 | -0.221 | -0.272 | -0.291 | -0.309 | -0.298 | -0.274 |
| Observation | 2,817 | $(\mathrm{N}=24 ; \mathrm{T}=127)$ |  |  |  |  |  |  |  |  |  |  |  |
| Variables | All | OG | PH | PL | PS | RE | RU | SE | SV | ST | TE | TR | TP |
| $\Delta$ Interest $^{+}$ | 1.945*** | 5.595*** | $2.390^{*}$ | 3.756*** | 4.008 | 1.297 | 1.836 | $-1.35$ | 1.585 | 1.24 | 1.718 | 3.092* | 0.43 |
|  | (0.428) | (2.160) | (1.240) | (1.218) | (5.900) | (1.541) | (1.562) | (1.920) | (2.483) | (1.421) | (1.329) | (1.744) | (1.146) |
| $\Delta$ Interest $^{-}$ | 1.535*** | 0.988 | 1.391* | 1.185* | 1.414 | 1.453 | 2.078** | 2.229** | 2.585* | 1.619* | 0.381 | 0.729 | $1.830^{* * *}$ |
|  | (0.129) | (1.253) | (0.710) | (0.691) | (3.461) | (0.913) | (0.891) | (1.109) | (1.453) | (0.829) | (0.777) | (1.060) | (0.660) |
| $\Delta / n E x c h a n g e_{-1}^{+}$ | 0.154 | 1.068* | -0.388 | 0.003 | -1.551 | 0.246 | 0.699 | 0.614 | 1.09 | 0.295 | -0.128 | 0.203 | 0.564* |
|  | (0.110) | (0.585) | (0.334) | (0.328) | (1.662) | (0.426) | (0.427) | (0.532) | (0.687) | (0.391) | (0.362) | (0.467) | (0.314) |
| $\Delta$ InExchange ${ }_{-1}^{-}$ | $-0.630^{* * *}$ | $-1.582^{* *}$ | $-0.356^{* *}$ | $-0.371^{* *}$ | - 1.056 | $-0.524^{* * *}$ | $-0.599^{* *}$ | $-0.762^{* * *}$ | $-0.810^{* *}$ | -0.689*** | $-0.633^{* * *}$ | $-0.842^{* * *}$ | -0.51 *** |
|  | (0.067) | (0.271) | (0.152) | (0.148) | (0.762) | (0.195) | (0.196) | (0.244) | (0.320) | (0.183) | (0.165) | (0.215) | (0.144) |
| $\Delta /$ Openness $^{+}$ | $-0.066^{* *}$ | -0.11 | -0.149 | -0.081 | 0.492 | -0.027 | - 0.270* | - 0.177 | -0.119 | -0.18 | 0.004 | -0.021 | -0.099 |
|  | (0.030) | (0.201) | (0.113) | (0.111) | (0.565) | (0.146) | (0.146) | (0.182) | (0.239) | (0.134) | (0.124) | (0.161) | (0.108) |
| $\Delta$ InOpenness ${ }^{\text {- }}$ | $-0.431^{* * *}$ | $-0.681^{* *}$ | $-0.355^{* *}$ | -0.278 | 0.066 | $-0.516^{* *}$ | $-0.467^{* *}$ | $-0.843^{* * *}$ | -0.544 | $-0.549^{* * *}$ | $-0.556^{* *}$ | $-0.440^{*}$ | $-0.539^{* * *}$ |
|  | (0.065) | (0.308) | (0.177) | (0.174) | (0.854) | (0.225) | (0.223) | (0.278) | (0.362) | (0.206) | (0.194) | (0.247) | (0.167) |
| $\triangle F D^{+}$ | $-0.187^{* * *}$ | -0.207 | -0.207* | $-0.314^{* * *}$ | -0.002 | -0.062 | $-0.487^{* * *}$ | -0.235 | -0.297 | -0.165 | $-0.339^{* * *}$ | -0.24 | -0.250** |
|  | (0.044) | (0.185) | (0.106) | (0.104) | (0.515) | (0.133) | (0.134) | (0.166) | (0.221) | (0.123) | (0.115) | (0.147) | (0.099) |
| $\triangle F D^{-}$ | $0.140^{* * *}$ | 0.122 | 0.16 | 0.176 | -0.258 | 0.038 | 0.583** | 0.246 | 0.451 | 0.277 | 0.233 | 0.256 | 0.086 |
|  | (0.045) | (0.327) | (0.183) | (0.181) | (0.911) | (0.238) | (0.237) | (0.298) | (0.383) | (0.218) | (0.200) | (0.260) | (0.176) |
| $\triangle / \mathrm{GGDP}$ | 0.095*** | 0.115 | 0.132 | 0.106 | -0.388 | -0.169 | $0.481^{* * *}$ | 0.148 | 0.109 | 0.249 | 0.078 | 0.162 | 0.048 |
|  | (0.035) | (0.232) | (0.131) | (0.129) | (0.652) | (0.169) | (0.169) | (0.211) | (0.275) | (0.155) | (0.143) | (0.185) | (0.125) |
| $\Delta / n$ Gold ${ }^{+}$ | 0.001 | 0.048 | -0.035 | -0.034 | -0.025 | -0.005 | -0.005 | 0.047 | 0.018 | -0.017 | 0.011 | 0.045 | -0.011 |
|  | (0.006) | (0.051) | (0.028) | (0.028) | (0.142) | (0.037) | (0.037) | (0.046) | (0.060) | (0.034) | (0.031) | (0.040) | (0.027) |
| $\Delta /{ }^{\text {GGold }}{ }^{-}$ | $-0.022^{* *}$ | -0.034 | -0.006 | -0.032 | -0.126 | -0.049 | 0.038 | $-0.090^{*}$ | 0.041 | -0.016 | $-0.065^{* *}$ | - 0.048 | -0.013 |
|  | (0.010) | (0.050) | (0.029) | (0.029) | (0.139) | (0.036) | (0.036) | (0.047) | (0.058) | (0.035) | (0.032) | (0.042) | (0.027) |

