Resources Policy 86 (2023) 104161

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

The time-varying impact of geopolitical risk on natural resource prices: The post-COVID era evidence

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ARTICLE INFO

JEL classification:
Q02
Q34

Keywords:
Time-varying effect
Risk compounding effect
COVID-19
Russia and Ukraine conflict
CoVaR

ABSTRACT

The geopolitical risk plays a pivotal role in affecting commodity price variations, especially natural resource commodity prices. Geopolitical risk is sensitive to political environmental changes and geopolitical events, including COVID-19 and the Russia-Ukraine conflict. On this basis, our study attempts to scrutinize the time-varying characteristics of geopolitical risk impact on natural resource commodity prices against recent geopolitical events. By applying the data from natural resource commodity markets, we unravel the fact that U.S. geopolitical risk has a stronger impact on energy market prices, and this impact becomes even stronger after the Russia-Ukraine conflict. Finally, we unfold that the downside risk comovement between metal prices and China geopolitical risk is stronger. Further, the downside risk comovement between energy prices and United States geopolitical risk is more profound. Our paper could deliver implications for policymakers and investors. We notify that the establishment of an early warning system for geopolitical events can be useful to policymakers. Our result further motivates investors to rebalance their portfolios' risk exposure in a time-varying way, especially after geopolitical events.

1. Introduction

The geopolitical dynamics serve as a key ingredient affecting commodity market variation, especially natural resource commodity prices, including oil, copper, gold and so on. For example, the oil price is highly sensitive to geopolitical risk, and geopolitical turmoil acts as a major source to increase the oil market risk premium. This could result from OPEC countries changing their oil supply policies as a response toward the geopolitical turmoil (Liu et al., 2019). As a result, the oil price may become volatile as geopolitical risk increases (Abbass et al., 2022; Gkillas et al., 2022). In addition to energy prices, other natural resource commodities, such as metal prices, are also firmly connected with geopolitical risk levels (Li et al., 2021; Chiang, 2022). As a consequence, we concentrate on the natural resource commodity market price change response to geopolitical risk variation, mainly including energy commodities (gas and crude oil) and metal commodities (copper, gold and silver). In this paper, we attempt to explore the time-varying characteristics of geopolitical risk impact on natural resource commodity prices against recent geopolitical events, including COVID-19 and the Russia-Ukraine conflict. We intend to demonstrate that those commodity prices and commodity market risks would exhibit a time-varying response to the geopolitical risk, where geopolitical events may play crucial parts.

In fact, geopolitical risk is usually associated with geopolitical events like international crises (Caldara and Iacoviello, 2022). COVID-19 is a public health crisis that intends to increase the geopolitical risk (Desalegn et al., 2022). The spread of COVID-19 placed a challenge on governments without sufficient coordination capacity, which could increase political risk as well (Wang et al., 2020). The close relation between geopolitical risk level and COVID-19 suggests that an appropriate political response to the spread of COVID-19 might be exceedingly crucial to stabilize the economic and political situation (Hartwell and Devinney, 2021). More recently, the Russia and Ukraine conflict exacerbated the geographical tension in Europe, which is also a critical event for geopolitical risk variation.

Geopolitical risk is crucial to natural resource commodity markets,

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https://doi.org/10.1016/j.resourpol.2023.104161
Received 31 March 2023; Received in revised form 6 August 2023; Accepted 11 September 2023
Available online 16 September 2023

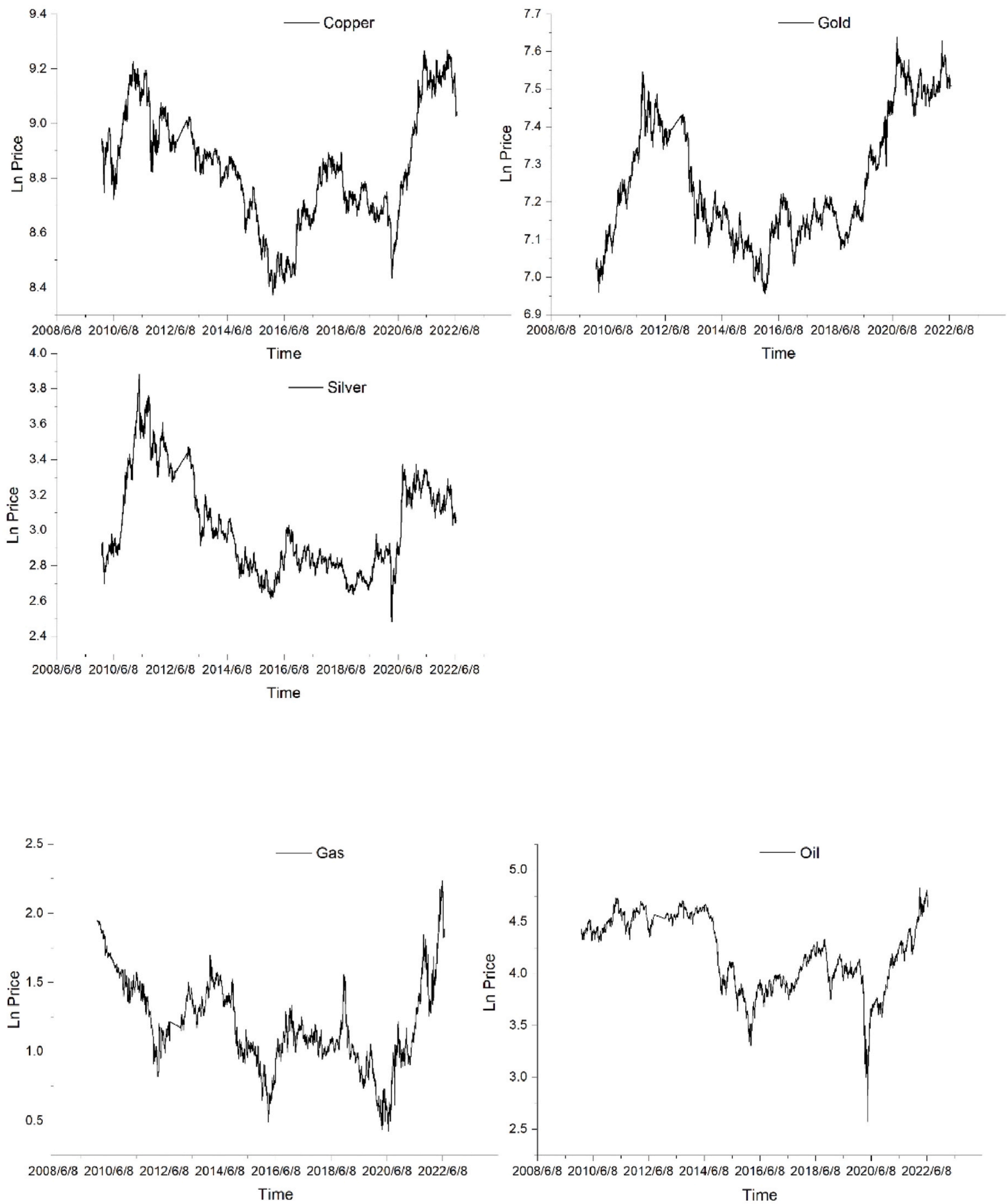

Fig. 1. Plot of five commodity futures prices starting from 1 January 2010 to 1 July 2022.

Table 1
Descriptive statistics of price differences of five natural resource commodity markets.

	Mean	Max	Min	Std. Dev.	Skew	Kurt	Obs
dP_t^{cop}	0.3051	515.50	−717.0	98.8447	−0.391	6.649	3001
dP_t^{gas}	−0.0004	1.0140	−1.407	0.1212	−0.329	21.516	3001
dP_t^{gold}	0.2372	101.10	−115.50	14.9607	−0.655	9.708	3001
dP_t^{oil}	0.0158	12.23	−15.24	1.5707	−0.742	14.435	3001
dP_t^{sil}	0.0039	2.5750	−4.5490	0.4612	−1.295	17.462	3001

Note: This table presents the mean and standard deviation (Std. Dev.), Skewness (Skew), Kurtosis (Kurt) with maximum and minimum values for price differences of five commodity futures markets, namely, copper futures market, the gas futures market, the gold futures market, the oil futures market, and the silver futures market respectively. Our sample runs from 1 January 2010 to 1 July 2022.

Table 2
Unit root test of the price difference series of five natural resource commodity markets.

