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Do oil prices and economic policy uncertainty matter for precious metal returns? New insights from a TVP-VAR framework

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ABSTRACT

Oil price shocks and economic policy uncertainty are the two main drivers of many macroeconomic and financial variables. In the context of commodity financialization, these two shocks are more interrelated and even have a combined effect on the precious metals market. Therefore, using the time-varying parameter vector autoregression (TVP-VAR) framework, we actively analyze the dynamic impacts of oil price shocks and economic policy uncertainty on precious metal returns using monthly data from April 1990 to April 2018. The results show that oil price shocks had positive effects on precious metal returns before the international financial crisis, while these impacts have been negative since the international financial crisis. The impacts of economic policy uncertainty on precious metal returns change over time and are positive in most cases. The effects of oil price shocks on precious metal returns are amplified by economic policy uncertainty. In the field of transmission channels of economic policy uncertainty, we find that news uncertainty and inflation uncertainty are the most significant. In addition, during a major economic crisis or emergency, we discover some evidence of overreactions in the precious metal markets.

1. Introduction

As an important strategic resource, precious metals are a significant factor in the developmental progress of national economies and are directly related to the normal operation of national core industries (Kang et al., 2017a; Wu et al., 2019). Precious metals are also major international financial investment commodities that influence the stability of financial markets and the global economy (Huynh, 2020). At present, the international spot precious metal market consists of spot gold, silver, platinum and palladium markets, among which spot gold is the most influential (Baruník et al., 2016) because gold, as a special commodity, is considered a tool to hedge economic policy risks and market turbulence (Hartmann et al., 2004; O'Connor et al., 2015; Raza et al., 2018). As an alternative to gold investment, silver is also favored by an increasing number of investors due to its low investment threshold; thus, it has become a new force in the field of financial investment (Jain & Ghosh, 2013; Vigne et al., 2017). In recent years, investors have begun to possess platinum and palladium as alternatives to gold (Jain & Ghosh, 2013). As safe assets, with the turmoil in the global economic situation, the hedged precious metal is widely seen as a safe haven for equity investors due to its diversification and higher returns (Dimitriou et al., 2020; Sikiru and Salisu, 2021), there has been an explosive growth in the investment demand of precious metals, causing violent fluctuations in price. Therefore, it is necessary to further understand the law of the price fluctuation of precious metals not only to

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analyze the reasons for the fluctuation of the precious metal market more comprehensively but also to provide a basis for investors' investment behavior.

Crude oil is regarded as the lifeblood of the modern industrial economy (Chen et al., 2020; Wen et al., 2018, Wen, Min, Zhang, & Yang, 2019), as an important resource, it plays a vital role in the economic activity in the world. In particular, crude oil not only has common commodity attributes, but also has obvious financial attributes as a financial product (He, 2020; Qin et al., 2020). As the most influential raw material and basic energy source, crude oil is also a vital input for the production of precious metals (Chen & Zhu, 2019), giving it an inseparable relationship with the precious metal market. Many recent studies have explored the relationship between the oil market and precious metals returns or volatility (Shao et al., 2021). In a general way, oil may affect precious metal prices through the inflation channel (Behmiri & Manera, 2015; Le and Chang, 2011; Narayan et al., 2010; Reboredo, 2010, 2013), exchange rate channel (Hammoudeh & Yuan, 2008; Sari et al., 2010; Zhang and Wei, 2010), and export revenue channel (Melvin and Sultan, 2010; Reboredo, 2013; Tiwari and Sahadudheen, 2015). In view of this, scholars have done a great deal of research studying the correlation between oil price changes and precious metal prices (Antonakakis & Kizys, 2015; Balcilar et al., 2015; Mensi et al., 2015). Pindyck and Rotemberg (1990) found that oil price is a driving factor to precious metal returns. Increasing studies have proved that the impact on the precious metal market generated by oil price shocks cannot be ignored (Sari. et al., 2010; Bhar & Hammoudeh, 2011; Balcilar et al., 2015; Bildirici & Turkmen, 2015; Zhu et al., 2015; Uddin et al., 2018; Shahzad et al., 2019; Churchill et al., 2019). However, with the development of the financialization of commodities, the supply and demand in the real economy have been gradually replaced by the investment behavior in the financial capital market as the main driving factor of price fluctuations. Financialized precious metals and crude oil have become significant tools for investors to hedge, and the price linkage between them has significantly changed (Li and Zhang, 2014). Thus, it is significant to further dissect the correlation between oil price and precious metal returns based on the background of commodity financialization.

As a vein of the global economy and financial markets, sharp fluctuations in crude oil prices have caused increased uncertainty in the global economy (Gong & Lin, 2017; Xiao et al., 2018). Various countries frequently issue economic policies to maintain their own economic stability, which also leads to an enhancement in the uncertainty of the economic policies (Baker et al., 2016). Economic policy uncertainty has important implications for the economy as a whole (Lee et al., 2021). Due to the safe-haven nature of precious metals, a large amount of capital has flowed into the precious metal market, leading to growth in precious metal prices and increased earnings. Economic policy is a combination of monetary, fiscal and regulatory policies, which all must be adjusted frequently (Adjei & Adjei, 2017; Raza et al., 2018). Economic policy uncertainty might affect precious metal returns through many roots. First, it might change decisions made by economic agents, including consumption and investment (Gulen & Ion, 2016). Second, it influences supply and demand and enhances the contraction of investment and economics, which might affect expenditures on financing and production (You et al., 2017). Third, it might also affect the interest rate, inflation and expected risk premiums (Pástor and Veronesi, 2013).

In recent years, the coupling of economic factors with commodity prices has been exacerbated by the surge in commodity investment. This enhances the effect on commodity returns generated by economic factors (Reboredo and Uddin, 2016). However, there is not enough attention paid to the correlation between economic policy uncertainty and the precious metal market. Although several studies have been conducted, they generally focus mainly on gold, which has a significant attraction for investors (Gao & Zhang, 2016; Zhou et al., 2018). For example, Shafiee and Topal (2010) investigated the influencing factors of gold prices and found that the safe-haven role of gold has been a key factor for the increase in gold prices in times of financial instability. Białkowski et al. (2015), Van et al. (2016) and Lau et al. (2017) also reached similar conclusions. On this basis, Bouoiyour et al. (2018) reported proof of a significant positive effect on gold returns from economic policy uncertainty when uncertainty reaches a peak. In addition, Huynh (2020) determined that gold was still the main "safe-haven" asset for hedging uncertainty after examining the prices of four representative precious metals by applying the multilayer perceptron neural network nonlinear Granger causality and transfer entropy models.