Table 6 (continued)

| Variables | All | OG | PH | PL | PS | RE | RU | SE | SV | ST | TE | TR | TP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\Delta /{ }^{\text {a }}$ II ${ }^{+}$ | $-0.014^{* * *}$ | -0.024* | $-0.016^{* *}$ | -0.013* | -0.047 | -0.011 | -0.016* | -0.006 | -0.029** | $-0.024^{* * *}$ | -0.004 | -0.009 | -0.011 |
|  | (0.003) | (0.012) | (0.007) | (0.007) | (0.034) | (0.009) | (0.009) | (0.011) | (0.015) | (0.008) | (0.008) | (0.010) | (0.007) |
| $\Delta / \mathrm{nOil}^{-}$ | -0.004 | 0.01 | 0.007 | 0.008 | -0.006 | 0.006 | 0.006 | -0.02 | 0.003 | 0.01 | -0.012 | -0.004 | -0.012 |
|  | (0.004) | (0.015) | (0.008) | (0.008) | (0.042) | (0.011) | (0.011) | (0.014) | (0.018) | (0.010) | (0.009) | (0.012) | (0.008) |
| Constant | $-1.031^{* * *}$ | -1.155*** | $-1.215^{* *}$ | $-1.383^{* * *}$ | $-0.590^{* * *}$ | $-1.186^{* *}$ | $-0.746^{* *}$ | $-1.031^{* * *}$ | $-0.796^{* *}$ | $-1.093^{* * *}$ | $-1.347^{* * *}$ | $-1.088^{* * *}$ | $-1.027^{* * *}$ |
|  | (0.043) | -0.316 | -0.328 | -0.368 | -0.184 | -0.325 | -0.214 | - 0.287 | -0.231 | -0.303 | -0.361 | - 0.302 | -0.279 |
| Observation | 2,817 | ( $\mathrm{N}=24 ; \mathrm{T}=127$ ) |  |  |  |  |  |  |  |  |  |  |  |

Superscripts ${ }^{*}$,** and ${ }^{* * *}$ denote the significance at 10 per cent, 5 per cent, and 1 per cent confidence levels, respectively. Standard errors are in parentheses. The correlation coefficients of each variable's increase ( + ) and decrease ( - ) are presented. The symbol $\Delta$ denotes the first difference for short-run estimation.
Sectors including AC Aquaculture, AV Aviation, BK Banking, BM Building Materials, BU Business, CI Construction Investment, DI Development Investment, ED Education, EN Energy, FE Fertilizer, FO Food, MI Minerals, OG Oil
\& Gas, PH Pharmaceutical, PL Plastic, PS Public Services, RE Real Estate, RU Rubber, SE Securities, SV Services, ST Steel, $T E$ Technology, $T R$ Trade, $T P$ Transportation. As the data for economic growth (GDP per capita) only has positive values, only $\triangle I n G D P$ and $\ln G D P$ are reported.

Plastic, Rubber, Technology, and Transportation. However, only the Business and Rubber sectors experienced increased market risk when financial development diminished. Finally, Rubber and Business are the sectors most affected by macroeconomic indicators because the market risks in these two sectors are sensitive to changes in macroeconomic indicators in the short run.

Table 7 presents the asymmetric effects of macroeconomic indicators on market risk across Vietnamese sectors in the long run. We interpret these effects for all sectors being considered. The effect of a declining interest rate on market risks remains significant, whereas that of an increased interest rate becomes insignificant in the long run. Specifically, a fall in interest rates significantly reduces market risk in Vietnam. This finding implies that a decreased LIBOR rate will reduce the market risk in Vietnam in the long term. Similarly, a reduction in trade openness significantly reduces market risk in Vietnam, indicating that a decrease in Vietnam's total exports and imports will reduce the country's market risk in the long run. We also document that an increase in the exchange rate abates market risks, implying that an appreciation in the VND against the USD mitigates market risks in the long run.
By contrast, we find that either an increase or decrease in financial development significantly heightens market risk in Vietnam. However, the market risk effect of the latter exhibits a larger magnitude than that of the former. This finding signifies that market risk in Vietnam has increased in response to long-term changes in the long run in the depth, access, and efficiency of the country's financial institutions and markets. Furthermore, we observe that economic growth significantly magnifies market risk, implying that an improvement in Vietnam's GDP per capita is associated with an increase in market risk in the long run.
The long-run effects of macroeconomic indicators on market risk across Vietnamese sectors have changed significantly compared to those in the short run. We find that an increase in interest rate and economic growth has the most widespread effect on market risks across Vietnamese sectors in the long run. An increase in the LIBOR rate significantly affected market risks in nine of the 24 sectors. We also document that 6 out of the 24 sectors were affected by Vietnam's economic growth. Finally, the Minerals sector is the most affected by macroeconomic indicators, followed by the Oil \& Gas and Rubber sectors. Specifically, market risks in these three sectors are more prone to the effects of changes in macroeconomic indicators in the long run.

## Robustness analysis

Table 8 presents the asymmetric effect of macroeconomic indicators on market risk across Vietnamese sectors using Alison's (2019) asymmetric fixed effects model. This method captures within-individual changes rather than between-individual differences in the variables. The dependent variable was a function of the accumulated positive and negative changes in the independent variable. Thus, the technique is appropriate as a robustness test for the long-run estimation results presented in Table 7. We find that the robustness test results align with the long-run estimation results in Table 7 using the panel NARDL. The impact of the macroeconomic indicators on market risk remains largely the same. We conclude that our empirical results regarding the asymmetric effects of macroeconomic indicators on market risk across sectors in Vietnam, using the
Table 7 The long-run effects of macroeconomic indicators on market risk across 24 sectors in Vietnam, 2012-2022