Series	Prob.	Z(t)
dP_t^{cop}	0.0000	−31.3689
dP_t^{gas}	0.0001	−61.2988
dP_t^{gold}	0.0001	−55.6625
dP_t^{oil}	0.0001	−57.3725
dP_t^{sil}	0.0001	−55.9103

Note: The table presents the individual unit root test results for each futures market, and all five series are stationary series based on the unit root test. Our sample runs from 1 January 2010 to 1 July 2022.

and those two events are also influential on the geopolitical risk level. Therefore, we study the risk compounding effect by combining the COVID-19 and Russia-Ukraine conflict effects on natural resource commodity prices. This is because in the meantime of the Russia and Ukraine conflict during early 2022, the impact of COVID-19 still persisted. Therefore, there is a risk compounding effect by combining the two events, namely, the COVID-19 and Russia-Ukraine conflict, and we denote this period as the "post-COVID" era. As a result, we scrutinize the response of natural resource commodity markets to geopolitical risk against the backdrop of the two events. It is plausible that the market response to geopolitical risk would vary as the economic and political situation has changed. Consequently, it is necessary to examine the time-varying effect of the market response to geopolitical risk, and the time-varying effect has two stages. We first investigate the effect of COVID-19

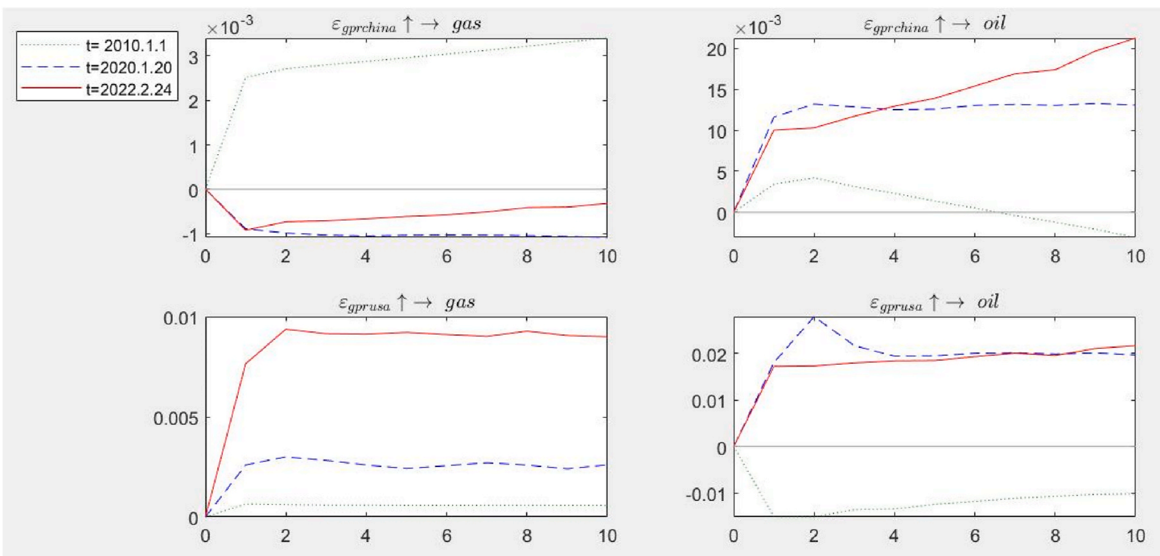

Fig. 2. Time-varying impulse response functions of geopolitical risk to energy futures price differences. The figure presents the response of energy futures price changes to geopolitical risk shocks for 10 periods. The left side presents the response of gas price changes to geopolitical risk in both China and the United States. The right side presents the response of oil price changes to geopolitical risk in both China and the United States. The three lines represent three timing points: green line (sample starting point), blue line (the outbreak of COVID-19) and red line (the Russia and Ukraine conflict). Our sample runs from 1 January 2010 to 1 July 2022.

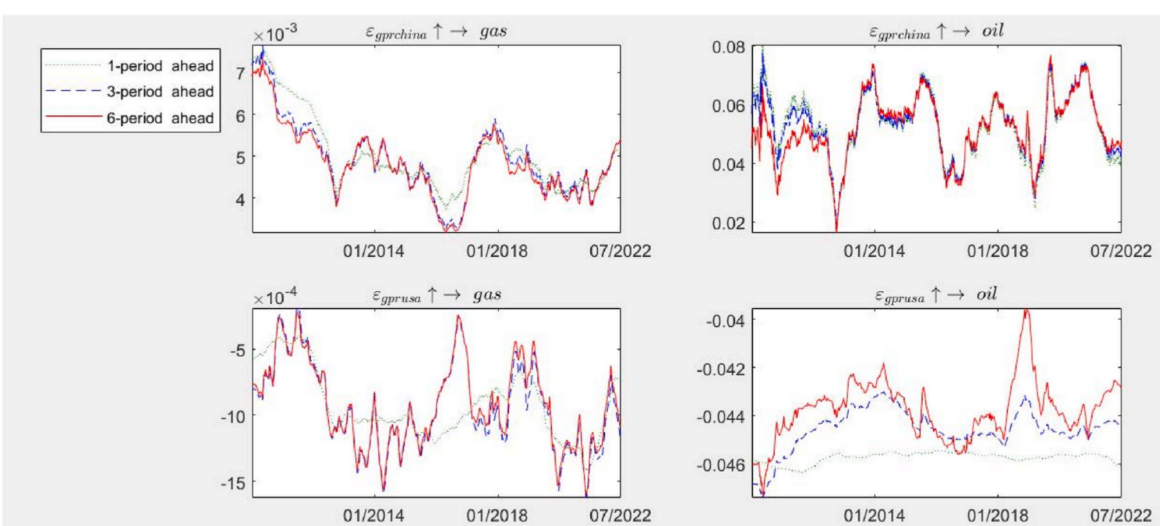

Fig. 3. Time-varying impulse response functions of geopolitical risk to energy futures price differences. The figure presents the response of energy futures price changes to geopolitical risk shocks for three different future periods. The left side presents the response of gas price changes to geopolitical risk in both China and the United States. The right side presents the response of oil price changes to geopolitical risk in both China and the United States. The three lines represent three different time lengths: green line (1-period ahead), blue line (3-period ahead) and red line (6-period ahead). Our sample runs from 1 January 2010 to 1 July 2022.

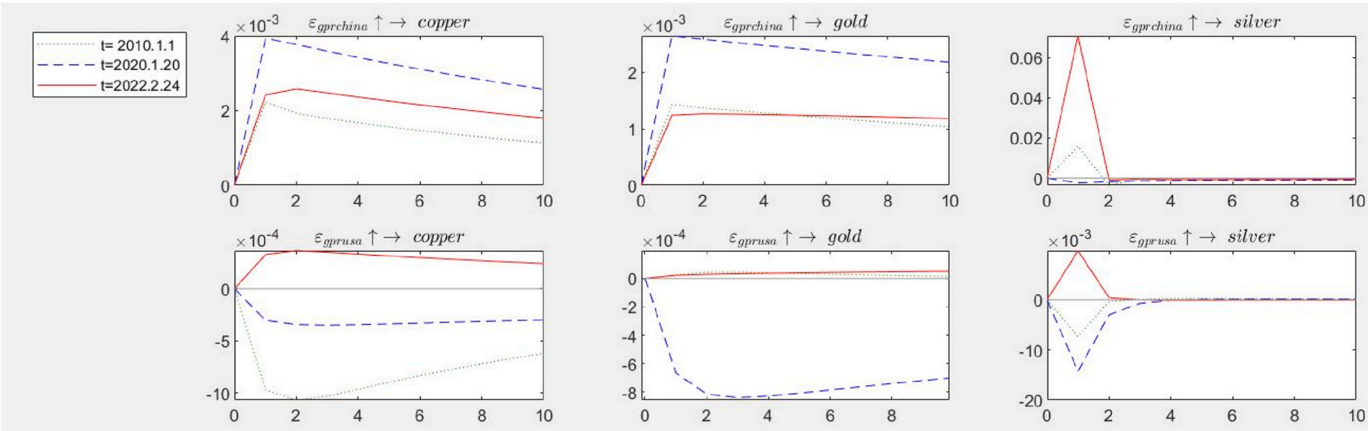

Fig. 4. Time-varying impulse response functions of geopolitical risk to metal futures price differences. The figure presents the response of metal futures price changes to geopolitical risk shocks for 10 periods. The left side presents the response of copper price changes to geopolitical risk in both China and the United States. The middle graphs present the response of gold price changes to geopolitical risk in both China and the United States. The right side presents the response of silver price changes to geopolitical risk in both China and the United States. The three lines represent three timing points: green line (sample starting point), blue line (the outbreak of COVID-19) and red line (the Russia and Ukraine conflict). Our sample runs from 1 January 2010 to 1 July 2022.