From the above, we can see that the existing literature mainly studies the impacts on precious metal prices generated by oil prices or economic policy uncertainty in isolation. However, these two shocks are interrelated and even generate a joint effect on precious metal markets (Kang and Ratti, 2013; Kang et al., 2016; Chen et al., 2019). As a result, it is essential to detect the effect of oil price changes on precious metal market while accounting for economic policy uncertainty. Moreover, the existing research mainly adopts vector autoregression (VAR) and structural vector autoregression (SVAR), assuming that the responses of precious metal prices to these two shocks is stable over time instead of changing over time. This is far from true and cannot reflect the change and heterogeneity of the transmission mechanism. Thus, the time-varying effect of crude oil prices and economic policy uncertainty on precious metal returns cannot be accurately understood (Wen, Xu, Ouyang, & Kou, 2019).

Based on the background of commodity financialization, we have included oil price shocks, economic policy uncertainty, and precious metal returns into a unified framework and systematic studied the dynamic impacts of shocks using the TVP-VAR model, which makes it possible to estimate the dynamic time-varying relationship between the variables. However, applying stochastic volatility would improve the estimation, in accordance with Nakajima (2011). To confirm the combined effect of shocks on precious metal returns, two types of shocks are identified: oil price and economic policy uncertainty. Moreover, to capture the transmission mechanism of the latter, four EPU components— namely, news coverage, government purchase forecast disagreement, CPI forecast disagreement and tax code expiration—are also considered. This work uses Bayesian techniques to estimate the model, which is applied widely in large-dimensional parameter space and nonlinear models.

This research makes contributions in three main aspects. First, we involve economic policy uncertainty into the research system of the crude oil and precious metal markets. It breaks through the limitations of previous research in terms of the correlation between the markets from traditional channels and opens up a new analytical perspective in this field. Second, unlike previous studies, we divide economic policy uncertainty into four components and delve into the specific transmission mechanism of shocks. Third, we better reflect the changes in the responses of various precious metal returns through the TVP-VAR model. More importantly, we can compare and analyze the impact generated by shocks of crude oil price on precious metal returns over several critical periods.

The remainder of the paper is organized as follows. Section 2 explains the data and TVP-VAR methodology. Section 3 discusses the empirical results. The fourth section summarizes the policy significance of this paper.

2. Data and methodology

2.1. Data description

Following Gupta and Modise (2013), Kim et al. (2017) and Chen et al. (2020), we select the U.S. refiners' acquisition cost for imported crude oil as the international crude oil price (POI), and the data come from the Energy Information Administration. To reflect the change in economic policy uncertainty (EPU), we follow Kang et al. (2017b, 2017c) and Chen et al. (2019) to select the total index of U.S.EPU put forward by Baker et al. (2016), derived from the website www.economicpolicyuncertainty.com. Following Le and Chang (2012) and Zhang and Wei (2010), prices of four representative precious metals—i.e., gold (PGO), silver (PSI), platinum (PPL) and palladium (PPA)—are selected based on the London PM fix gold price, and the data source is the Wind database. To provide an extensive demonstration of the link between precious metal returns and economic policy uncertainty, news coverage (NC), government purchase forecaster disagreement (GPFD), CPI forecaster disagreement (CFD) and tax code expiration (TCE) extracted from the Wind database are chosen as proxy variables for the four components of the EPU index. The data sample interval of the four variables is April 1990 to April 2018. Since the value of each spot precious metal market index varies widely, the monthly index rate of return is adopted in the application of data; that is,

$$R_t = Ln(P_t / P_{t-1}) \tag{1}$$

where R_t is the precious metal return in period t, and P_t is the precious metal price in period t. The returns of gold, silver, platinum and palladium are denoted by DPGO, DPSI, DPPL and DPPA, respectively. Figs. 1–3 present the time trends of international oil prices, the prices of four representative precious metals and economic policy uncertainty.

According to Fig. 1, international crude oil prices show a sustained growth trend overall. When there is a large fluctuation in crude oil prices, the uncertainty in the market increases, resulting in difficulty for investors in accurately predicting risk. Investors then overreact or underreact to oil price fluctuations, which will further increase volatility. The jump in the time trend of oil prices will appear only at the moment an unexpected event occurs. It is noteworthy that international oil prices have characteristics of volatility aggregation and intermittent jumping; that is, large (small) fluctuations tend to be followed by small (large) fluctuations. However, oil prices tend to undergo intermittent jumping when hit by unexpected abnormal information. Moreover, the dates of well-known events are observed to coincide mostly with events that trigger movements in oil prices. Oil prices rose to a peak at an unprecedented rate beginning in 2007 and fell in a near-straight line during the 2008 financial crisis. As the global economy recovered, there was a growth in prices of crude oil. And there is a sharp drop in global crude prices in the second half of 2014 as a result of the rapid growth of U.S. shale oil production. Hereafter, although oil prices have been fluctuating, the overall trend is a recovery.

Fig. 2 shows the price trends of spot gold, silver, platinum and palladium. Similar to those for crude oil, precious metal price fluctuations are very frequent and violent, and the trends are similar to some extent, but the degree of volatility of different precious metals in different periods is divergent. Among them, the long-term trends of gold and silver prices are similar, while those of platinum and palladium are more volatile, and palladium even exhibits a "U-shaped" trend.

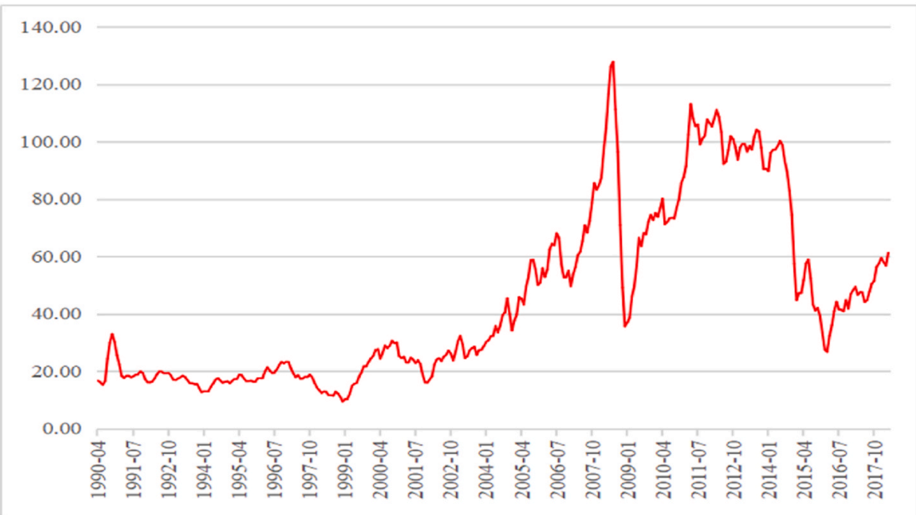

Fig. 1. Time trend of international oil prices: Prices are in U.S. dollars.

