Can gold or silver be used as a hedge against policy uncertainty and COVID-19 in the Chinese market?

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Abstract

Purpose – The purpose of this study is to present evidence as to whether the use of gold or silver can be justified as an asset to hedge against policy uncertainty and COVID-19 in the Chinese market.

Design/methodology/approach – By using a GARCH model with a generalized error distribution (GED), this study specifies that the gold (or silver) return is a function of a set of economic and uncertainty variables, which include volatility from interest rate innovation, a change in economic policy uncertainty (EPU), a change in geopolitical risk (GPR) and volatility due to pandemic diseases, while controlling for stock market returns, inflation rates, economic growth and the Chinese currency value.

Findings – This study employs monthly data of gold and silver prices over the period from January 2002 to August 2021 to examine hedging behavior. Estimated results show that the gold return is positively correlated to the stock return and a rise in uncertainty from economic policy innovation, geopolitical risk, volatility due to US interest rate innovation as well as COVID-19 infection. This result suggests that gold cannot be used to hedge against a stock market decline, but can be used to hedge against uncertainty in general. However, the silver return only responds positively to a rise in uncertainty from the inflation rate and geopolitical risk. Evidence shows that silver returns are negatively correlated with stock returns, and display hedging characteristics. However, the evidence lacks statistically significance during the COVID-19 period, suggesting that the role of silver as a safe-haven asset against stock market turmoil is weak for this time period.

Research limitations/implications – More general nonlinear specifications can be developed. The tests may include different measures of uncertainty that interact with each other or with the lagged error terms. An implication of the model is that gold can be used to hedge against a broad range of uncertainties for economic policy change, political risk and/or a pandemic. However, the use of gold as an asset to hedge against a stock downturn in Chinese market should be done with caution.

Practical implications – This study has important policy implications as regards a choice in assets in formatting a portfolio to hedge against uncertainty. Specifically, this study presents empirical evidence on gold and silver return behavior and finds that gold returns respond positively to heightened uncertainty. Thus, gold is a good asset to hedge against uncertainty arising from policy innovations and infectious disease uncertainty.

Social implications – This paper provides insightful information on the choice of assets toward hedging against risk in the uncertainty market conditions. It provides information to investors and policy makers to use gold price movements as a signal for detecting the arrival of uncertainty. This study also provides information for demanding a risk premium for infectious disease.

Originality/value – This study empirically analyzes and verifies the role that gold serves as a safe haven asset to hedge against uncertainty in the Chinese market. This paper contributes to the literature by presenting evidence of risk/uncertainty premiums for holding gold against various sources of uncertainty such as economic policy uncertainty, geopolitical risk and equity market volatility due to US interest rate innovation and/or COVID-19. This study finds evidence that supports the use of a nonlinear specification, which demonstrates the interaction of uncertainty with the lagged change of infectious disease and helps to explain the gold/silver return behavior. Further, evidence shows that the gold return is positively correlated to the stock return. This finding contrasts with evidence in the US market. However, silver returns are negatively correlated with stock returns, but this correlation becomes insignificant during the period of COVID-19.

Keywords Gold price, Silver price, Inflation, Economic policy uncertainty, Geopolitical risk, Safe-haven

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1. Introduction

Gold has been widely held by Chinese residents not only for its beauty but also for its capacity to retain value. During times of dramatic social change, economic downturn, financial crisis or war, gold is a favored instrument used as a hedge against risk (Capie *et al.*, 2005; Worthington and Pahlavani, 2007; Toraman *et al.*, 2011; Yousef and Shehadeh, 2020). This is because gold is a portable, measurable and universally accepted asset that can be easily converted into cash for consumption. It is, therefore, also internationally accepted as a means of investment. Similarly, silver is likely to share a similar role as gold. From an investment perspective, however, its status is somehow not compatible to gold. In practice, the inclination has been to use silver for industrial purposes.

There is a considerable number of studies (Chai *et al.*, 2019; Baur and Smales, 2020; Koh and Baffes, 2020) that examine the variations of gold prices in response to crises, economic or political shocks, but little attention has been given to the investigation of the behavior of silver asset prices. Further, the studies in the literature have mainly focused on the advanced markets where prices of gold are denominated by U.S. dollars (USD). In general, the literature documents that gold prices are sensitive to inflation pressures, economic failure, currency value downturn, and stock price variability, among others (Worthington and Pahlavani, 2007; Batten *et al.*, 2014; Beckmann *et al.*, 2015; Jones and Sackley, 2016; Pukthuanthong and Roll, 2011; Li and Lucey, 2017). Yet, the relevancy of applying these arguments to the Chinese gold market is less clear. The investigation of pricing in the silver market is not even mentioned unless it is in the context of historical discussions of inflation related to Ming's economy (Li, 2011).