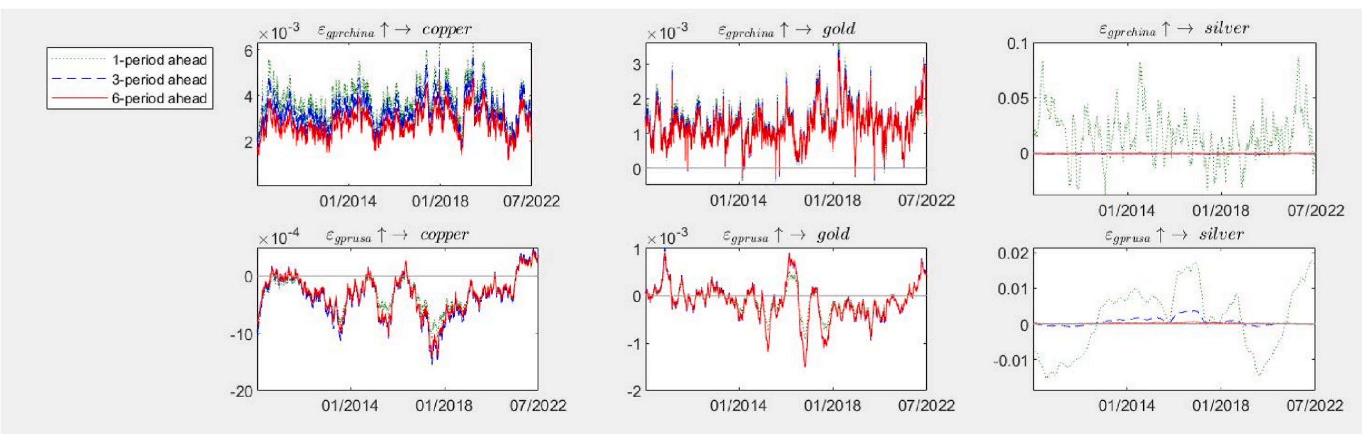

Fig. 5. Time-varying impulse response functions of geopolitical risk to energy futures price differences. The figure presents the response of energy futures price changes to geopolitical risk shocks for three different future periods. The left side presents the response of copper price changes to geopolitical risk in both China and the United States. The middle graphs present the response of gold price changes to geopolitical risk in both China and the United States. The right side presents the response of silver price changes to geopolitical risk in both China and the United States. The three lines represent three different time lengths: green line (1-period ahead), blue line (3-period ahead) and red line (6-period ahead). Our sample runs from 1 January 2010 to 1 July 2022.

Table 3
Descriptive statistics of CoVaR between five natural resource commodity markets with geopolitical risk in both China and the US.

	Mean	Max	Min	Std. Dev.
$CoVaR_t^{gasc}$	−2.469	−0.0007	−52.736	3.258
$CoVaR_t^{gasus}$	−1.802	−6.02E-05	−172.64	6.604
$CoVaR_t^{oilc}$	−3.7123	−0.0002	−148.91	8.146
$CoVaR_t^{oilus}$	−10.464	−0.0003	−154.44	16.474
$CoVaR_t^{copc}$	−42.086	−0.0106	−230.0	25.037
$CoVaR_t^{copus}$	−73.594	−0.0217	−443.7	65.626
$CoVaR_t^{goldc}$	−6.967	−0.0363	−63.58	5.945
$CoVaR_t^{goldus}$	−3.032	−0.00003	−96.325	8.145
$CoVaR_t^{silc}$	−5.047	−0.0019	−82.5	7.001
$CoVaR_t^{silus}$	−15.208	−0.0105	−133.31	13.978

Note: This table presents the mean and standard deviation (SD) with maximum and minimum values for CoVaR between five natural resource commodity markets with geopolitical risk in both China and the US. Our sample runs from 1 January 2010 to 1 July 2022.

spread by choosing the outbreak of COVID-19 as the timing point for our Time-Varying Parameters-Vector Autoregression (TVP-VAR) model. Then, we choose the outbreak of the Russia-Ukraine conflict as the timing point for our TVP-VAR model, which is additional to the COVID-19 spread effect.

The necessities for using the TVP-VAR method are twofold. First, commodity markets do not always retain the same status (Kumar et al., 2021), and especially our sample period covers both COVID-19 and Russia-Ukraine conflict (Ghazani et al., 2023). As a result, the time-varying VAR method can capture commodity market moving characteristics in such a turbulence episode when commodity markets experienced extreme market events (Tiwari et al., 2022). More importantly, the TAP-VAR model can depict the time-varying evolution of commodity markets, which can be extraordinarily helpful to policy-makers in terms of policy analysis under different market scenarios with policy transmission (Koop et al., 2009; Chan et al., 2020).

By applying the TVP-VAR method, we constructed two TVP-VAR models for the natural resources of the energy sector with geopolitical risk and the natural resources of the metal sector with geopolitical risk. We unravel the fact that U.S. has a stronger impact on energy market

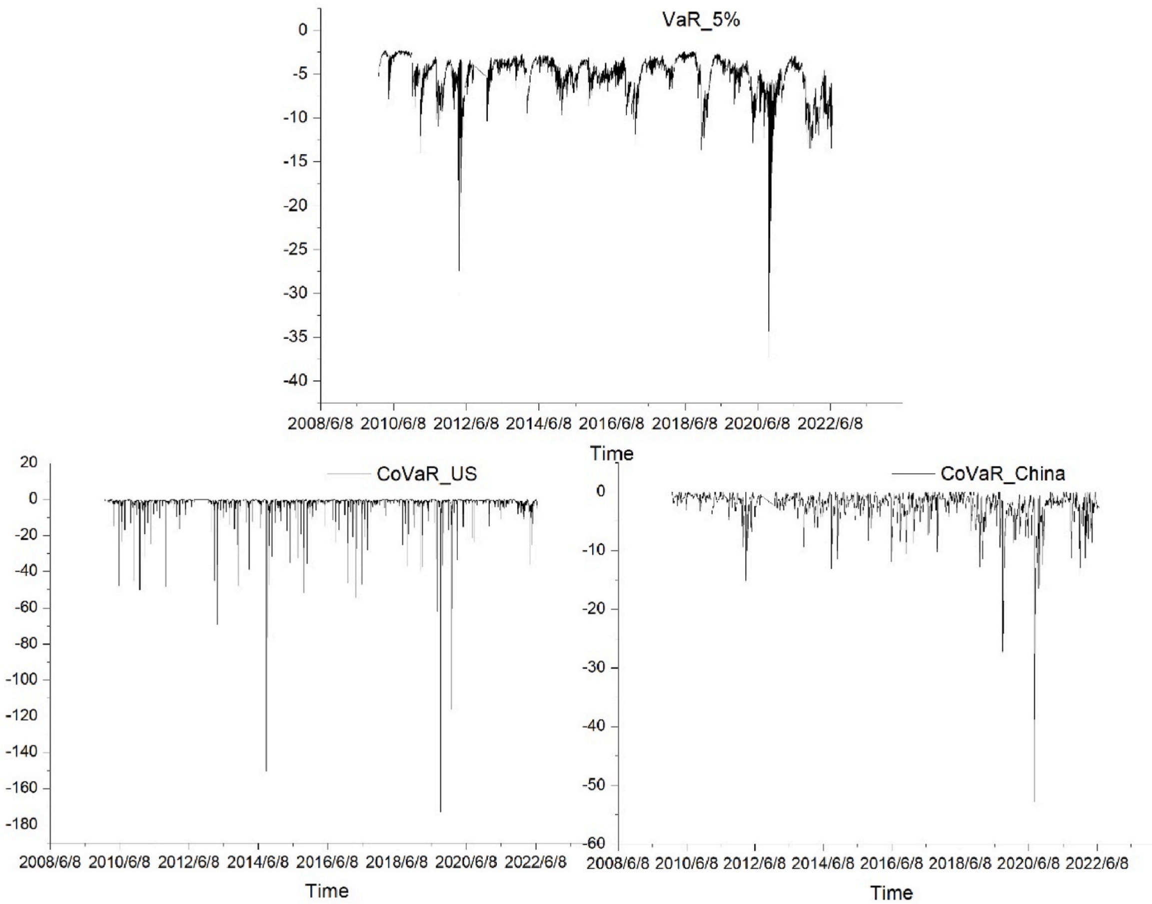

Fig. 6. Time-varying VaR of the gas futures market and CoVaR between geopolitical risk and gas futures returns. The top graph presents the VaR of the gas futures market at the 95% level of confidence. The bottom left-hand graph presents the CoVaR between the geopolitical risk of the United States and gas futures returns. The bottom right-hand graph presents the CoVaR between the geopolitical risk of China and gas futures returns. Our sample runs from 1 January 2010 to 1 July 2022.

prices since U.S. takes the oil price as a crucial factor for its national energy security (Krane and Medlock, 2018). We find that this impact becomes even stronger after the Russia-Ukraine conflict, resulting from the U.S. was more involved in the energy market as well as geopolitical issues in Europe to resist Russia. On the other hand, China exhibits a heavier impact on metal markets because China is one of the largest importers of copper and retains tremendous gold reserves.

Higher geopolitical risk usually produces larger downside risks (Caldara and Iacoviello, 2022). As a result, we unveil the time-varying effect of geopolitical risk shocks on natural resource commodity markets, which suggests the general response of those commodity markets to geopolitical risk shocks. We further analyze the downside risk comovement between commodity market prices and geopolitical risk shocks by adopting the Conditional Value-at-Risk (CoVaR) measure.