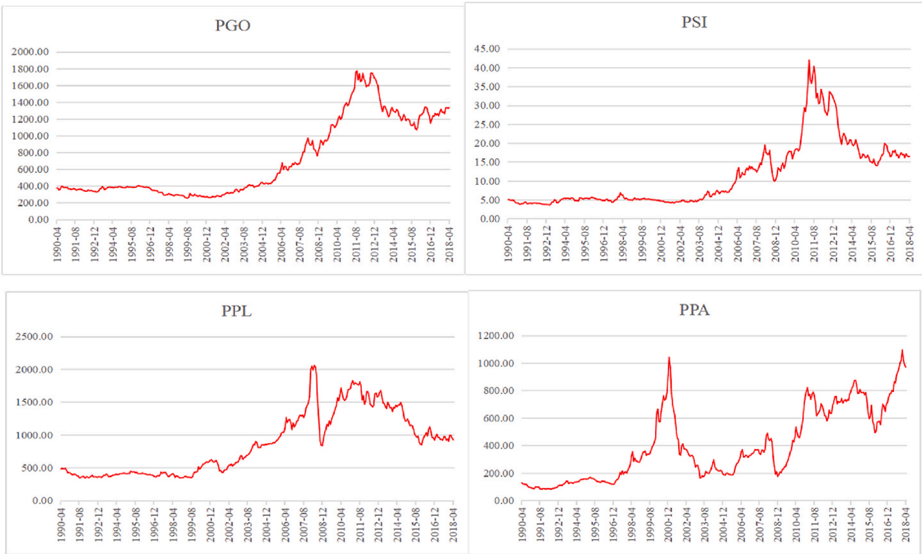

Fig. 2. Time trends of precious metal prices: All futures prices are in U.S. dollars. Gold: CFD (XAU) Gold, Silver: CFD (XAG) Silver, Platinum: CFD (XAT) Platinum, Palladium: CFD (XAD) Palladium. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

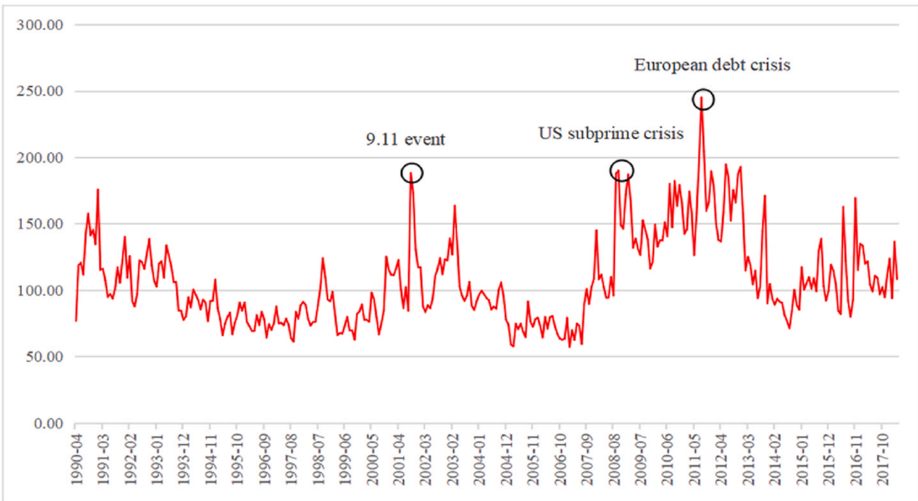

Fig. 3. Time trend of the economic policy uncertainty index.

We present the economic policy uncertainty index and mark some typical events in Fig. 3. The volatility of the index is relatively fierce, indicating that the economy (including the precious metal market) has been affected by the uncertainties. In general, since 1995, the index has experienced roughly four periods of sharp fluctuations: (1) The first period was around October 2001. During this period, the peak occurred around the landmark event of the 9/11 terrorist attacks, which triggered a global economic recession and affected the domestic economy, especially imports and exports. (2) The second period of severe volatility occurred around September 2008. The landmark event of this wave was the global financial crisis aroused by the U.S. subprime crisis. (3) The third period of sharp fluctuations, which occurred mainly around November 2011, was defined by the European debt crisis.

2.2. Methodology

Following Sims (1980), the VAR model has been widely used in the field of macroeconomics, but its assumption of fixed parameters has greatly constrained its explanatory power. Subsequent scholars gradually addressed this problem. For example, Cogley and Sargent (2001) used the coefficient drift VAR model for analysis, but the evolution of variance and covariance was constrained; Cogley and Sargent (2005) further extended the model drift coefficient and time-varying variance, but the synchronization relationship between the variables remained unchanged.

Previous studies mainly used VAR and SVAR models, assuming that the relationship between variables does not change over time (Zhou et al., 2019; Esmaeili and Rafei, 2021). However, oil supply and demand conditions are different in different periods, and changes in oil prices caused by supply and demand factors will have a dynamic impact on macroeconomic variables (Gong & Lin, 2018). Economic policy uncertainty can affect financial markets through multiple channels (Zhang et al., 2021), and a growing number of papers have also proved the significant dynamic impact of economic policy uncertainty on financial market returns (Badshah et al., 2019). In fact, research in recent years has captured the time-varying relationships between oil prices, economic policy uncertainty, and macroeconomic variables (Chen et al., 2020; Qin et al., 2021; Toparlı et al., 2019; Wen et al., 2018, Wen, Min et al., 2019; Yang et al., 2021). It is necessary to study the impact of oil prices and economic policy uncertainty on precious metal returns from a time-varying perspective.

Since Primiceri (2005) developed the VAR model into the TVP-VAR model, in which intercept terms, coefficients, variances and covariance terms are allowed to change over time. The TVP-VAR model allows for interactions between variables and can remove the reverse effect (Feng et al., 2021), which has been one of the most widely used empirical models to study the dynamic time-varying relationship between variables, and make comparative analysis of the influence during some important periods (Wen, Min et al., 2019; Zhou et al., 2020; Li et al., 2021). Therefore, this paper uses the TVP-VAR model to analyze the time-varying impact of crude oil price and economic policy uncertainty on precious metal returns.