| Long-run estimation |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Variables | All | AC | AV | BK | BM | BU | Cl | DI | ED | EN | FE | FO | MI |
| Interest ${ }^{+}$ | 0.226 | -0.32 | $-2.752$ | -0.479 | 0.359 | -0.757 | 0.249 | - 1.408 | 1.527 | $1.841^{* * *}$ | 1.732** | 1.313* | $-5.263^{* * *}$ |
|  | (0.203) | (0.852) | (3.157) | (1.315) | (0.903) | (0.760) | (0.848) | (1.417) | (1.498) | (0.615) | (0.755) | (0.781) | (1.548) |
| Interest ${ }^{\text {- }}$ | $-0.222^{* *}$ | -0.676* | 2.981* | -0.496 | -0.438 | -0.288 | -0.375 | 0.392 | $-0.245$ | -0.124 | -0.539 | -0.591* | - 0.432 |
|  | (0.089) | (0.373) | (1.698) | (0.574) | (0.396) | (0.335) | (0.372) | (0.618) | (0.656) | (0.269) | (0.331) | (0.343) | (0.673) |
| $\ln$ Exchange ${ }_{-1}^{+}$ | $-0.528^{* * *}$ | -0.593* | - 0.704 | $-1.308^{* * *}$ | $-0.963^{* * *}$ | $-0.660^{* *}$ | -0.257 | -0.549 | 0.208 | -0.023 | -0.115 | -0.555* | - 0.83 |
|  | (0.078) | (0.328) | (0.804) | (0.506) | (0.357) | (0.291) | (0.327) | (0.543) | (0.576) | (0.236) | (0.291) | (0.298) | (0.592) |
| InExchange- | $-0.057^{*}$ | -0.024 | 0.296 | -0.029 | -0.071 | -0.072 | 0.044 | 0.309 | 0.147 | -0.131 | 0.036 | -0.193* | 0.159 |
|  | (0.030) | (0.125) | (0.518) | (0.192) | (0.133) | (0.112) | (0.124) | (0.207) | (0.220) | (0.090) | (0.111) | (0.114) | (0.225) |
| InOpenness+ | -0.040 | 0.141 | $-1.238^{* * *}$ | 0.15 | -0.016 | -0.158* | -0.041 | 0.063 | 0.01 | 0.033 | 0.133 | 0.009 | $-0.635^{* * *}$ |
|  | (0.025) | (0.105) | (0.300) | (0.161) | (0.111) | (0.093) | (0.105) | (0.174) | (0.185) | (0.075) | (0.093) | (0.095) | (0.189) |
| InOpenness ${ }^{-}$ | $-0.200^{* * *}$ | -0.205 | 0.485 | -0.149 | -0.221 | -0.21 | -0.169 | 0.096 | $-0.236$ | $-0.503^{* * *}$ | $-0.534^{* * *}$ | $-0.446^{* *}$ | 0.535 |
|  | (0.051) | (0.215) | (0.553) | (0.330) | (0.228) | (0.191) | (0.216) | (0.358) | (0.378) | (0.155) | (0.190) | (0.196) | (0.395) |
| $F D^{+}$ | 0.095*** | -0.097 | 2.101** | 0.011 | 0.138 | -0.054 | 0.131 | 0.118 | 0.086 | 0.253** | 0.312** | 0.165 | $-0.770^{* * *}$ |
|  | (0.033) | (0.140) | (0.868) | (0.217) | (0.148) | (0.126) | (0.139) | (0.230) | (0.244) | (0.100) | (0.124) | (0.128) | (0.250) |
| $F D^{-}$ | $0.183^{* * *}$ | 0.217 | 0.708 | 0.389 | 0.27 | 0.468** | 0.061 | 0.564 | $-0.165$ | -0.225 | -0.111 | -0.199 | 1.359*** |
|  | (0.055) | (0.231) | (0.594) | (0.357) | (0.245) | (0.207) | (0.230) | (0.385) | (0.407) | (0.167) | (0.205) | (0.212) | (0.419) |
| $\operatorname{lnGDP}$ | $0.176^{* * *}$ | 0.087 | 0.817** | 0.232 | 0.229 | 0.393** | 0.2 | 0.302 | -0.044 | -0.141 | -0.089 | -0.046 | 1.426*** |
|  | (0.044) | (0.184) | (0.412) | (0.282) | (0.195) | (0.164) | (0.183) | (0.306) | (0.323) | (0.132) | (0.163) | (0.168) | (0.334) |
| InGold ${ }^{+}$ | 0.018*** | 0.01 | 0.031 | 0.047 | 0.036 | 0.02 | 0.002 | 0.024 | -0.041 | -0.012 | -0.01 | -0.005 | 0.015 |
|  | (0.005) | (0.022) | (0.063) | (0.034) | (0.024) | (0.020) | (0.022) | (0.036) | (0.038) | (0.016) | (0.019) | (0.020) | (0.040) |
| InGold ${ }^{-}$ | 0.055*** | 0.052* | 0.136 | 0.049 | 0.071** | 0.03 | 0.03 | -0.001 | $-0.016$ | $0.078 * * *$ | $0.071^{* * *}$ | $0.084^{* * *}$ | -0.042 |
|  | (0.007) | (0.029) | (0.099) | (0.046) | (0.031) | (0.026) | (0.029) | (0.047) | (0.050) | (0.021) | (0.025) | (0.026) | (0.051) |
| InOil ${ }^{+}$ | 0.005*** | 0.004 | 0.018 | 0.015* | 0.006 | 0.003 | -0.006 | -0.004 | $-0.006$ | 0.003 | 0.007 | 0.008 | $-0.021^{* *}$ |
|  | (0.001) | (0.006) | (0.020) | (0.009) | (0.006) | (0.005) | (0.006) | (0.010) | (0.010) | (0.004) | (0.005) | (0.005) | (0.011) |
| InOil ${ }^{-}$ | $-0.004^{* *}$ | -0.013* | -0.089* | 0.006 | -0.005 | -0.002 | -0.001 | -0.008 | $-0.002$ | -0.008 | 0.001 | -0.009 | -0.025* |
|  | (0.002) | (0.007) | (0.046) | (0.011) | (0.008) | (0.007) | (0.007) | (0.012) | (0.013) | (0.005) | (0.007) | (0.007) | (0.013) |

Table 7 (continued)