Similar to the TVP-VAR results, based on the CoVaR measure, we unfold the fact that the downside risk comovement between metal prices and China geopolitical risk is stronger. On the other hand, the downside risk comovement between energy prices and United States geopolitical risk is more obvious. It is arguable that China's economic performance and political environment would be highly relevant to its total copper consumption, which yields a notable effect on metal market prices.

Therefore, our paper contributes to the literature in two ways. From an empirical perspective, we reveal the time-varying effect of geopolitical risk on natural resource prices against the most recent political issues, including the COVID-19 and Russia-Ukraine conflict. Moreover, we uncover the downside risk comovement between natural resource prices and geopolitical risk level under such a new international political environment. From a practical perspective, our paper contributes knowledge to both policymakers and investors. For policymakers, we unveil that a large change in political circumstances can influence the geopolitical risk level and further propagate into natural resource commodity markets. Therefore, the establishment of an early warning system for geopolitical events may be sensible. For investors, our paper enhances their awareness of different commodity market responses to geopolitical events in different time periods, and we thereby assist them in understanding the time-varying commodity market responses to geopolitical events. This result can be helpful in motivating them to rebalance their portfolios' risk exposure in a time-varying way, especially after geopolitical events.

The remainder of our paper is organized as follows. Section 2 delivers a relevant literature review. In section 3, we introduce sample data and variable measures with relevant methodology. In section 4, we describe the empirical results for both the TVP-VAR model and the CoVaR method. Section 5 delivers a further discussion with the conclusions of our paper.

2. Literature review

2.1. The impact of geopolitical risk on natural resource commodity prices

A fruitful stream of literature has started to study the relationship between natural resource commodity prices and geopolitical risk (Demirer et al., 2018; Q. Ding et al., 2021, 2023; Yang et al., 2022; Chu et al., 2023; Mohammed et al., 2023). Plakandaras et al. (2019) studied the dynamic relationship between oil prices and geopolitical risk. The results show that the types of geopolitical risk exert different degrees of

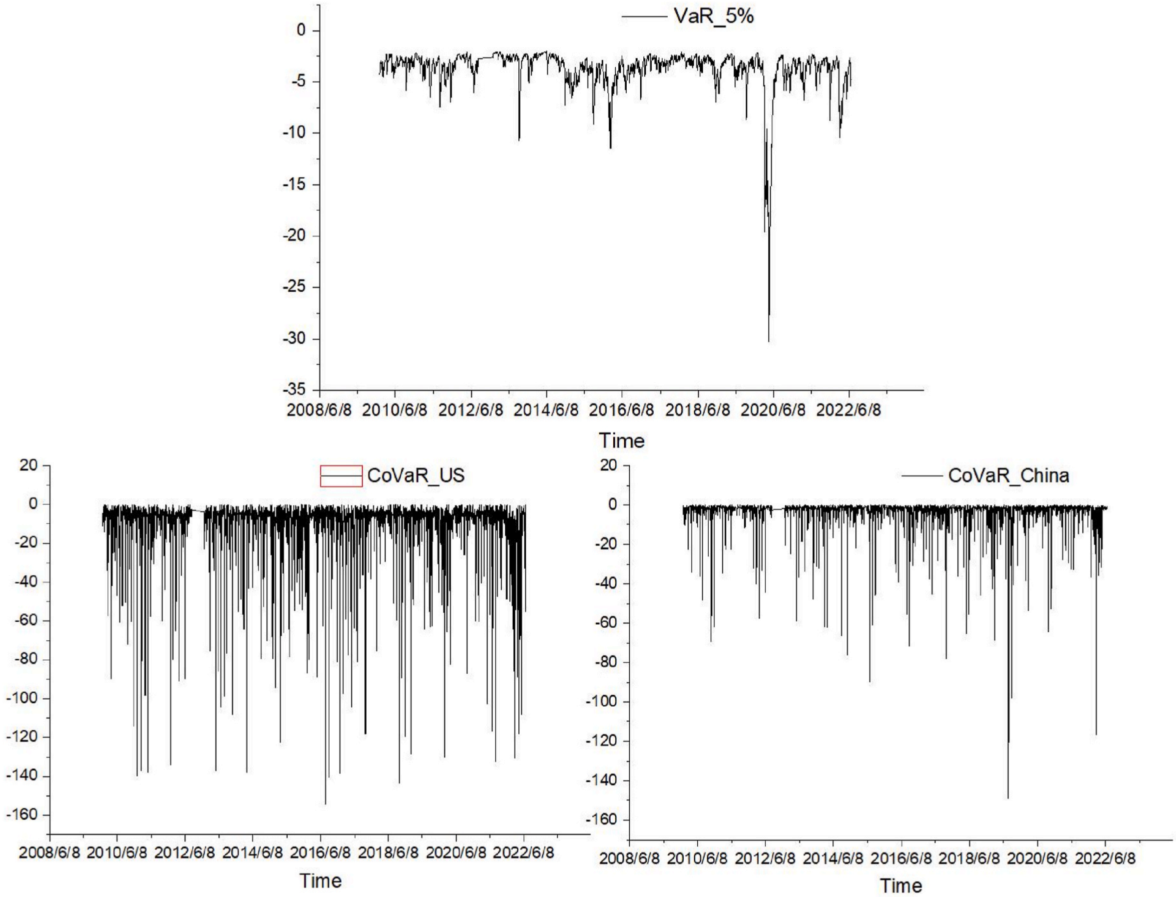

Fig. 7. Time-varying VaR of the oil futures market and CoVaR between geopolitical risk and oil futures returns. The top graph presents the VaR of the oil futures market at the 95% level of confidence. The bottom left-hand graph presents the CoVaR between the geopolitical risk of the United States and oil futures returns. The bottom right-hand graph presents the CoVaR between the geopolitical risk of China and oil futures returns. Our sample runs from 1 January 2010 to 1 July 2022.

impact on the oil market. War-related geopolitical risk, more specifically, is the most concise in forecasting short-term oil returns. More recently, utilizing global data, Cunado et al. (2020) found the dynamic effects of geopolitical risk on oil prices. The results indicate that oil prices were significantly negatively impacted by geopolitical risk, mainly due to the drop in oil demand led by global economic activities. More recently, relevant studies begin to focus on the nexus between and energy sector of commodities and geopolitical risk (Doğan et al., 2020, 2021; Lau et al., 2023). Nevertheless, few scholars have explored the time-varying effects of geopolitical risk on different natural resource commodity prices, especially under chaotic episodes of the international environment.

2.2. The COVID-19 effect on geopolitical risk and financial markets

COVID-19 continues to spread overwhelmingly in many countries, which causes unpredictable effects on geopolitical risk levels. In a recent study, Baker et al. (2020) reveal that during the last 22 trading days, 18 stock market jumps were recorded, and 16 to 18 of them were treated as a response to "bad news" attributed to either the new infectious disease or US policy responses to the COVID-19 outbreak. Similarly, with the coherence wavelet method and wavelet-based Granger causality tests applied to recent US daily data, Sharif et al. (2020) uncover that the effect of COVID-19 on geopolitical risk is substantially higher than that on US economic uncertainty. The study reveals that COVID-19 is perceived differently over the short and long term and may be initially regarded as an economic crisis. The COVID-19 pandemic is a source of systematic risk; consequently, there is a need for further research on the effects of coronavirus spread, aiming at natural resource commodity prices through the conduction path of geopolitical risks. More recently, a plethora of studies concentrated of the COVID-19 effect on the financial markets (Ali et al., 2023; Khalfaoui et al., 2023) and financial crisis (Ghazani et al., 2023; Hanif et al., 2023; Popkova et al., 2023).

2.3. The effect of the Russia-Ukraine conflict on geopolitical risk

Apart from COVID-19, the Russia-Ukraine conflict severely jeopardized the global economy, including commodity prices. Będowska-Sójka et al. (2022) explore the correlation on the investment tool by the wavelet coherence method to examine whether geopolitical risks that serve as a proxy for the Russia-Ukrainian war can impact as a hedge against different commodities prices, including oil, gold, and silver. According to the wavelet coherence results from Shahzad et al. (2023), there existed strong comovement in the period of the Russia-Ukrainian conflict between geopolitical risk and other commodity returns at different scales. Moreover, the findings claim that geopolitical risks and financial instability are essential in influencing metals, precious, and energy markets. However, during the last several months of 2022, rather limited studies have been dedicated to evaluating the effect of geopolitical risk indices of the Russia-Ukrainian conflict on natural resource commodity prices, while Russia occupies a significant proportion of exports in global energy and precious metals.