To define a TVP-VAR model, we can begin with an SVAR model:

$$Ay_t = B_1 y_{t-1} + B_2 y_{t-2} + \ldots + B_s y_{t-s} + \mu_t; t = (s+1), \ldots, n \tag{2}$$

where s is the number of lagging orders; y_t is a $k \times 1$ vector of endogenous variables; A and $B_1, \ldots, B_s$ are $k \times k$ matrices of the coefficients; and μ_t is the $k \times 1$ structural impact. Suppose $\mu_t \sim N(0, \Psi\Psi)$, $\Psi = \begin{pmatrix} \sigma_1 & 0 & \ldots & 0 \\ 0 & \sigma_2 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & \ldots & \sigma_k \end{pmatrix}$. For simplicity, assume that structural shock A is the lower triangular matrix, as shown in Equation (3):

$$A = \begin{pmatrix} 1 & 0 & \ldots & 0 \\ \alpha_{21} & 1 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ \alpha_{k1} & \alpha_{k2} & \ldots & 1 \end{pmatrix} \tag{3}$$

Equation (2) can be rewritten as

$$y_t = \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \ldots + \Phi_s y_{t-s} + A^{-1}\Psi\varepsilon_t, \varepsilon_t \sim N(0, I_k) \tag{4}$$

where $\Phi_i = A^{-1}B_i$, and $i = 1, 2, \ldots, s$. The elements in each row of the matrix Φ_i are further processed and converted into form β, a $k^2 s \times 1$ vector. At the same time, $X_t = I_k.(y_{t-1}^{'}, \ldots, y_{t-s}^{'})$ is defined, in which is the Kronecker product. Thus, the model can be noted as

$$y_t = X_t\beta + A^{-1}\Psi\varepsilon_t \tag{5}$$

The parameters in Equation (5) are state variables that change with time, so they can be denoted by β_t, Ψ_t and A_t. According to the research of Primiceri (2005), Nakajima et al. (2011), Cao (2012), Jebabli et al. (2014) and Wen, Zhao, & Hu (2019), the elements of the lower triangle in matrix A_t can be transformed and expressed as $\alpha_1 = (\alpha_{21}, \alpha_{31}, \alpha_{32}, \alpha_{41}, \ldots, \alpha_{k,k-1})^{'}$, and $h_t = (h_{1t}, h_{2t}, \ldots, h_{kt})^{'}, h_{jt} = \log \sigma_{jt}^2$. To reduce the estimated parameters, we assume that the parameters obey the random walk process; i.e., $\beta_{t+1} = \beta_t + \mu_t, \alpha_{t+1} = \alpha_t + \mu_{\alpha t}, h_{t+1} = h_t + \mu_{ht}$ and

$$\begin{pmatrix} \varepsilon_t \\ \mu_{\beta_t} \\ \mu_{\alpha_t} \\ \mu_{h_t} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \sum\beta & 0 & 0 \\ 0 & 0 & \sum\alpha & 0 \\ 0 & 0 & 0 & \sum h \end{pmatrix}\right) \tag{6}$$

Given the high dimensions of parameter space and the nonlinear context (Bijsterbosch & Falagiarda, 2015; Koop et al., 2009), following Primiceri (2005), Gambetti and Musso (2017), and Gong and Lin (2018), we estimate the TVP-VAR model by applying the Bayesian approach. Parameters including $\beta_t, \alpha_t, \ln\sigma_t, \sum\beta, \sum\alpha$ and $\sum h$ are to be estimated. Prerequisites assumed for these parameters are as follows: $\beta_0 \sim N(\widehat{\beta}, \widehat{V}_\beta)$, $\alpha_0 \sim N(\widehat{\alpha}, \widehat{V}_\alpha)$, $\ln\sigma_0 \sim N(\ln\widehat{\sigma}_0, I_n)$, $\sum\beta \sim W(s_1k_1\widehat{V}_\beta, s_1)$, $\sum\alpha \sim W(s_2k_2\widehat{V}_\alpha, s_2)$, $\sum\sigma \sim W(s_3k_3I_n, s_3)$, where

$N(a,b)$ represents the normal distribution with mean a and variance b, and $W(Z,h)$ represents the Wishart distribution with scale matrix Z and h degrees of freedom. OLS is used to calibrate the prerequisites with the estimation of $\hat{\beta}, \hat{\alpha}, \widehat{V}_{\beta}, \widehat{V}_{\alpha}$ and $\ln\hat{\sigma}_0$ using OLS. The values s_1, s_2 and s_3 are the degrees of freedom of each prior. They are set equal to the rows for $\sum\beta, \sum\alpha$ and $\sum h$, respectively. The parameters k_1, k_2 and k_3 control the tightness of the priors.

3. Empirical results and analyses

3.1. Descriptive statistics

Considering that the basic data series used in this study are all time series, it is vital to implement stationarity tests on each data set. We adopt the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to determine the stationarity. As we can see in Table 1, the original sequences of EPU, the returns of gold, silver, platinum and palladium pass this test at a 1% significance level, indicating that they reject the null hypothesis of unit roots, but POI is stationary after the first difference processing.

As shown in Table 2, the optimal number of lag lengths for constructing the TVP-VAR model is identified by calculating the LR, FPE, AIC, SC and HQ. According to the minimum value principle of AIC and FPE, the optimal lag length is set to 2.

3.2. Model estimation results and diagnosis

Before using the Bayesian method to simulate sampling and estimate the TVP-VAR model, it is significant to assign initial values to the parameters. As shown in Table 3, the mean values are all within the confidence interval, and the Geweke convergence diagnostic value fails the significance test at the 5% level, indicating that the parameters converge to the posterior distribution. In addition, the invalid factors are all small, with a maximum value of 75.46. Given the number of simulated samples studied in this paper, we know that enough irrelevant samples are obtained. Following Gong and Lin (2018) and Chen et al. (2020), it is indicated that the parameter estimation of this model is effective.

Finally, the sample autocorrelation coefficient, sample convergence trajectory and posterior density distribution diagram are shown in Fig. 4 from top to bottom. It can be seen that the sampling times set in this paper can eliminate the autocorrelation between samples and that the sample sequence fluctuates in a "white noise" trajectory near the mean. At the same time, Fig. 4 also verifies that the samples obtained by sampling with the Markov chain Monte Carlo algorithm are irrelevant and effective.

3.3. Impulse response analysis in different lag periods

The TVP-VAR model can capture dynamic impulse response in different lag periods. Figs. 5 and 6 show the dynamic impulse responses of precious metal returns to crude oil prices and economic policy uncertainty in the 4th, 8th and 12th periods of lags.

As we can see in Fig. 5, the impacts of crude oil prices on gold returns are time varying. Taking four periods ahead as an example, we can see that the responses of gold returns were mainly positive before the international financial crisis, reaching the maximum value of 0.0025 around 2001. After 2008, the response of gold returns showed a negative and sharp increase after an impact, reaching the bottom of −0.0018 around the second half of 2009, implying that the gold returns had the greatest response intensity to crude oil prices during the two periods of 2001 and 2008. Furthermore, this positive response tended to be flat after 2018. From the perspective of different lag periods, the impact in the 4th lag period is the largest, followed by the 8th and 12th lag periods, indicating that the impacts of crude oil prices on gold returns are also different from time to time, and the impacts are gradually weakened with the increase in lag duration.