| Long-run estimation |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Variables | All | AC | AV | BK | BM | BU | Cl | DI | ED | EN | FE | FO | MI |
| Constant | $-1.031^{* * *}$ | -0.646 | -5.014* | - 1.375 | -1.556 | $-2.937^{* *}$ | -1.409 | - 2.225 | 0.33 | 1.082 | 0.774 | 0.373 | - 10.672*** |
|  | (0.043) | (1.416) | (2.715) | (1.718) | (1.353) | (1.311) | (1.316) | (2.274) | (2.218) | (0.997) | (1.344) | (1.250) | (2.598) |
| Observation | 2,817 | $(\mathrm{N}=24 ; \mathrm{T}=127$ ) |  |  |  |  |  |  |  |  |  |  |  |
| Variables | All | OG | PH | PL | PS | RE | RU | SE | SV | ST | TE | TR | TP |
| Interest ${ }^{+}$ | 0.226 | $-3.118^{* *}$ | 0.046 | 0.38 | -8.559*** | -0.182 | - 2.560 ** | -0.244 | - 1.622 | -1.157 | 1.03 | -0.432 | 0.352 |
|  | (0.203) | (1.260) | (0.700) | (0.588) | (2.471) | (0.960) | (1.099) | (1.158) | (1.678) | (0.955) | (0.704) | (1.012) | (0.672) |
| Interest ${ }^{\text {- }}$ | $-0.222^{* *}$ | 0.069 | 0.095 | 0.074 | 0.558 | -0.132 | 0.023 | -0.757 | 0.606 | -0.185 | $-0.865^{* * *}$ | -0.767* | 0.294 |
|  | (0.089) | (0.553) | (0.308) | (0.258) | (1.081) | (0.422) | (0.482) | (0.509) | (0.732) | (0.419) | (0.313) | (0.443) | (0.297) |
| $\ln$ Exchange $_{-1}^{+}$ | $-0.528^{* * *}$ | $-1.450 * *$ | -0.251 | -0.323 | $-2.350^{* *}$ | -0.558 | -0.265 | $-1.161^{* * *}$ | -0.559 | $-0.918^{* *}$ | $-0.571^{* *}$ | $-1.137^{* * *}$ | -0.068 |
|  | (0.078) | (0.487) | (0.270) | (0.227) | (0.950) | (0.375) | (0.423) | (0.445) | (0.635) | (0.377) | (0.270) | (0.397) | (0.259) |
| $\ln$ Exchange $_{-1}$ | -0.057* | 0.051 | -0.062 | -0.103 | -0.704* | -0.03 | -0.06 | -0.014 | $-0.447^{*}$ | -0.044 | 0.017 | -0.142 | 0.01 |
|  | (0.030) | (0.185) | (0.103) | (0.086) | (0.363) | (0.142) | (0.161) | (0.170) | (0.242) | (0.140) | (0.103) | (0.151) | (0.099) |
| InOpenness ${ }^{+}$ | -0.040 | -0.172 | -0.049 | -0.069 | -0.342 | -0.159 | $-0.393^{* *}$ | -0.032 | -0.279 | $-0.227^{*}$ | 0.01 | 0.117 | -0.059 |
|  | (0.025) | (0.155) | (0.086) | (0.072) | (0.304) | (0.118) | (0.135) | (0.143) | (0.208) | (0.118) | (0.086) | (0.125) | (0.083) |
| InOpenness ${ }^{-}$ | $-0.200^{* * *}$ | 0.255 | -0.143 | -0.084 | 0.772 | -0.187 | 0.043 | -0.351 | 0.117 | -0.072 | $-0.441^{* *}$ | -0.123 | -0.201 |
|  | (0.051) | (0.319) | (0.178) | (0.149) | (0.622) | (0.243) | (0.279) | (0.293) | (0.416) | (0.241) | (0.178) | (0.255) | (0.171) |
| $F D^{+}$ | 0.095*** | -0.313 | 0.078 | 0.105 | -0.539 | 0.003 | -0.272 | 0.142 | -0.004 | -0.029 | 0.121 | -0.035 | 0.092 |
|  | (0.033) | (0.205) | (0.114) | (0.097) | (0.402) | (0.157) | (0.180) | (0.191) | (0.275) | (0.156) | (0.117) | (0.166) | (0.111) |
| $F D^{-}$ | 0.183*** | 1.213*** | 0.121 | 0.179 | 0.028 | 0.289 | 0.842*** | 0.618** | -0.05 | 0.491* | 0.093 | 0.438 | 0.084 |
|  | (0.055) | (0.343) | (0.190) | (0.160) | (0.671) | (0.261) | (0.299) | (0.315) | (0.456) | (0.259) | (0.191) | (0.275) | (0.183) |
| $\ln$ GDP | 0.176*** | 0.735*** | 0.134 | 0.116 | 0.434 | 0.339 | 0.773*** | 0.345 | 0.347 | 0.565*** | 0.088 | 0.178 | 0.042 |
|  | (0.044) | (0.272) | (0.151) | (0.127) | (0.535) | (0.207) | (0.237) | (0.250) | (0.363) | (0.206) | (0.151) | (0.218) | (0.145) |
| InGold ${ }^{+}$ | 0.018*** | 0.069** | 0.023 | 0.019 | $0.112^{*}$ | 0.006 | -0.006 | 0.038 | 0.038 | 0.035 | -0.016 | 0.035 | 0.016 |
|  | (0.005) | (0.033) | (0.018) | (0.015) | (0.063) | (0.025) | (0.028) | (0.031) | (0.042) | (0.025) | (0.018) | (0.027) | (0.018) |
| InGold ${ }^{-}$ | 0.055*** | -0.004 | 0.064*** | 0.037* | $-0.147^{*}$ | 0.046 | 0.008 | 0.047 | 0.019 | 0.046 | 0.060** | 0.070* | 0.005 |

Table 7 (continued)

| Variables | All | OG | PH | PL | PS | RE | RU | SE | SV | ST | TE | TR | TP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| InOil ${ }^{+}$ | (0.007) | (0.043) | (0.024) | (0.020) | (0.083) | (0.033) | (0.037) | (0.040) | (0.056) | (0.033) | (0.024) | (0.036) | (0.023) |
|  | 0.005*** | 0.017** | 0.005 | 0.006 | 0.001 | 0.01 | 0.002 | 0.004 | -0.002 | 0.003 | 0.002 | 0.015** | -0.003 |
|  | (0.001) | (0.009) | (0.005) | (0.004) | (0.017) | (0.007) | (0.008) | (0.008) | (0.012) | (0.007) | (0.005) | (0.007) | (0.005) |
| InOil ${ }^{-}$ | $-0.004^{* *}$ | 0.004 | - 0.005 | 0.005 | 0.008 | 0.001 | -0.003 | -0.003 | 0.009 | -0.004 | $-0.016^{* * *}$ | -0.007 | 0.002 |
|  | (0.002) | (0.011) | (0.006) | (0.005) | (0.022) | (0.008) | (0.010) | (0.010) | (0.015) | (0.008) | (0.006) | (0.009) | (0.006) |
| Constant | $-1.031 * * *$ | $-5.512^{* * *}$ | - 1.028 | - 1.01 | -3.714 | $-2.495$ | $-4.856^{* *}$ | $-2.467$ | - 2.296 | $-3.816^{* * *}$ | -0.728 | - 1.303 | -0.296 |
|  | (0.043) | (2.101) | (1.185) | (1.152) | (4.635) | (1.562) | (1.619) | (1.853) | (2.496) | (1.451) | (1.300) | (1.628) | (1.097) |
| Observation | 2,817 | ( $\mathrm{N}=24 ; \mathrm{T}=127$ ) |  |  |  |  |  |  |  |  |  |  |  |