In summary, early studies mainly focus on the relation between geopolitical risks and the oil market. Those studies have illuminated that oil demand can be heavily impacted by geopolitical risks such as war-related geopolitical risks. Studies that investigate the impact of

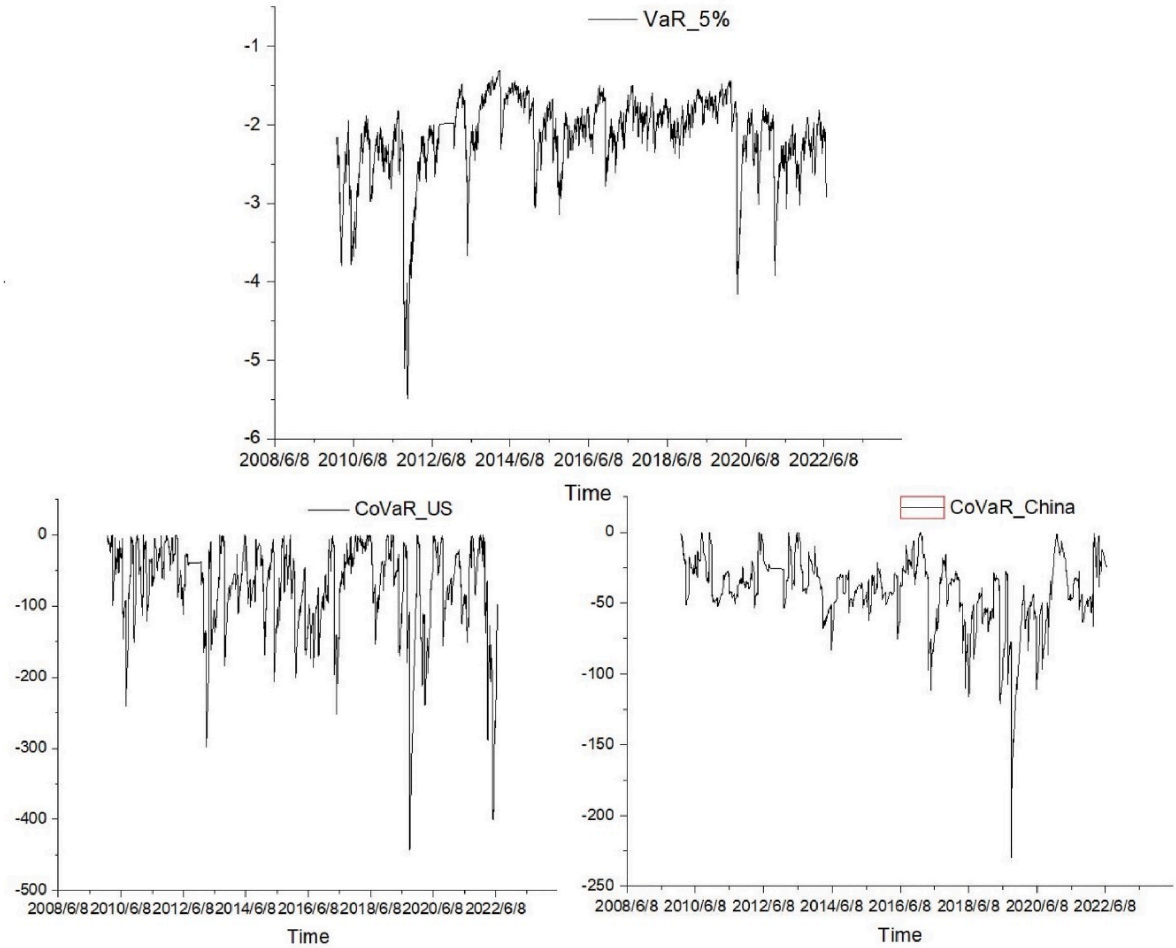

Fig. 8. Time-varying VaR of the copper futures market and CoVaR between geopolitical risk and copper futures returns. The top graph presents the VaR of the copper futures market at the 95% level of confidence. The bottom left-hand graph presents the CoVaR between the geopolitical risk of the United States and copper futures returns. The bottom right-hand graph presents the CoVaR between the geopolitical risk of China and copper futures returns. Our sample runs from 1 January 2010 to 1 July 2022.

geopolitical risks on other types of commodity markets, such as the metal commodity market and agricultural market, are relatively scarce (Gong and Xu, 2022). Moreover, the burgeoning literature has concentrated on the impact of recent geopolitical events such as the Russia-Ukraine conflict on geopolitical risk. Nevertheless, the impact of those geopolitical events on commodity markets through geopolitical risk has not been sufficiently explored from a time-varying perspective. As a result, our paper intends to fill the research gap by scrutinizing the impact of recent geopolitical events such as the Russia-Ukraine conflict on commodity markets through geopolitical risk based on a time-varying methodology. Understanding the dynamic correlations between geopolitical risk and commodity prices can help fund managers to manage portfolios. By monitoring the impact of geopolitical events on commodity prices, managers can be able to identify and predict the occurrence of risk events and adopt appropriate risk management strategies, such as hedging or diversifying portfolios.

3. Data and methodology

3.1. Data and variable estimations

In this paper, we focus on natural resource commodity market prices, mainly including energy commodities and metal commodities. We have collected the sample data for five commodity futures markets of the United States, namely, the copper futures market, the gas futures market, the gold futures market, the oil futures market, and the silver futures market. All sample data are collected on a daily basis from the WIND database. The sample covers the period from 1 January 2010 to 1 July 2022.

The previous literature review section presents existing research focusing on the impact of geopolitical risks on natural resource commodity prices and identifies two main areas of research in the current study. First, some scholars have studied the impact of geopolitical risks on the oil market and found that war-related geopolitical risks have a strong ability to predict short-term oil returns. Second, there is less research on other types of commodity markets, such as metal commodities and agricultural markets. The theoretical foundations for our study were underpinned by the time-varying connection between geopolitical risk and commodity prices (see Ivanovski and Hailemariam, 2022; Zhao, 2023).

We thereby used temporal parameter-vector autoregressive (TVP-VAR) models and conditional value-at-risk (CoVaR) measurements to study the temporal impact of geopolitical risk shocks on natural resource commodity markets. We collected sample data from five commodity futures markets, including the copper futures market, natural gas futures market, gold futures market, oil futures market, and silver futures market in the United States, covering the time period from January 1, 2010 to July 1, 2022. This sample period is after the financial crisis in 2008, but covers both COIVD-19 and Russia-Ukraine conflict.

We further use the geopolitical risk index to measure geopolitical

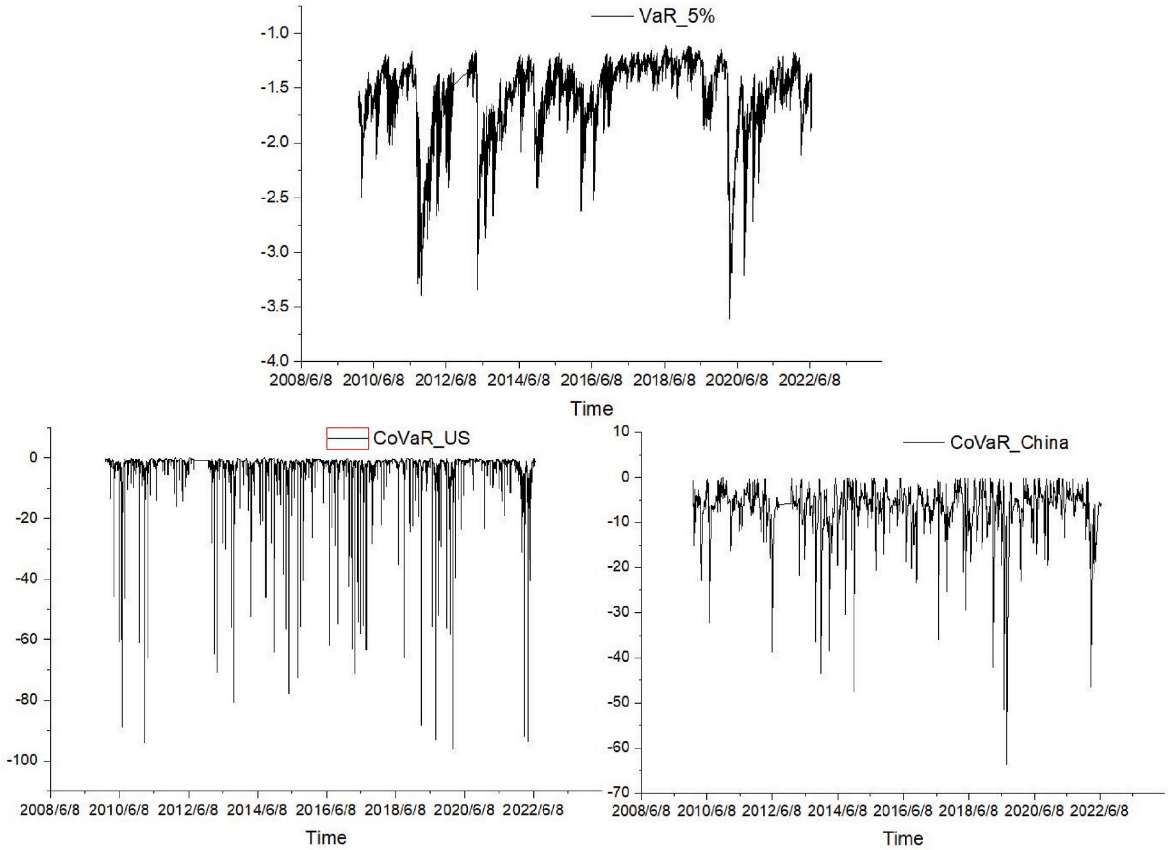

Fig. 9. Time-varying VaR of the gold futures market and CoVaR between geopolitical risk and gold futures returns. The top graph presents the VaR of the gold futures market at the 95% level of confidence. The bottom left-hand graph presents the CoVaR between the geopolitical risk of the United States and gold futures returns. The bottom right-hand graph presents the CoVaR between the geopolitical risk of China and gold futures returns. Our sample runs from 1 January 2010 to 1 July 2022.