As seen from Fig. 5, silver returns generated a negative reaction at the initial stage of the impact of crude oil prices, then remained positive from 1991 to 2008, and peaked in 1999 and 2007. The positive response to crude oil prices declined rapidly after 2007 and became a negative response after 2008. In addition, the negative response intensity was greatest in the second quarter of 2010. For the time-varying effects on platinum returns, after a short-term negative response, a positive response was observed from 1993 to 2004 and peaked in 1998. Since then, the negative response has been maintained. The negative response to shocks in 2007 increased rapidly, and the response intensity maximized in 2009 and then stabilized after 2018. Palladium returns responded positively to shocks of oil price from 1992 to 2004, and the positive response intensity reached its maximum value in 2001. After 2007, a negative response emerged, which reached the bottom in 2010 and stabilized after 2016. Similar to the gold return, with the expansion of lag periods, the responses of silver, platinum and palladium have gradually weakened.

Overall, the impacts of crude oil prices on precious metal returns have the following characteristics: (1) This conclusion is inconsistent with Sari et al. (2010), Li and Zhang (2014) and Churchill et al. (2019). The possible reason is that crude oil futures and precious metal products can be regarded as alternative financial investment products to some extent with the increasing trend of

Table 1
Stationary test.

Variable	POI	DPOI	EPU	DPGO	DPSI	DPPL	DPPA
ADF	−3.10	−11.13***	−5.75***	−16.27***	−15.18***	−13.82***	−13.76***
PP	−2.44	−10.16***	−5.63***	−16.21***	−15.10***	−13.90***	−13.94***

Notes: *** indicates the 1% significance level. A linear trend and an intercept are included in the test equations.

Table 2
Lag selection results.

Lag	Log L	LR	FPE	AIC	SC	HQ
0	2568.172	NA	6.61e-15	−15.62300	−15.55362	−15.59532
1	2845.859	543.5211	1.51e-15	−17.09670	−16.61101*	−16.90292*
2	2883.068	71.46807	1.50e-15*	−17.10407*	−16.20208	−16.74420
3	2913.566	57.46301	1.56e-15	−17.07052	−15.75222	−16.54456
4	2946.187	60.27001	1.59e-15	−17.04992	−15.31531	−16.35786
5	2970.644	44.29013	1.71e-15	−16.97954	−14.82862	−16.12138
6	3005.820	62.41605*	1.72e-15	−16.97451	−14.40729	−15.95026
7	3029.892	41.83239	1.86e-15	−16.90178	−13.91825	−15.71144
8	3056.694	45.59622	1.97e-15	−16.84570	−13.44586	−15.48926

Note: * indicates the optimal hysteresis order determined by the corresponding method.

Table 3
TVP-VAR model estimation results.

Estimation results						
Parameter	Mean	Stdev	95%L	95%U	Geweke	Inef
$(\Sigma_\beta)_1$	0.0231	0.0026	0.0185	0.0287	0.746	18.26
$(\Sigma_\beta)_2$	0.0217	0.0022	0.0176	0.0265	0.314	15.67
$(\Sigma_\alpha)_1$	0.0660	0.0211	0.0365	0.1237	0.778	71.53
$(\Sigma_\alpha)_2$	0.0612	0.0153	0.0387	0.0979	0.000	75.46
$(\Sigma_h)_1$	0.2693	0.0374	0.2046	0.3501	0.983	47.47
$(\Sigma_h)_2$	0.3147	0.0718	0.1849	0.4651	0.852	70.33

Notes: Mean denotes the posterior mean; Stdev denotes the standard deviation; and Inef. denotes the inefficiency factor.

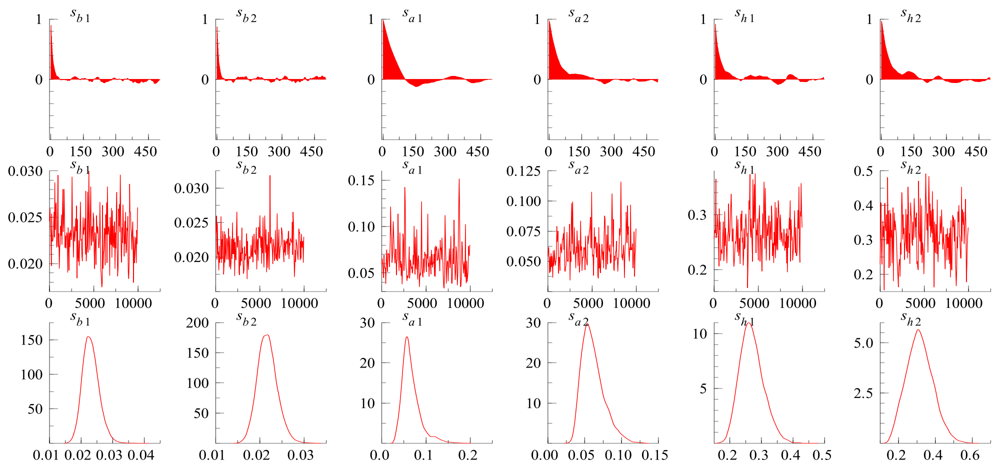

Fig. 4. Sample autocorrelation diagram, sample path and posterior density diagram.

financialization of commodities after the international financial crisis (Bouri et al., 2017; Tang and Xiong, 2012). Therefore, rising oil prices bring more capital into the crude oil market in pursuit of high returns. Naturally, it will also attract capital to a certain extent from the precious metal market to the crude oil market, resulting in falling prices and returns in the precious metal market. (2) Different precious metals suffered divergent shocks, and palladium returns appear the most volatile after an impact, silver and platinum followed close behind, while gold suffered least. This is because there is a gold futures market, and the speculative atmosphere of the gold futures market is heavier than that of the silver futures market, which affects the realization of its price discovery function. (3) The impact of crude oil prices is divergent in different lag periods, and the impact gradually weakens as time passes. This result shows that the spot precious metal market can make effective adjustments to ease off the shock generated by oil price fluctuation to ensure price stability over time. (4) After a passive effect of crude oil price, there would inevitably be a quick rebound in precious metal returns, indicating that the precious metal market has a leverage effect (i.e., asymmetry). In addition, a decrease in precious metal returns can cause more volatility in the precious metal market than a rise in returns.