Superscripts ${ }^{*, * *}$ and ${ }^{* * *}$ denote the significance at 10 per cent, 5 per cent, and 1 per cent confidence levels, respectively. Standard errors are in parentheses. The correlation coefficients of each variable's increase ( + ) and decrease ( - ) are presented. The symbol $\Delta$ denotes the first difference for short-run estimation.
Sectors including AC: Aquaculture; AV: Aviation; BK: Banking; BM: Building Materials; BU: Business; CI: Construction Investment; DI: Development Investment; ED: Education; EN: Energy; FE: Fertilizer; FO: Food; MI: Minerals; OG: Oil \& Gas; PH: Pharmaceutical; PL: Plastic; PS: Public Services; RE: Real Estate; RU: Rubber; SE: Securities; SV: Services; ST: Steel; TE: Technology; TR:Trade; TP: Transportation. As the data for economic growth (GDP per capita) only has positive values, only $\triangle \ln G D P$ and $\ln G D P$ are reported.
Table 8 The asymmetric effect of macroeconomic indicators on market risk across 24 sectors in Vietnam, 2012-2022

| Asymmetric fixed effects estimation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Variables | All <br> (Table 7) | All (Robust) | AC | AV | BK | BM | BU | Cl | DI | ED | EN | FE | FO | MI |
| Interest ${ }^{+}$ | 0.226 | $1.100^{* * *}$ | 0.380* | 0.648 | 0.877*** | 0.737*** | 0.355* | 0.13 | 0.063 | 0.222 | 0.427*** | 0.811*** | 0.606*** | $-0.248$ |
|  | (0.203) | (0.088) | (0.214) | (0.498) | (0.275) | (0.228) | (0.213) | (0.208) | (0.316) | (0.282) | (0.160) | (0.232) | (0.193) | (0.376) |
| Interest ${ }^{\text {- }}$ | $-0.222^{* *}$ | -0.192 | 0.214 | - 0.02 | 0.28 | -0.066 | -0.33 | $-0.819^{* *}$ | 0.132 | -0.902* | -0.259 | 0.226 | 0.037 | -0.284 |
|  | (0.089) | (0.209) | (0.380) | (1.134) | (0.487) | (0.418) | (0.378) | (0.369) | (0.560) | (0.517) | (0.293) | (0.426) | (0.343) | (0.666) |
| InExchange ${ }^{+}$ | $-0.528^{* * *}$ | $-0.257^{* * *}$ | -0.054 | - 0.471 | -0.476* | -0.373 | -0.158 | -0.312 | -0.125 | -0.759*** | -0.247 | -0.044 | $-0.357^{*}$ | 0.086 |
|  | (0.078) | (0.077) | (0.204) | (0.434) | (0.261) | (0.228) | (0.202) | (0.198) | (0.300) | (0.282) | (0.160) | (0.233) | (0.184) | (0.357) |
| InExchange ${ }^{-}$ | -0.057* | -0.046 | 0.081 | -0.19 | 0.052 | -0.011 | 0.091 | 0.049 | 0.385** | -0.088 | -0.085 | 0.048 | -0.023 | -0.023 |
|  | (0.030) | (0.037) | (0.104) | (0.303) | (0.133) | (0.115) | (0.103) | (0.101) | (0.153) | (0.142) | (0.080) | (0.117) | (0.094) | (0.182) |
| InOpenness ${ }^{+}$ | -0.040 | $-0.128^{* *}$ | 0.045 | $-0.841^{* * *}$ | -0.161 | $-0.220^{* *}$ | $-0.160^{*}$ | -0.074 | 0.052 | -0.212* | -0.109 | -0.108 | $-0.182^{* *}$ | -0.147 |
|  | (0.025) | (0.019) | (0.085) | (0.219) | (0.109) | (0.095) | (0.084) | (0.082) | (0.125) | (0.117) | (0.066) | (0.097) | (0.076) | (0.149) |
| InOpenness ${ }^{-}$ | $-0.200 * * *$ | -0.017 | -0.144 | 0.235 | $-0.331^{*}$ | -0.133 | $-0.408^{* *}$ | $-0.258^{* *}$ | -0.086 | -0.097 | $-0.225^{* *}$ | -0.088 | -0.259** | $-0.585^{* *}$ |
|  | (0.051) | (0.032) | (0.135) | (0.302) | (0.173) | (0.151) | (0.134) | (0.131) | (0.199) | (0.187) | (0.106) | (0.154) | (0.122) | (0.237) |
| $F D^{+}$ | 0.095*** | 0.435*** | -0.108 | 0.022 | -0.087 | -0.01 | -0.027 | 0.049 | 0.056 | -0.105 | -0.024 | -0.018 | -0.041 | -0.153 |
|  | (0.033) | (0.024) | (0.078) | (0.425) | (0.100) | (0.087) | (0.078) | (0.076) | (0.116) | (0.108) | (0.061) | (0.089) | (0.071) | (0.137) |
| $F D^{-}$ | $0.183^{* * *}$ | 0.078* | 0.031 | 0.785** | 0.172 | 0.132 | 0.249** | 0.126 | 0.311** | 0.099 | 0.061 | 0.172 | 0.018 | 0.262 |
|  | (0.055) | (0.044) | (0.106) | (0.384) | (0.136) | (0.118) | (0.105) | (0.103) | (0.156) | (0.147) | (0.083) | (0.121) | (0.096) | (0.186) |
| $\ln G D P$ | 0.176*** | $0.142^{* * *}$ | 0.018 | 0.809*** | 0.208* | 0.169* | 0.208** | 0.078 | -0.022 | 0.171 | 0.092 | 0.082 | 0.204** | 0.167 |
|  | (0.044) | (0.017) | (0.088) | (0.253) | (0.113) | (0.098) | (0.087) | (0.085) | (0.130) | (0.122) | (0.069) | (0.100) | (0.079) | (0.154) |
| InGold ${ }^{+}$ | 0.018*** | -0.001 | -0.019 | 0.015 | -0.049** | -0.02 | $-0.041^{* *}$ | -0.016 | -0.034 | 0.007 | -0.012 | -0.005 | -0.026* | $-0.055^{* *}$ |
|  | (0.005) | (0.004) | (0.016) | (0.044) | (0.020) | (0.018) | (0.016) | (0.015) | (0.023) | (0.022) | (0.012) | (0.018) | (0.014) | (0.028) |
| InGold ${ }^{-}$ | 0.055*** | $-0.043^{* * *}$ | 0.001 | 0.015 | -0.041 | -0.029 | -0.021 | $-0.041^{* *}$ | -0.046 | -0.029 | 0.005 | -0.003 | 0.015 | -0.0004 |
|  | (0.007) | (0.005) | (0.020) | (0.050) | (0.026) | (0.022) | (0.020) | (0.020) | (0.030) | (0.028) | (0.016) | (0.023) | (0.018) | (0.036) |
| InOil ${ }^{+}$ | 0.005*** | $-0.019^{* * *}$ | -0.006 | - 0.02 | $-0.014^{*}$ | $-0.019^{* * *}$ | -0.009 | $-0.013^{* *}$ | -0.006 | -0.020 ** | $-0.010^{* *}$ | -0.01 | -0.006 | - 0.006 |
|  | (0.001) | (0.001) | (0.006) | (0.019) | (0.007) | (0.006) | (0.006) | (0.005) | (0.008) | (0.008) | (0.004) | (0.006) | (0.005) | (0.010) |
| InOil ${ }^{-}$ | $-0.004^{* *}$ | $-0.015^{* * *}$ | -0.009 | 0.026 | -0.004 | -0.005 | -0.004 | 0.004 | $-0.020^{* *}$ | -0.01 | -0.002 | 0.001 | -0.005 | $-0.027^{* *}$ |