risk. The Geopolitical Risk Index was developed by Caldara and Iacoviello at the Federal Reserve Board. The Geopolitical Risk Index can be downloaded from their website (see Caldara and Iacoviello, 2022). The GPR index measures the automated text-search results of the digital archives of 10 newspapers, reflecting eight categories of threats, which encompass war threats and peace threats and so on. We use the percentage change in the geopolitical risk index to measure the time-varying geopolitical risk and the GPR is on a monthly basis.

In our variable description, the superscript 'cop' represents copper futures, 'gas' represents gas futures, 'gold' represents gold futures, 'oil' represents oil futures and 'sil' represents silver futures. We further use 'gprchina' to present the percentage change in the geopolitical risk index for China, and we use 'gprusa' to present the percentage change in the geopolitical risk index for the United States. For the empirical analysis, we use the futures prices (P_t^i), and we take the price difference to generate a stationary time series, denoted as dP_t^i, which is defined as $dP_t^i = P_t^i - P_{t-1}^i$. We further use the scaled price change, which represents the return and can be defined as $r_t^i = dP_t^i / P_{t-1}^i$. Fig. 1 depicts the movement of five commodity markets, and it is observable that the volatility of commodity markets has considerably increased after 2020.

3.2. TVP-VAR model

Since we intend to investigate the time-varying effect of geopolitical risk shocks on natural resource commodity prices, we adopt the Time-Varying Parameters-Vector Autoregression (TVP-VAR) model to construct the time-varying framework.

Theoretically, the adoption of the TVP-VAR model allows us to capture both gradual and unexpected fluctuations for all commodity prices, providing a sophisticated portrait regarding the impact of geopolitical risk on commodity price movements. The highly volatile nature of commodity prices creates the challenge of analyzing different geopolitical events on commodity price movements using linear methodologies over a long time horizon. Consequently, the TVP-VAR model, which is nonlinear and time-varying, takes into account such volatility and nonlinearity, building up a better understanding of the geopolitical risk impact on commodity price movements. Additionally, the TVP-VAR model retains an outstanding advantage over other nonlinear methods, which estimate the evolution of time-varying parameters and error terms, and such an advantage is crucial for capturing the dynamics of geopolitical risk effects over time (Balli et al., 2021; Zhao, 2023).

Therefore, the TVP-VAR model is helpful to reflect the impulse response of the commodity market at the chosen timing point, and it is also useful to reveal the time-varying relations between variables during our sample period. Therefore, the TVP-VAR model could provide new insights into the time-varying geopolitical risk impacts on commodity markets against the backdrop of recent geopolitical events such as COVID-19 and the Russia and Ukraine conflict.

The basic Vector Autoregression (VAR) model, as well as the extended TVP-VAR model, has been widely used in recent financial studies (Drachal, 2021; Adekoya et al., 2022; Chen et al., 2022). The basic VAR (p) model takes the following form (for $\mathbf{X_t}$ is the vector of endogenous variables concerned):

$$X_t = \theta_0 + \sum_{j=1}^{p} \boldsymbol{\theta}_j \mathbf{X}_{\mathbf{t-j}} + \boldsymbol{\varepsilon}_t, \tag{1}$$

where $\boldsymbol{\theta_0}$ is a K × 1 vector of constants, $\boldsymbol{\theta_j}$ for j = 1 …., p, is a K × K matrix of model coefficients, and $\boldsymbol{\varepsilon_t}$ is a K × 1 vector of IID (Independent and Identically Distributed) Gaussian residuals terms for the VAR model.

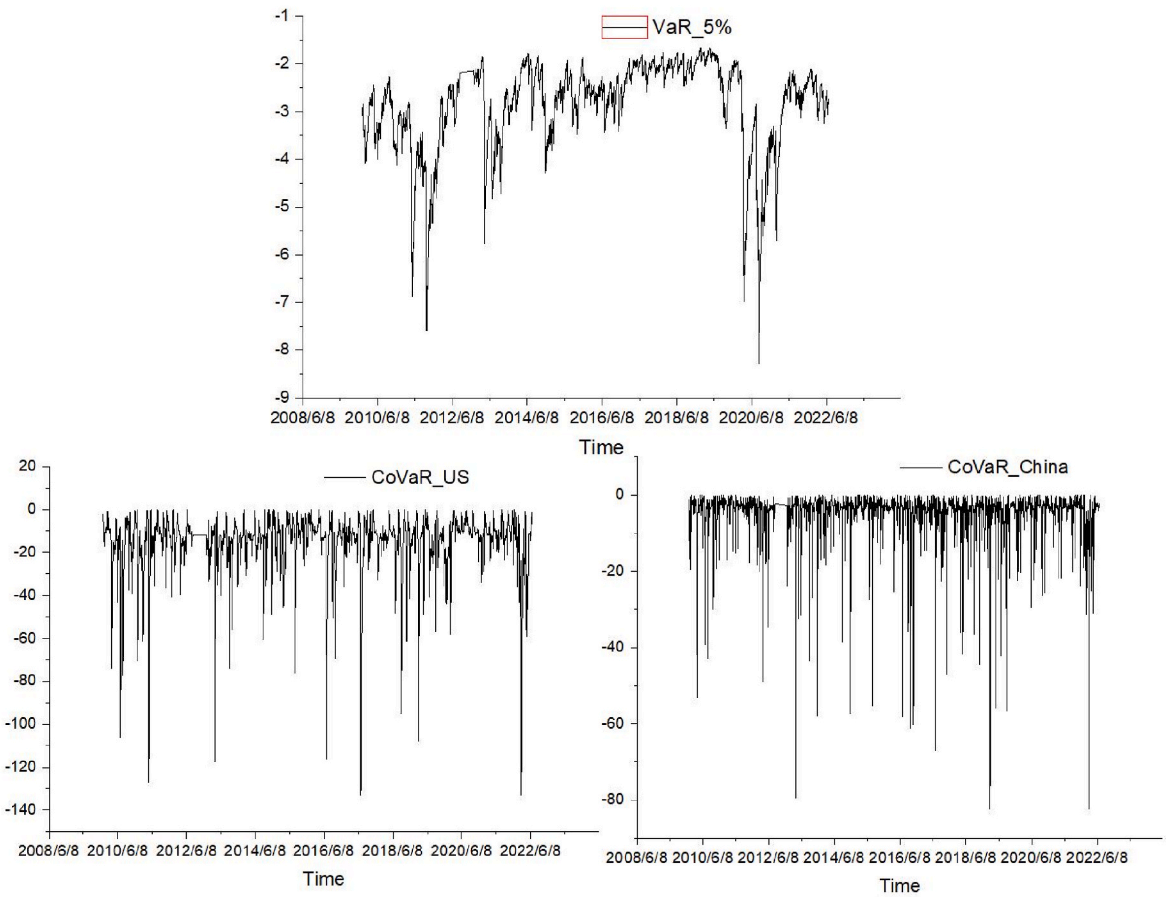

Fig. 10. Time-varying VaR of the silver futures market and CoVaR between geopolitical risk and silver futures returns. The top graph presents the VaR of the silver futures market at the 95% level of confidence. The bottom left-hand graph presents the CoVaR between the geopolitical risk of the United States and silver futures returns. The bottom right-hand graph presents the CoVaR between the geopolitical risk of China and silver futures returns. Our sample runs from 1 January 2010 to 1 July 2022.

Table 4
Extreme value summary of VaR and CoVaR between five natural resource commodity markets with geopolitical risk in both China and the US.

	VaR_t	CoVaR_t^c	CoVaR_t^{us}
Gas	−37.315	−52.735	−172.641
Oil	−30.351	−148.91	−154.44
Copper	−5.498	−230.0	−443.712
Gold	−3.608	−63.58	−96.325
Silver	−8.286	−82.50	−133.31

Note: This table presents the minimum values for VaR of five commodity markets as well as CoVaR between five natural resource commodity markets with geopolitical risk in both China and the US. Our sample runs from 1 January 2010 to 1 July 2022.