There are good reasons to examine the behavior of gold and silver in Chinese markets. First, from a historical perspective, both gold and silver possess some unique monetary features in Chinese society. Particularly, gold has long been perceived as a precious metal that can "store value" for facilitating future investments and consumptions; whereas silver [*liang* (tael, about 1.33 oz.)] was used to serve as a "unit of account" and "means of payment" during the Ming (1368–1644) and Qing (1644–1911) dynasties (Chen, 1975). Second, China is the largest gold producer and consumer in the world market [1]. The use of gold has ranged from jewelry fabrication and various industrial applications to a vehicle of investment and a component of international reserves held by central banks for stabilizing exchange rate volatility. More important, gold is considered as a "flight-to-safety" asset to hedge against uncertainty and in turn provides a non-pecuniary income to economic agents. Given these special functions of gold/silver in the Chinese economy, it is of interest to study whether gold/silver can serve as a safe-haven asset or a hedge against uncertainty in times of market turmoil [2].

Evidence (Baur and Lucey, 2010; Ji *et al.*, 2020) suggests that gold acts as a safe-haven asset during the period of crises. However, Cheema *et al.* (2020) and Hasan *et al.* (2021) cannot find strong evidence to support gold has its safe-haven properties during the outbreak of COVID-19. A number of papers recently report that gold price sensitively responds to changes in economic policy uncertainty (EPU). For instance, the hedging ability of gold against EPU was favorably supported by the studies of Bilgin *et al.* (2018), Raza *et al.* (2018), and Yousef *et al.* (2021). The analysis was expanded by Baur and Smales (2020), Chiang (2021) and Li *et al.* (2021), who find evidence that gold becomes an asset to hedge against a rise in geopolitical risk (GPR).

Until the recent outbreak of COVID-19, analyses of gold price behavior have essentially ignored the impact of uncertainty due to health-related market threats. With the construction of the EMV index by Baker *et al.* (2020a, b), we are now able to obtain a health risk index($V_{D,t}$). The development of the EMV index, in fact, provides one of the motivations for this study, since we can now investigate the impact of the COVID-19 pandemic on gold returns. It is apparent that the spread of the pandemic caused enormous social and economic damage, sparked market fears and precipitated investors' rush to safe haven assets as a way of protecting against losses to their wealth. Koh and Baffes (2020) report that a rise in gold prices reflects markets' longing for a safe haven, which escalated during the COVID-19 pandemic (Yousef and Shehadeh, 2020; Yousef *et al.*, 2021; Chiang, 2022).

In response to the prevailing literature, this study develops an econometric model that incorporates the main economic factors that influence gold return. The elements of economic factors are: stock market return ($R_{m,t}$), inflation rate (Δp_t), GDP growth (Δy_t) and change in Chinese yuan exchange rate ($\Delta \mathrm{FX}_t$); the uncertainty variable are: economic policy uncertainty (EPU_t), geopolitical risk (GPR_t), financial market volatility due to interest rate innovation ($V_{r,t}$) and equity market volatility ($V_{D,t}$) arising from pandemic diseases. The economic variables follow the traditional wisdom in explaining gold/silver return (Christie-David *et al.*, 2000), while the uncertainty variables, which are based on the uncertainty indices provided by Baker *et al.* (2016), Davis (2016) and Baker *et al.* (2020a), reflect forward-looking uncertainty as reported by news outlets. The information captured in the uncertainty variables appears to more immediately reflect the elements that affect gold returns and are not subject to model prediction extracted from past patterns.