Table 8 (continued)

| Asymmetric fixed effects estimation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Variables | All <br> (Table 7) | All (Robust) | AC | AV | BK | BM | BU | Cl | DI | ED | EN | FE | FO | MI |
|  | (0.002) | (0.002) | (0.006) | (0.031) | (0.008) | (0.007) | (0.006) | (0.006) | (0.009) | (0.009) | (0.005) | (0.007) | (0.006) | (0.011) |
| Constant | $-1.031^{* * *}$ | 0.028*** | 0.025*** | 0.056*** | 0.041*** | 0.035*** | 0.025*** | 0.027*** | 0.025*** | 0.024*** | 0.027*** | 0.037*** | 0.033*** | 0.012 |
|  | (0.043) | (0.004) | (0.005) | (0.009) | (0.006) | (0.005) | (0.004) | (0.004) | (0.007) | (0.006) | (0.003) | (0.005) | (0.004) | (0.008) |
| Observation | 2,817 | 2,817 | $\begin{aligned} & (N=24 ; \\ & T=127) \end{aligned}$ |  |  |  |  |  |  |  |  |  |  |  |
| Variables | All <br> (Table 7) | All (Robust) | OG | PH | PL | PS | RE | RU | SE | SV | ST | TE | TR | TP |
| Interest ${ }^{+}$ | 0.226 | $1.100^{* * *}$ | 0.829** | $0.602^{* * *}$ | 0.493*** | 1.01 | 0.234 | 0.156 | 0.888*** | 0.421 | 0.450* | 0.331 | $0.751^{* * *}$ | 0.215 |
|  | (0.203) | (0.088) | (0.324) | (0.175) | (0.176) | (0.660) | (0.219) | (0.237) | (0.305) | (0.322) | (0.234) | (0.211) | (0.239) | (0.176) |
| Interest ${ }^{-}$ | $-0.222^{* *}$ | -0.192 | 1.281** | -0.029 | -0.013 | 5.379*** | -0.023 | 0.494 | 0.209 | 1.623*** | 0.368 | -0.732* | -0.468 | -0.063 |
|  | (0.089) | (0.209) | (0.594) | (0.320) | (0.323) | (1.169) | (0.402) | (0.436) | (0.560) | (0.571) | (0.430) | (0.375) | (0.424) | (0.312) |
| InExchange ${ }_{-1}^{+}$ | $-0.528^{* * *}$ | $-0.257^{* * *}$ | -0.274 | -0.187 | -0.161 | 1.088* | 0.037 | 0.331 | -0.365 | 0.522* | -0.092 | $-0.517^{* *}$ | -0.436* | -0.084 |
|  | (0.078) | (0.077) | (0.324) | (0.175) | (0.176) | (0.627) | (0.219) | (0.238) | (0.306) | (0.306) | (0.235) | (0.201) | (0.227) | (0.167) |
| $\ln$ Exchange ${ }_{-1}^{-}$ | $-0.057^{*}$ | -0.046 | -0.017 | $-0.016$ | 0.014 | -0.285 | 0.016 | -0.169 | 0.138 | $-0.484^{* * *}$ | -0.084 | 0.116 | 0.09 | 0.068 |
|  | (0.030) | (0.037) | (0.163) | (0.088) | (0.089) | (0.320) | (0.110) | (0.119) | (0.154) | (0.156) | (0.118) | (0.103) | (0.116) | (0.085) |
| InOpenness+ | - 0.040 | $-0.128^{* * *}$ | -0.127 | $-0.126^{*}$ | $-0.147^{* *}$ | -0.226 | $-0.249^{* * *}$ | $-0.222^{* *}$ | $-0.263^{* *}$ | $-0.525^{* * *}$ | $-0.235^{* *}$ | -0.13 | -0.094 | $-0.149^{* *}$ |
|  | (0.025) | (0.019) | (0.135) | (0.073) | (0.073) | (0.261) | (0.091) | (0.099) | (0.127) | (0.127) | (0.098) | (0.084) | (0.095) | (0.070) |
| InOpenness ${ }^{-}$ | $-0.200^{* *}$ | -0.017 | -0.294 | -0.188 | $-0.104$ | $-0.826^{* *}$ | $-0.101$ | $-0.466^{* * *}$ | $-0.397^{*}$ | -0.196 | -0.192 | $-0.238^{*}$ | -0.115 | $-0.290^{* * *}$ |
|  | (0.051) | (0.032) | (0.215) | (0.116) | (0.117) | (0.415) | (0.145) | (0.158) | (0.203) | (0.203) | (0.156) | (0.133) | (0.151) | (0.111) |
| $F D^{+}$ | 0.095*** | 0.435*** | -0.057 | -0.05 | -0.059 | 0.058 | 0.033 | -0.04 | 0.023 | -0.101 | 0.017 | -0.025 | -0.01 | -0.063 |
|  | (0.033) | (0.024) | (0.125) | (0.067) | (0.068) | (0.241) | (0.084) | (0.091) | (0.117) | (0.118) | (0.090) | (0.077) | (0.087) | (0.064) |
| $F D^{-}$ | $0.183^{* * *}$ | 0.078* | 0.211 | 0.089 | 0.248*** | $-1.578^{* *}$ | 0.196* | 0.239* | 0.366** | $-0.327^{* *}$ | 0.089 | 0.249** | 0.172 | 0.142 |
|  | (0.055) | (0.044) | (0.169) | (0.091) | (0.092) | (0.326) | (0.114) | (0.124) | (0.159) | (0.159) | (0.122) | (0.104) | (0.118) | (0.087) |
| $\ln$ GDP | $\begin{aligned} & 0.176^{* * *} \\ & (0.044) \end{aligned}$ | $\begin{aligned} & 0.142^{* *} \\ & (0.017) \end{aligned}$ | $\begin{aligned} & 0.121 \\ & (0.140) \end{aligned}$ | $\begin{aligned} & 0.084 \\ & (0.075) \end{aligned}$ | $\begin{aligned} & 0.146^{*} \\ & (0.076) \end{aligned}$ | $\begin{aligned} & -0.264 \\ & (0.270) \end{aligned}$ | $\begin{aligned} & 0.249^{* * *} \\ & (0.095) \end{aligned}$ | $\begin{aligned} & 0.181^{*} \\ & (0.102) \end{aligned}$ | $\begin{aligned} & 0.228^{*} \\ & (0.132) \end{aligned}$ | $\begin{aligned} & 0.345^{* * *} \\ & (0.132) \end{aligned}$ | $\begin{aligned} & 0.177^{*} \\ & (0.101) \end{aligned}$ | $\begin{aligned} & 0.158^{*} \\ & (0.087) \end{aligned}$ | $\begin{aligned} & 0.105 \\ & (0.098) \end{aligned}$ | $\begin{aligned} & 0.126^{*} \\ & (0.072) \end{aligned}$ |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 8 (continued)