In order to estimate the time-varying parameters of the VAR model, we employ the Markov Chain Monte Carlo (MCMC) method. On this basis, the time-varying parameters can be obtained through a smooth estimation procedure (Chib and Greenberg, 1995; Bitto and Frühwirth-Schnatter, 2019). The Bayesian estimator is also employed during the procedure by referring to the posterior distribution (Koop et al., 2009).

3.3. CoVaR measure

We use Conditional Value-at-Risk (CoVaR) as the measure of extreme movement of natural resource commodity prices under the condition of extreme movement of geopolitical risk (Tobias and Brunnermeier, 2016). Theoretically, CoVaR is excessively useful in capturing tail dependence and extreme risk spillover (Ji et al., 2018). In our paper, the adoption of the CoVaR measure can be helpful in identifying the effect of extreme movement of geopolitical risk since recent geopolitical events are exceedingly influential. As a result, the CoVaR measure can aid in understanding the adverse effects of geopolitical events on extreme commodity price movements.

Before we construct our CoVaR, we first define the Value-at-Risk (VaR) measure. We define the extreme move of natural resource commodity market i as the q-quantile of the return distribution with the return of natural resource commodity market i defined as r_t^i with confidence level q (see equation (1)), and in this study, we take $q = 0.05$:

$$\Pr\left(r_t^i \leqslant \text{VaR}_{q,t}^i\right) = q, \tag{1}$$

where $VaR_{q,t}^i$ is the Value-at-Risk value of natural resource commodity market i at time t with confidence level q.

Then, we define CoVaR as the VaR of a natural resource commodity market under the condition that there is an extreme move of geopolitical risk index j (see equation (2) and j = China or United States):

$$\Pr\left(r_t^i \leqslant \text{CoVaR}_{q,t}^{ij} \middle| r_t^j \leqslant \text{VaR}_{q,t}^j\right) = q, \tag{2}$$

where Co $VaR_{q,t}^{ij}$ is the conditional value-at-risk value of natural resource commodity market i at time t with confidence level q under the condition of extreme movement of geopolitical risk index j. $VaR_{q,t}^j$ is the Value-at-Risk value of geopolitical risk index j at time t with confidence level q.

Following Girardi and Ergün (2013), we employ the Dynamic Conditional Correlation-Generalized AutoRegressive Conditional Heteroskedasticity (DCC-GARCH) model to estimate the CoVaR between natural resource commodity market i and geopolitical risk index j. We first estimate the VaR of natural resource commodity market i based on a univariate GARCH model with conditional mean. Then, we estimate a bivariate DCC-GARCH model specified by Engle (2002) for the return of natural resource commodity market i and percentage change of geopolitical risk index j. Finally, we estimate CoVaR between natural resource commodity market i and geopolitical risk index j based on the bivariate probability density functions derived from the bivariate DCC-GARCH model.

4. Empirical results

This section scrutinizes the time-varying characteristics of natural resource commodity price responses to geopolitical risk variation. Section 4.1 delivers the empirical results for the general time-varying responses of commodity price changes toward geopolitical risk variation. Section 4.2 presents the empirical results for the time-varying comovement of the downside risks between commodity price changes and geopolitical risk variation.

Table 1 presents the statistical properties of our natural resource commodity dataset, and the descriptive statistics presented are the mean, maximum, minimum, and standard deviation of the time series of commodity market price changes over the sample period. From those observations, it can be seen that the means for five commodities are all positive and close to zero except for the gas commodity, which is negative. The standard deviation of the copper price difference, which is 98.84, is the highest among the five commodities, followed by the gas price difference, with 14.96. The last three commodities' standard deviations are relatively lower compared with the other two differences.

In Table 2, we present the unit root test for natural resource commodity price changes. We can draw a safe conclusion that according to the ADF statistics, all five series reject the hypothesis of a unit root at the 1% significance level.

4.1. Time-varying effect of geopolitical risk impact on commodity price changes

Based on equation (1), we have established two separate VAR systems, namely, the energy price changes with two geopolitical risk indices and the metal price changes with two geopolitical risk indices. We employ the MCMC method to capture the time-varying characteristics of the VAR parameters, which produces the TVP-VAR models for both the energy and metal sectors. We adopt impulse response functions based on our TVP-VAR models to illuminate the time-varying characteristics of commodity price changes toward geopolitical risk variation.

Fig. 2 presents the response of energy futures price changes to geopolitical risk shocks for 10 periods at different timing points. The first timing point is at the beginning of our sample (i.e., 2010.1.1), which serves as the benchmark timing point for the other two timing points. The second timing point is the outbreak of COVID-19 (i.e., 2020.1.20), and the third timing point is the outbreak of the Russia-Ukraine conflict (i.e., 2022.2.24). For the two top graphs, we show the gas and oil price changes toward geopolitical risk shock from China. Before the outbreak of the COVID-19 and Russia-Ukraine conflict, geopolitical risk shocks from China had a positive impact on gas price changes, indicating that the variation in geopolitical risk in China could increase the price changes in the gas market. It is also true for the crude oil market.

On the other hand, after the outbreak of the COVID-19 and Russia-Ukraine conflict, geopolitical risk shocks from China had a negative impact on gas price changes, while the shock was still positive for the crude oil market, and the impact magnitude became more substantial, especially for the Russia-Ukraine conflict timing point. The impact increased even after 8 periods.

In contrast, for the two bottom graphs, we demonstrate the gas and oil price changes toward geopolitical risk shock from the United States. Before the outbreak of COVID-19 and the Russia-Ukraine conflict, geopolitical risk shocks from the United States had a positive impact on gas price changes, indicating that the variation in geopolitical risk in the United States could increase the price changes in the gas market. After the outbreak of the COVID-19 and Russia-Ukraine conflict, the geopolitical risk shock impact of the United States became even larger on the gas market.

On the other hand, before the outbreak of the COVID-19 and Russia-Ukraine conflict, geopolitical risk shocks from the United States had a negative impact on oil price changes, while the shock became positive afterwards.

Fig. 3 presents the response of energy futures price changes to geopolitical risk shocks for the whole sample period regarding the 1-period ahead effect, 3-period ahead effect and 6-period ahead effect. For the gas market, the response reacts oppositely for geopolitical risk shocks from China and the United States. There was an ascending trend in the gas market response to geopolitical risk shocks from the United States during the periods 2011–2012 and 2015–2016. Conversely, the gas market response to geopolitical risk shocks from China moved down during the same period. This is also true for the oil market response for the periods of 2012-2013 and 2019–2020. The oil market response to geopolitical risk shocks from the United States moved up while the response to geopolitical risk shocks from China decreased. More importantly, the impact from U.S. Geopolitical risk on the two energy markets is mostly negative, while the impact from China is mostly positive.

Fig. 4 presents the response of metal futures price changes to geopolitical risk shocks for 10 periods at different timing points. The three timing points are the same as the energy sector. For the three top graphs, we show the copper, gold and silver price changes toward geopolitical risk shock from China. After the outbreak of the COVID-19 and Russia-Ukraine conflict, geopolitical risk shocks from China had a more significant impact on the three metal price changes, indicating that the variation in geopolitical risk in China could increase the price changes in the metal commodity markets. The shock impact is persistent for the copper and gold markets over 10 periods, while the shock impact evaporates after 2 periods for the silver market.

In contrast, for the three bottom graphs, we demonstrate the metal changes toward geopolitical risk shock from the United States. Before the outbreak of the COVID-19 and Russia-Ukraine conflict, geopolitical risk shocks from the United States had a trivial impact on gold and silver price changes, while the impact on the copper market was considerably negative. After the outbreak of COVID-19, the geopolitical risk shock impact of the United States became more negative on the gold and silver markets, indicating that the variation in U.S. Geopolitical risk could lessen the price changes of the two metal markets. Nevertheless, after the Russia-Ukraine conflict, the impact from U.S. geopolitical risk shocks become positive, especially for the copper market. Similar to the China geopolitical risk shocks, the impact on the silver market diminishes after 2 periods.

Fig. 5 presents the response of metal futures price changes to geopolitical risk shocks for the whole sample period regarding the 1-period ahead effect, 3-period ahead effect and 6-period ahead effect. The impact of Chinese geopolitical risk shocks is more notable than that of U.S. geopolitical risk for both copper and gold markets. The impact from U.S. geopolitical risk on the two metal markets varies approximately 0 and is mostly negative. For the silver market, the impact of geopolitical risk is only noticeable for the 1-period ahead effect, and the impact gradually evaporates after 3 periods.

4.2. Time-varying downside risk comovement between geopolitical risk and commodity prices

This section exhibits the downside risk of five natural resource commodity markets with the VaR measure, and it also exhibits the downside risk connection with CoVaR between natural resource commodity markets and two geopolitical risk indices from a time-varying perspective. The statistical summary of CoVaR between five natural resource commodity markets with geopolitical risk in both China and the US is presented in Table 3. It can be seen that the copper market has the largest CoVaR (loss) with geopolitical risk, whereas the gas market is relatively stable with the response to geopolitical risk in terms of CoVaR (loss).