Fig. 6 presents the impact of economic policy uncertainty on precious metal returns. First, in terms of gold, there is a positive and negative alternating trend, and the positive response is more intense, concentrating in 1993–2001, 2008–2011 and 2014–2018. Since the second half of 1992, the responses of gold returns to economic policy uncertainty have undergone two “up-down” phases. The first

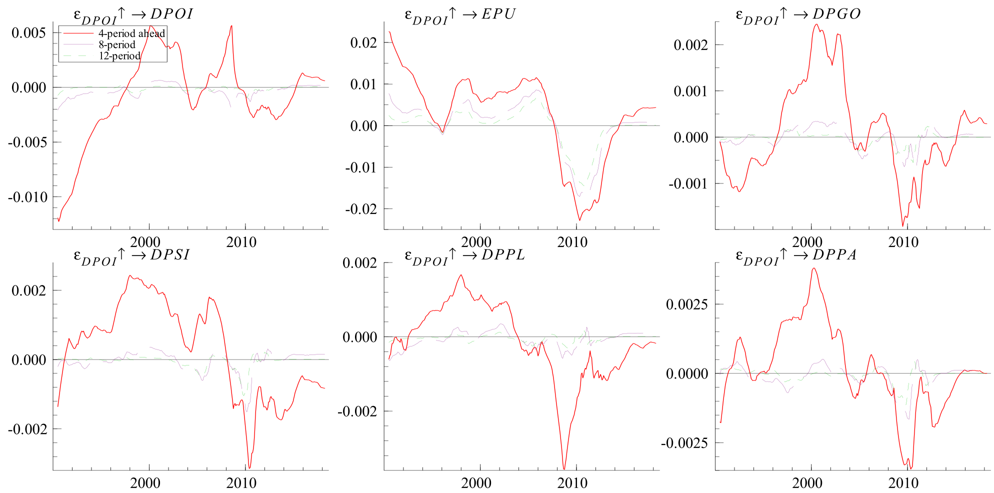

Fig. 5. The impulse responses of precious metal returns to oil price shocks in different lag periods.

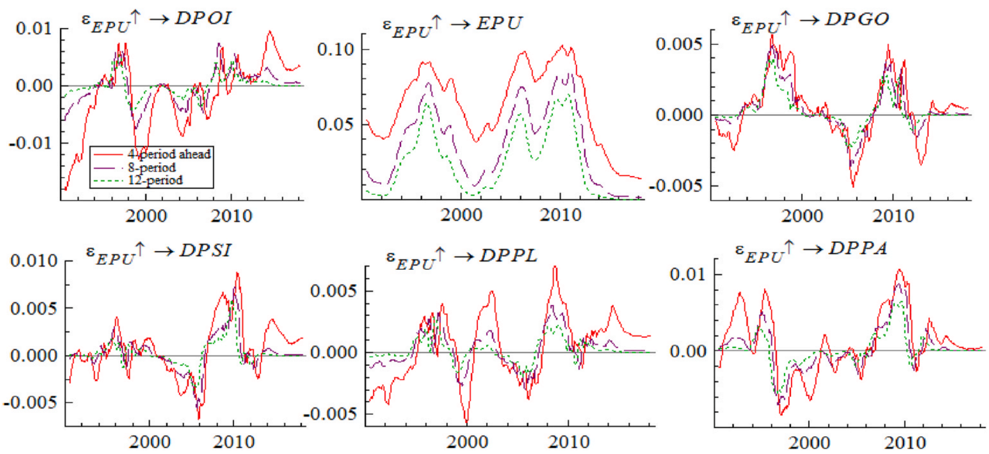

Fig. 6. The impulse responses of precious metal returns to economic policy uncertainty in different lag periods.

phase between 1992 and 2006 was the most volatile and had the longest duration. In 2008, there was a maximum value of negative response; then, the negative response weakened, and the positive response increased, peaking in 2010. After 2016, the volatility was relatively flat. Second, there are both negative and positive responses of silver returns to the impact. The reaction showed a relatively gentle upward trend during the initial period. After 2000, the positive response decreased, and the negative response increased. In 2006, the negative response maximized and then rebounded rapidly. From 2007 to 2011, the response was positive and peaked in 2011, followed by a cliff slide. After 2018, there was still a continuous positive response. Third, the impact on platinum returns is generally on the rise and has a more obvious cyclical characteristic, which has undergone four "up-down" stages. They peaked in the second half of 1997, 2003, and 2009 and fell to a trough in 2000, 2008, and the second half of 2011. Among them, the largest positive and negative effects occurred in approximately 2000 and 2009. After 2018, there was a continuous positive response. Finally, for the palladium returns, the negative responses performed more strongly from the second half of 1996–2007, and the remaining periods featured mainly positive effects. Interestingly, unlike crude oil prices, the impact of economic policy uncertainty on precious metal returns shows convergence.

In general, the effects on precious metal return prices generated by economic policy uncertainty changed as time goes by and were positive in most cases, implying that precious metal performs well as a safe haven against economic policy risk, while the efficiency of precious metals as a safe haven is not stable and depends on economic conditions (Yin and Liu, 2015). This is because different economic policy uncertainty events (e.g., economic environment change, macro policy promulgation, economic crisis, and market turbulence) have different effects on the gold market. The impact of a single event can be positive or negative, and multiple EPU events often coexist at a given time point, influencing the gold market simultaneously and eventually forming complex and changeable effects (Chai et al., 2019; Pástor and Veronesi, 2013). (2) Different precious metals suffer divergent shocks, and palladium returns experienced the largest fluctuations after being impacted, silver and gold followed behind. Platinum suffers the least impact. (3) Unlike crude oil prices, the impact of economic policy uncertainty has not been significantly reduced with the expansion of lag lengths, showing that economic policy uncertainty affects precious metal returns for a longer period. (4) After the negative impact caused by economic policy uncertainty, there would inevitably be a quick rebound in precious metal returns, indicating that the precious metal market itself has a leverage effect.

3.4. Impulse response analysis at different time points

This article uses three peaks of economic policy uncertainty—namely, the 9/11 terrorist attacks (October 2001), the global financial crisis (September 2008) and the European debt crisis (November 2011). On this basis, the impact generated by crude oil prices and economic policy uncertainty on precious metal returns in these three periods is simulated. Figs. 7 and 8 show the impulse responses to these two shocks at the above three points.