| Variables | All <br> (Table 7) | All (Robust) | OG | PH | PL | PS | RE | RU | SE | SV | ST | TE | TR | TP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\overline{l n G o l d ~}^{+}$ | $0.018^{* * *}$ | -0.001 | -0.035 | -0.02 | -0.025* | $-0.109 * *$ | -0.031* | $-0.052^{* * *}$ | -0.03 | $-0.048^{* *}$ | -0.02 | $-0.023$ | $-0.036 * *$ | -0.024* |
|  | (0.005) | (0.004) | (0.025) | (0.014) | (0.014) | (0.049) | (0.017) | (0.018) | (0.024) | (0.024) | (0.018) | (0.016) | (0.018) | (0.013) |
| InGold ${ }^{-}$ | $0.055^{* * *}$ | $-0.043^{* * *}$ | -0.02 | 0.014 | -0.02 | 0.096 | -0.025 | 0.02 | $-0.052^{*}$ | 0.05 | $-0.006$ | $-0.025$ | -0.033 | $-0.034^{* *}$ |
|  | (0.007) | (0.005) | (0.032) | (0.017) | (0.017) | (0.063) | (0.022) | (0.023) | (0.030) | (0.031) | (0.023) | (0.020) | (0.023) | (0.017) |
| InOil ${ }^{+}$ | $0.005^{* * *}$ | $-0.019^{* * *}$ | 0.0002 | $-0.008^{*}$ | -0.007 | 0.022 | -0.009 | 0.003 | $-0.017^{* *}$ | -0.012 | -0.01 | $-0.009$ | $-0.015^{* *}$ | $-0.010^{* *}$ |
|  | (0.001) | (0.001) | (0.009) | (0.005) | (0.005) | (0.017) | (0.006) | (0.007) | (0.008) | (0.008) | (0.006) | (0.005) | (0.006) | (0.005) |
| InOil ${ }^{-}$ | $-0.004^{* *}$ | $-0.015^{* * *}$ | -0.004 | $-0.010^{* *}$ | 0.0001 | $-0.046^{* *}$ | 0.002 | -0.009 | -0.003 | $-0.019^{* *}$ | $-0.006$ | $-0.006$ | - 0.005 | -0.004 |
|  | (0.002) | (0.002) | (0.010) | (0.005) | (0.005) | (0.019) | (0.007) | (0.007) | (0.009) | (0.009) | (0.007) | (0.006) | (0.007) | (0.005) |
| Constant | $-1.031^{* * *}$ | 0.028*** | 0.051*** | 0.024*** | 0.033*** | 0.056*** | 0.035*** | 0.031*** | 0.049*** | 0.038*** | 0.035*** | 0.023*** | 0.024*** | 0.025*** |
|  | (0.043) | (0.004) | (0.007) | (0.004) | (0.004) | (0.014) | (0.005) | (0.005) | (0.007) | (0.007) | (0.005) | (0.004) | (0.005) | (0.004) |
| Observation | 2,817 | 2,817 | ( $\mathrm{N}=24 ; \mathrm{T}=127$ ) |  |  |  |  |  |  |  |  |  |  |  |

Superscripts *,** and ${ }^{* * *}$ denote the significance at 10 per cent, 5 per cent, and 1 per cent confidence levels, respectively. Standard errors are in parentheses. The correlation coefficients of each variable's increase ( + ) and decrease $(-)$ are presented. The symbol $\Delta$ denotes the first difference for short-run estimation.
Sectors including AC Aquaculture, AV Aviation, BK Banking, BM Building Materials, BU Business, CI Construction Investment, DI Development Investment, ED Education, EN Energy, FE Fertilizer, FO Food, MI Minerals, OG Oil
\& Gas, PH Pharmaceutical, PL Plastic, PS Public Services, RE Real Estate, RU Rubber, SE Securities, SV Services, ST Steel, TE Technology, TR Trade, TP Transportation. As the data for economic growth (GDP per capita) only has positive values, only $\triangle \ln G D P$ and $\ln G D P$ are reported.
panel NARDL as the main estimation technique and the asymmetric fixed-effects model as the robustness analysis, are robust.

## Discussions

Our findings are consistent with those of previous studies and address existing problems in the literature on market risk. We find that market risks across the Vietnamese sectors surge during extreme events, which is consistent with the findings of Bui et al. (2022a, b). These findings indicate that market risks across the Vietnamese sector soared during the COVID-19 pandemic.

Regarding market risk spillovers, the Building Materials, Technology, and Securities sectors were the primary risk transmitters in Vietnam during extreme events. The building-materials sector safeguards the infrastructure required for the development of other sectors. The Technology sector facilitates the development of other sectors by directly improving operational activities. Meanwhile, Securities are considered an influential sector because substantial abnormal security-margin transactions significantly heighten market risk under extreme events. This circumstance, in turn, impacts other related sectors through asset-liability connections or high leverage. These results align with the findings of previous studies on market risk spillovers across sectors in the US States (Chiu et al. 2015) and China (Zhang et al. 2020).
By contrast, the mineral, development investment, and education sectors were the most significant risk recipients. These sectors tend to depend more on the performance of other sectors in the Vietnamese economy for their own functioning. For example, the current shift in other sectors towards environmentally friendly operations, such as the widespread adoption of renewable energy sources, will significantly reduce the demand for minerals. Additionally, extreme events related to climate change, such as natural disasters and regulations aimed at reducing greenhouse gas emissions, can disrupt the mineral sector and supply chain. The role of the Development Investment sector is to enhance the operational capabilities of all socioeconomic activities. Therefore, this sector will experience significant risk if the operations of other sectors are interrupted by extreme events, particularly geopolitical conflicts. The educational sector is not directly dependent on the operating activities of other sectors. However, the Education sector can still be affected by rapid changes in technology and the labor market in other sectors. The COVID-19 pandemic has accelerated this change, forcing the education sector to adapt to digital transformation.