Fig. 6 reveals the VaR of the gas market and the CoVaR between geopolitical risk and gas futures returns. The top graph presents the VaR of the gas futures market at the 95% level of confidence, and the largest possible downside risk occurred after the outbreak of COVID-19. The bottom left-hand graph presents the CoVaR between the geopolitical risk of the United States and gas futures returns. The bottom right-hand graph presents the CoVaR between the geopolitical risk of China and gas futures returns. It is noticeable that the comovement of downside risk between the gas market and United States geopolitical risk level reached the minimum level at the beginning of 2020, and it occurred in July 2020 for the impact of China geopolitical downside risk. The largest possible downside risk also occurred after the outbreak of COVID-19 for the oil market (see Fig. 7), and the large downside comovement between the oil market and United States geopolitical risk level was more intensive than for the impact of China geopolitical downside risk.

Fig. 8, Figs. 9 and 10 unveil the VaR of the copper, gold and silver markets at the 95% level of confidence, respectively. The bottom left-hand graph presents the CoVaR between the geopolitical risk of the United States and copper futures returns. The bottom right-hand graph presents the CoVaR between the geopolitical risk of China and copper futures returns (see Fig. 8). Similar to the gas market, the minimum level regarding the comovement of downside risk between the copper market and United States was realized at the beginning of 2020, and it occurred in July 2020 for the impact of China geopolitical downside risk. The VaR movement of precious metal markets (gold and silver) exhibits a similar pattern during the sample period. The large downside comovement between precious metal markets and China geopolitical risk level was more intensive than for the impact from United States geopolitical downside risk (see Figs. 9 and 10).

In Table 4, we summarize the extreme values of VaR and CoVaR between five natural resource commodity markets with geopolitical risk in both China and the US. The CoVaRs between metal markets with geopolitical risk in both China and the US are largely distinguished from the VaR of the metal markets themselves. On the other hand, the energy markets' CoVaRs are much closer to their own markets' VaR. It is thereby arguable that the impact of geopolitical risk might be larger on metal markets than on energy markets.

4.3. Results and discussions

In summary, for the energy commodity sector, the geopolitical influence of U.S. becomes more substantial as U.S. takes the oil price as a key ingredient for national energy security (Krane and Medlock, 2018). After the Russia-Ukraine conflict, U.S. turned to be more involved in the energy market as well as geopolitical issues in Europe to resist Russia. Therefore, energy markets have become more sensitive to geopolitical risk changes in the United States (see Figs. 2, Figs. 6 and 7). In contrast, U.S. Geopolitical risk is less influential in metal markets such as the gold futures market. In contrast, the gold price can be used to forecast the U.S. political conditions (Qin et al., 2020). On the other hand, China geopolitical risk has a stronger impact on metal futures prices. China has become one of the world's largest gold purchasers and has a massive amount of gold reserves (Prasad, 2019). More importantly, China is also one of the world's largest copper importers (Wen et al., 2019). As a result, China geopolitical risk has become more influential in metal markets. Becerra et al. (2022) discover that China's economic information has been extremely useful in predicting copper prices, and they argue that China's economic performance and political environment would be highly relevant to its total copper consumption. As a result, metal prices such as copper prices and gold prices are more sensitive to changes in the China geopolitical risk level (see Figs. 4, Figs. 8 and 9).

Therefore, the responses of commodity markets to geopolitical risk tend to be time-varying. From TVP-VAR analysis, the commodity markets, especially energy markets, exhibit different responses to geopolitical risk for different time periods (see Figs. 3 and 5). The long-run (6-month) effect of geopolitical risk on energy markets is more obvious than the short-term effect. It is also notable that two geopolitical events play significant roles in the geopolitical risk effect, increasing the response of commodity markets in general (see Figs. 2 and 4). As a result, our results enhance investors' awareness of different market responses to geopolitical events in different time periods. The impact of geopolitical risk by geopolitical events on commodity markets could be helpful to formulate commodity portfolios for investors in the long run.

From Figs. 6–10, the commodity markets' risk measures, VaR and CoVaR, also vary with time, especially after geopolitical events. Geopolitical events could enlarge the risk exposures of commodity markets, as exhibited in those five figures. Consequently, investors should also include geopolitical risk in their risk prediction models as they construct portfolios in commodity markets, and they should pay attention to geopolitical events and rebalance their portfolios' risk exposure in a timely manner according to the time-varying risk measures of VaR and CoVaR.

In particular, there are two main channels that geopolitical risk could affect natural resource prices. First, geopolitical risk can lead to supply disruptions for natural resources. Russia is a major oil-producing country, and therefore conflicts between Russia and Ukraine can significantly impact the supply of oil and lift oil prices. Such oil supply disruptions resulting from geopolitical risk can have both short-term and long-term effects on natural resource prices, further transforming into the European energy crisis (Siddi, 2023). Geopolitical risk can also generate demand shocks in natural resource markets. During the COVID-19 period, natural resource demand such as the oil demand has been considerably affected by worldwide lockdowns. Therefore, the geopolitical risks can affect the natural resource prices from both demand and supply channels.

5. Conclusions and policy implications

To conclude, this paper attempts to reveal the time-varying effect of geopolitical risk on natural resource prices against the most recent political issues, including the COVID-19 and Russia-Ukraine conflict. Moreover, we also intend to uncover the downside risk comovement between natural resource prices and geopolitical risk level under such a new international political environment. By applying the data from natural resource commodity markets, we unravel the fact that U.S. geopolitical risk has a stronger impact on energy market prices, and this impact becomes even stronger after the Russia-Ukraine conflict. On the other hand, China geopolitical risk exhibits a heavier impact on metal markets. Finally, we unfold the fact that the downside risk comovement between metal prices and China geopolitical risk is stronger. On the other hand, the downside risk comovement between energy prices and United States geopolitical risk is more obvious.

The key policy implication of this paper is that policy makers need to consider the geopolitical risk impact on natural resource commodity markets, and increased commodity prices may be transmitted to inflation (Chen et al., 2014; S. Ding et al., 2021; Chien et al., 2022), as well as the huge economic cost of the Russia-Ukraine conflict, including the soaring gas price in Europe (Liadze et al., 2022).

From policymakers' perspective, it can be essential to pay attention to both the demand and supply sides when there is a shock in the geopolitical risk level, which can be transmitted to commodity markets. Policy makers can either increase the domestic supply of natural resources or reduce demand by imposing carbon emission restrictions

(Dogan et al., 2021). Finally, it would be worthwhile for policy makers to pay heavy attention to the large change in political circumstances, which can influence the geopolitical risk level and further propagate into natural resource commodity markets. The early warning system of such a gigantic change in political circumstances for policy makers would be extraordinarily valuable.

From investors' perspective, our paper reinforces investors' awareness of different markets' responses to geopolitical events in different time periods, and thus, we assist investors in formulating commodity portfolios in the long run. Additionally, investors should also include geopolitical risk in their risk prediction models as they construct portfolios in commodity markets, and they should pay attention to geopolitical events and rebalance their portfolios' risk exposure in a time-varying way, especially after geopolitical events.

The scientific values of our paper is twofold. Firstly, studying the time-varying effect of geopolitical risk on natural resource prices can shed the practical insights to the existing literature. We unveil the mechanisms through which geopolitical events can influence commodity market dynamics, as well as the supply and demand interactions. Our empirical results can reinforce the financial research filed by incorporating the complexities of real-world geopolitical risks with recent geopolitical events and their impacts on natural resource markets. Furthermore, our paper can enhance the current risk assessment frameworks. By analyzing the dynamic relationship between geopolitical risk and natural resource prices, our paper is helpful in capturing the changing nature of geopolitical risk as well as the comovement between geopolitical risk and natural resource prices. This can be valuable to the development of more accurate risk assessment tools, stress testing methodologies, and scenario analyses, enabling policymakers and market participants to better understand and manage the potential risks associated with geopolitical events toward natural resource prices.

CRediT authorship contribution statement

Shusheng Ding: Conceptualization, Methodology, Formal analysis, Software. Kaihao Wang: Data curation, Writing – original draft. Tianxiang Cui: Visualization, Investigation, Software. Min Du: Supervision, Project administration, Validation, Writing – review & editing.

Declaration of competing interest

We acknowledge the support of The National Social Science Fund of China (Project No. 21AJL003 and 21BJY262), Ningbo Science and Technology Bureau (Project No. 2023J194), and International Research Centre for Sustainable Finance, Ningbo University.

We hereby confirm that the above statements accurately represent any potential conflicts of interest related to our manuscript. We understand the importance of transparency and ethical conduct in research and publication and will promptly inform the editorial team of any changes or updates to the information provided.

Data availability

Data will be made available on request.

Acknowledgments:

This paper is supported by the International Research Centre for Sustainable Finance, Ningbo University.

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