Fig. 7 shows the impulse responses of various precious metal returns to crude oil prices at three time points. Three lines of each panel represent the response trends at different points in time. Overall, the four markets all show positive responses quickly and reach the peak in the current period. However, in the second month, the reaction of four precious metals to shocks from crude oil quickly turned negative. These results indicate that during a major economic crisis or emergency, precious metal markets have overreactions to crude oil price shocks at the beginning, which must be corrected by subsequent reverse adjustments (Sari et al., 2010; Wen, Xu, Ouyang, & Kou, 2019). In addition, the direction and duration of responses vary greatly for different time periods. The shock that occurred in October 2008 was the strongest among the three time points, followed by the impact in August 2011, both of which dominated the positive impact. The shock was the weakest during the period surrounding the 9/11 attacks. This finding indicates that during a financial crisis, precious metal returns respond more strongly to oil price shocks than normal. During these periods, other fiscal policies may be required, and there should be more emphasis on promoting price elasticity in the precious metal market to cope with crude oil price shocks. For different types of precious metals, during the global financial crisis and European debt crisis in 2008 and 2011, respectively, silver returns suffered most from the shocks in crude oil prices, while the impact on palladium returns was the largest during the 9/11 attacks. Judging from the duration of shocks, the shock of crude oil prices in these three periods could not stabilize over the short term. Among them, the impact of silver returns generally started to level off after approximately six months, while gold, platinum and palladium were affected for longer, usually disappearing after 8 months.

Fig. 8 depicts the response of four precious metal returns to economic policy uncertainty at three time points. It can be seen that, there are some overreactions in the precious metal markets. Similar to crude oil prices, during the global financial crisis and European debt crisis, economic policy uncertainty generated a positive effect on precious metal returns. Among them, returns of gold and silver showed positive responses quickly and reached a peak in the current period, indicating that during a major economic crisis or emergency, the impact of economic policy uncertainty are very fast, and the lag period is short. Around the 9/11 attacks, the impact was the weakest and alternated between positive and negative. At the three points in time, the four precious metal returns responded differently to economic policy uncertainty, indicating that the precious metal market had various responses to different economic policy uncertainty events. For different types of precious metals, in the periods surrounding the 9/11 attacks and the 2008 global financial crisis, palladium returns suffered most, while spot silver returns suffered most during the European debt crisis of 2011.

As for the duration of shocks, economic policy uncertainty surrounding the 9/11 terrorist attacks and 2011 European debt crisis generated impacts for relatively short periods of time, generally stabilizing around the eighth period. During the global financial crisis in 2008, precious metals were affected for longer, and the positive impact did not disappear after the 15th period. However, the responses of platinum returns lasted the longest in these three periods.

3.5. The transmission channel of economic policy uncertainty

To study the effect mechanism of economic policy uncertainty on precious metal returns, we compare the impulse responses to four components of policy uncertainty: news coverage, government purchase forecaster disagreement, CPI forecaster disagreement and tax code expiration. Fig. 9 shows the pulse responses of precious metal returns to these four uncertainties at different lag periods and time points. These findings indicate that precious metal returns experience divergent responses to four uncertainties. With the expansion of lag lengths, the impact of news coverage and CPI forecaster disagreement has gradually weakened. However, the weakening trends of the effect of the remaining two components are not obvious. In addition, the response magnitudes of precious metal returns to news coverage and CPI forecaster disagreement are relatively greater. These results indicate that crude oil price shocks mainly affect the precious metal markets through news uncertainty and inflation uncertainty.

4. Conclusions and policy implications

Based on the background of commodity financialization, we have combined oil price shocks, economic policy uncertainty and precious metal returns into a unified framework and systematically studied the dynamic impacts generated by the two factors using the TVP-VAR model. In addition, we clarified the effect of economic policy uncertainty in the process of international oil price shocks affecting precious metal returns. The main conclusions are the following.

First, the impacts of oil price shocks and economic policy uncertainty on precious metal returns are time varying. Before the international financial crisis, crude oil prices showed a volatile upward trend, during which precious metal returns were impacted positively. After the 2008 financial crisis, crude oil prices fell off a cliff, which had a more negative effect on precious metal returns. In most cases, the impacts of economic policy uncertainty on precious metal returns have been positive, implying that precious metals perform well as a safe haven against economic policy risk. However, the efficiency of precious metals as a safe haven is not stable and

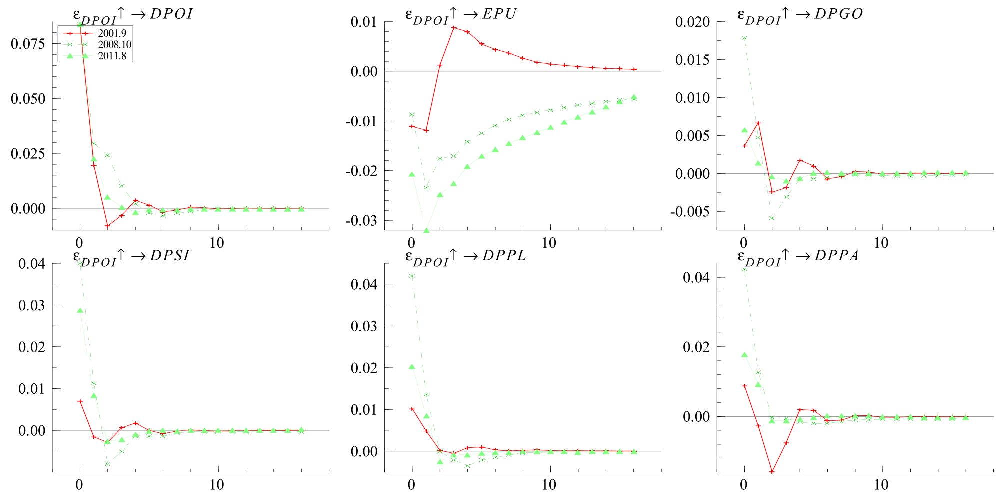

Fig. 7. The impulse responses of precious metal returns to oil price shocks at different time points.

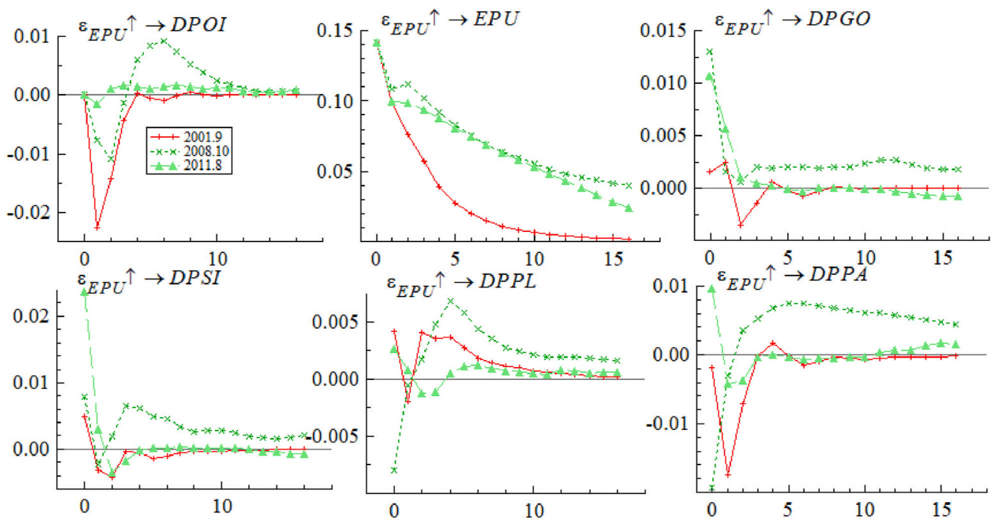

Fig. 8. The impulse responses of precious metal returns to economic policy uncertainty at different time points.

depends on economic conditions. Economic policy uncertainty magnifies the effects of oil price shocks. In addition, the negative impact caused by these two shocks will inevitably cause precious metal returns to rebound quickly, indicating that the precious metal market itself has a leverage effect (asymmetry).