## Concluding remarks and policy implications

The ongoing gloomy economic outlook with various extreme events, such as the continuing COVID-19 pandemic and the Russia-Ukraine conflict, poses particular dangers for emerging markets such as Vietnam. In addition, the slowdown in major economies such as the US and China, Vietnam's largest trading partners, has disrupted the country's trading activities. At the same time, the Vietnamese government may struggle to address these emerging extreme events because of budget deficits. Moreover, various extreme events signal soaring stock market risk and significant risk spillovers among international stock markets. Indeed, existing literature has widely examined market risk and its spillover effects across countries during extreme events. However, the market
risk spillovers across Vietnam's stock market sector remain unaddressed. In addition, the asymmetric effects of macroeconomic indicators on market risk across sectors have largely been ignored in the literature, particularly in emerging markets such as Vietnam.
This study examines market risk spillovers and investigates the asymmetric effects of macroeconomic indicators on market risk across Vietnamese sectors. First, the Value-at-Risk (VaR) technique and Vector Autoregression (VAR) model were used to estimate market risks and their spillovers across 24 Vietnamese sectors from 2012 to 2022. We examine the asymmetric effects of macroeconomic indicators on market risk using a panel nonlinear autoregressive distribution lag (NARDL) model.

The empirical results confirm that market risks across sectors surge during extreme events, such as the COVID-19 pandemic and ongoing conflict, implying that Vietnam's stock market responds to extreme events significantly. Furthermore, market risk spillovers across Vietnamese sectors are significant, and the interconnectedness among sectors is paramount. This finding confirms that market risks from extreme events spread rapidly and significantly across the Vietnamese sectors. Building Materials, Technology, and Securities sectors are the most significant risk transmitters in Vietnam. Therefore, the government should prioritize stabilizing these sectors to abate the spread of market risk in other sectors. In the Building Materials sector, the government should ensure that domestic demand is met prior to exports. The government should enhance the legal system for science, technology, and innovation in the technology sector by following market mechanisms and international standards. Furthermore, investments in science, technology, and innovation should be gradually increased to meet the development requirements of science and technology. For the Securities sector, the government should strengthen the supervision of stock market operations to prevent acts of manipulation, such as disclosing false information or using multiple trading accounts to artificially create a strong demand for shares.

The Minerals, Development Investment, and Education sectors were the most significant market risk absorbers in Vietnam during the research period. As such, the government should pay more attention to these sectors, as they are the most vulnerable and fragile sectors in the market. For the Minerals sector, the government should focus on developing technical standards made to the specifications of Vietnam's geographical conditions. Attention should also be paid to the modernization of mining operations, mine designs, and additional training for the labor force. In the Development Investment sector, the government should develop a legal framework to strictly control development investment projects, ensuring their practicality, science, legality, and consistency. Additionally, the government should periodically review and update the national curriculum for the Education sector. Salaries and preferential allowances for teachers should be enhanced to improve the quality of education.
Finally, our empirical analysis confirms that market risk responds asymmetrically to changes in interest rates, exchange rates, trade openness, financial development, and economic growth. In the short run, either an increase or decrease in interest rates magnifies market risks in Vietnam. Market risks in Vietnam have also increased in response to slow financial development. By contrast, the depreciation of the VND against the USD, trade openness, and rapid financial development reduced market risks in Vietnam. Rubber and Business are the sectors most affected in the short run. In the long run,
market risks in Vietnam decreased in response to a decline in interest rates and trade openness. An appreciation of the VND against the USD also reduces market risks in Vietnam. By contrast, either a rise or fall in financial development and economic growth heightens market risk in Vietnam. Minerals, Oil \& Gas, and Rubber are the sectors that are most affected in the long run.

To formulate and implement appropriate and effective policies to limit market risk spillovers across sectors, the Vietnamese government must focus on the nature of the significant risk spillovers and the asymmetric effects of macroeconomic indicators on market risks across sectors. A clear delineation between short- and long-term effects can help governments revise their macroeconomic policies to mitigate market risks and limit their spillovers. Macroeconomic indicators have the greatest impact on market risk in the Minerals, Oil $\mathcal{E}$ Gas, and Rubber sectors. These sectors are unsustainable and polluting. Therefore, investors should diversify their investment portfolios towards sustainable investments. Balancing traditional investing with environmental, social, and governance-related (ESG) insights will help investors mitigate market risk and improve long-term returns while having an environmental and social impact. Companies are also incentivized to proactively tackle key issues such as climate change and social justice.
Our study revealed various directions for future research in this area. A study examining market risk spillovers among emerging markets and developing economies (EMDEs) provides a better understanding of the interconnectedness among international stock markets in terms of market risks. Future research may also consider the effects of uncertainty variables such as economic policy uncertainty, geopolitical risks, and climate policy uncertainty on market risk. These variables can be direct measures of different tail events and significant determinants of market risk. Additionally, studies on market risk spillovers among different financial markets in Vietnam, including equity, bonds, foreign exchange, and commodities, should be conducted. Such a study can reveal the relative importance of each financial market in transmitting or absorbing risks, thereby assessing the vulnerability of Vietnam's financial system to extreme events.

| Abbreviations |  |
| :--- | :--- |
| VaR | Value-at-risk |
| VAR | Vector Autoregression |
| NARDL | Nonlinear autoregressive distribution lag |
| GFC | Global Financial Crisis |
| EMDEs | Emerging markets and developing economies |
| HOSE | Ho Chi Minh City Stock Exchange |
| HNX | Hanoi Stock Exchange |
| TSI | Total spillover index |

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## Author contributions

Conceptualization: Duc Hong Vo; Methodology: Duc Hong Vo \& Hung Le-Phuc Nguyen; Formal analysis and investigation: Duc Hong Vo \& Hung Le-Phuc Nguyen; Writing—original draft preparation: Duc Hong Vo \& Hung Le-Phuc Nguyen Writing—review and editing: Duc Hong Vo; Resources: Duc Hong Vo; Supervision: Duc Hong Vo.

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## Availability of data and materials

The datasets used and analyzed in this study are available from the corresponding author upon reasonable request.

## Declarations

## Competing interests

The authors declare that they have no competing interests.

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