Second, during a major economic crisis or emergency, we discover some evidence of overreactions in the precious metal market. Both impacts are rapid and increase in the short term, especially around the 9/11 terrorist attacks, the global financial crisis and the European debt crisis. However, there are significant differences in how these events affected precious metal returns at different points in time. During the global financial crisis and European debt crisis, the strength of the impact on precious metal returns was largest, while it was the weakest after the 9/11 terrorist attacks, proving that precious metal returns responded more strongly during the financial crisis, which further reflects the hedging function of the precious metal market.

Finally, the impacts of crude oil prices on precious metal returns are divergent in different lag periods. That is, crude oil price shocks significantly affect precious metal returns over the short term, and continue as it may, the degree of its effects is significantly weakened. However, the impacts of EPU on precious metal returns show convergence, which indicates that the spot precious metal market can effectively adjust under the effect of crude oil price shocks to ensure stable prices, but it cannot adjust to economic policy uncertainty shocks in a timely and effective manner. In a further study on the specific transmission channels of policy uncertainty, we discover that crude oil price shocks mainly affect the precious metal markets through news uncertainty and inflation uncertainty.

According to empirical results and analysis, international oil price shocks and economic policy uncertainty have dynamic impacts on precious metal markets. By combining specific analysis conclusions and current realities, this article attempts to put forward relevant suggestions.

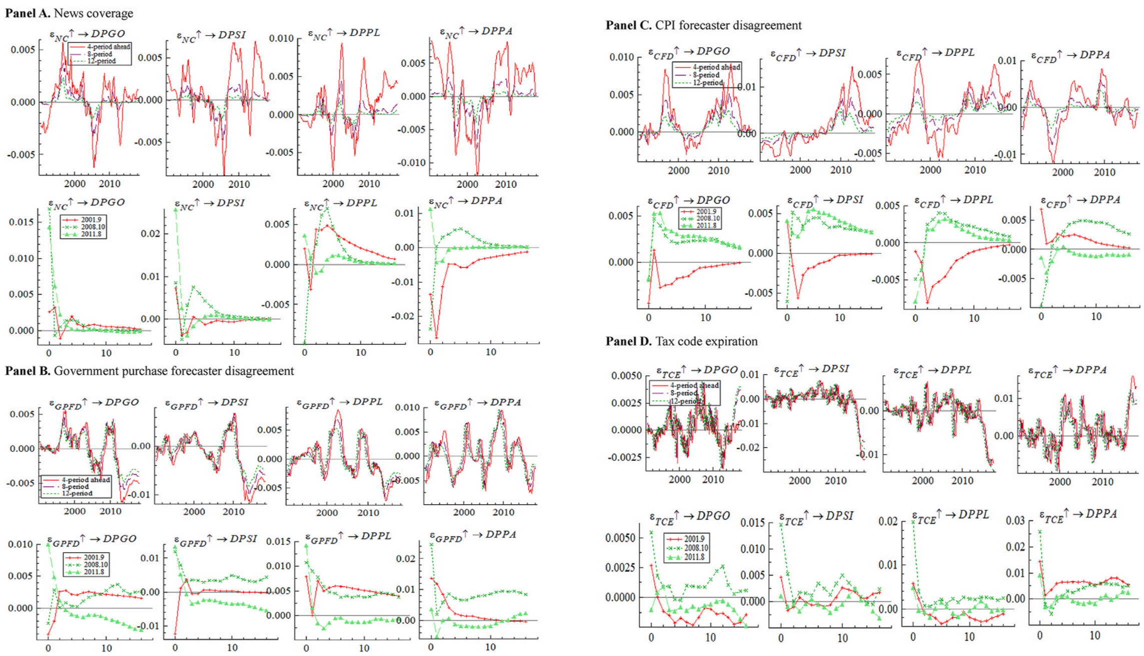

Fig. 9. The impulse responses of precious metal returns to four basic components of the economic policy uncertainty index.

Investors should pay more attention to the shocks discussed above when investing in precious metals. From empirical results, we find that the impacts on precious metal prices generated by these two shocks are time varying and complex, which brings significant risks to the precious metal market, particularly in times of major economic crisis and market turbulence. Investors should pay close attention to market changes, and dynamic portfolio management is required for oil price shocks and economic policy uncertainty to affect precious metal prices. Before investing, investors should collect as much information as possible and change their portfolio structure according to market trends to establish a risk-hedging mechanism. Moreover, there is evidence that the impact trend of oil price shocks will automatically weaken over time. It is recommended that investors not make panic or blind decisions when facing initial oil price shocks; instead, they should remain as rational as possible and avoid causing volatility through chaotic investment behavior.

Policymakers should establish a multilevel strategic oil reserve system with government-led national reserves and commercial reserves in parallel with market participants to improve the financial support system. They should also develop, promote and use new energy sources actively to reduce the dependence on fossil energy sources, such as petroleum. In addition, there is a need to accelerate the construction of the oil futures market to increase international oil pricing power, further mitigating the effect of international oil price fluctuations on spot precious metal market. Relevant management departments should also enrich the spot and futures varieties of precious metals and pay attention to the structural differences of different varieties in markets to formulate a differentiated trading mechanism. Furthermore, these departments should promote the price discovery function of the precious metal market and provide effective ways for related companies to avoid risks. However, at the same time, the “double-edged sword” feature of commodity financialization should not be overlooked which is to prevent immoderate speculative funds and the subsequent excessive financialization.

There is still some important and relevant work to be done. In the future, the economic policy uncertainty index constructed by Baker et al. (2016) can be used to further explore the impact of different economic policy uncertainties on macroeconomic and financial market returns (Hu & Chen, 2020). The TVP-VAR model used in this paper can be combined with spillover index to quantitatively measure the impact of oil price and economic policy uncertainty on precious metal returns, so as to judge the size of the relative role in the influencing mechanism.

Author statement

We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iref.2021.12.010.

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