This study contributes to literature in the following aspects. First, gold and silver returns are expressed in both the US dollar (USD) and Chinese yuan (CNY). By examining the gold return equations expressed in two different measures of currencies, the estimated results are comparable; however, opposite signs of the estimated coefficients are exhibited in the exchange rate variable. Second, test results for a multivariate model, which includes both economic factors and uncertainty variables, differ from a simple regression model and produce more information content. The inclusion of different forms of uncertainty in a multivariate setting helps to alleviate the bias arising from a missing variable problem. Third, evidence suggests that the gold return is positively correlated with the stock return, indicating gold does not serve as a safe haven against the risk of a stock market downturn in China. Fourth, evidence shows that gold plays a significant role in hedging against the adverse impact arising from inflation pressures, Chinese yuan depreciation, heightened EPU, GPR and a rise in equity market volatility due to interest changes or triggered by worsening in the infectious diseases. However, the silver market reacts quite differently. Evidence shows silver returns rise with an increase in the inflation rate or a geopolitical threat, suggesting that silver can serve as a hedge against these risks. However, the negative correlation between the silver return and stock returns that resulted during the COVID-19 period is statistically insignificant, suggesting that silver serves as a weak safe-haven asset against the COVID-19 pandemic.

This paper is organized as follows. Section 2 provides a literature review for gold and silver return behavior and selects appropriate independent variables for empirical estimations. Section 3 develops an econometric model that is pertinent to empirical analyses. Section 4 describe the monthly data for empirical estimations. Section 5 reports empirical results for estimating gold and silver equations, including robustness tests. Section 6 reports the dynamic correlations of gold-silver and gold-stock and tests their parametric responses to changes in uncertainty variables. Section 7 contains the concluding remarks and implications.

2. The literature review

2.1 Gold returns and economic factors

Gold and silver prices have been considered to be correlated at times of an upward move in inflation rates, stressful economic condition and uncertainty associated with stock volatility, fiscal crisis and political upheaval. The early literature observes that development of inflation tends to increase the price of gold, suggesting that gold is a popular asset, which investors use to hedge the risk of inflation. Fortune (1987), Worthington and Pahlavani (2007) and Wang et al. (2011) find evidence that gold prices rise with the rate of inflation and, hence, gold is viewed as an effective hedge against inflation.

A rise in depreciation of a national currency value has been observed to drive a demand in gold among investors seeking protection against a currency further deterioration. Studies of Sjaastad and Scacciavillani (1996) and O'Connor et al. (2015) find evidence to support the notion that a currency depreciation leads to a rise in gold prices. Moreover, Güris and Kiran (2014) confirm that the gold price can be used as a hedge against the exchange rate depreciation for Turkish Lira. Seeking to investigate a related issue, some researchers prefer to focus on the relation between gold prices and the real effective exchange rate (REER). This line of investigation shows that an appreciation of the US dollar or a rise in the real effective exchange rate (REER) causes a decline in the gold price. This negative relation has been reported in the study by Bilgin et al. (2018).

In addition to these economic factors, gold price behavior is often affected by stock market conditions. When stock markets experience a severe downturn, risk adverse investors tend to sell off stocks to avoid losses from a further worsening in prices and replace stocks with gold. This behavior leads to a negative relationship between gold and stock prices as observed by Dhawan (2019) and empirically supported by Baur and Lucey (2010). Recent evidence by Shahzad et al. (2020) also reports that gold possesses a safe-haven quality due to its ability to hedge against stock price downturns. Turning to emerging market behavior, Chkili (2016) finds that gold can act as a safe-haven for investors in BRICS stock markets during a crisis period. Similarly, Kumar (2014) finds a negative correlation between stock and gold returns at turbulent periods in India. In the Chinese market, Wen and Cheng (2018) find that both gold and the US dollar can serve as a safe haven for stocks in China, especially when US dollars are used in hedges against downside risk.

2.2 Gold returns and uncertainties

Much attention of recent studies is given to the safe-haven hypothesis. Baur and Lucey (2010) define safe-haven assets as those uncorrelated or negatively correlated with other assets or portfolios in times of market turmoil. Bekiros et al. (2017) demonstrate that gold acts as a hedge and safe-haven asset for BRICS stocks in crisis and non-crisis periods. Using daily returns of the MSCI equity index. Ji et al. (2020) show that gold can be characterized as a safe-haven asset for the stock return in the early period of pandemic. Shahzad et al. (2020) show that gold acts as a safe-haven asset and hedge for a decline in G7 stocks. Cheema et al. (2020), however, cannot find evidence supporting the hypothesis that gold can serve as a COVID-19 safe-haven asset against stock losses in the Chinese market. Using high-frequency data, Akhtaruzzaman et al. (2021) show that gold act as a safe-haven asset for stock markets during early stage of pandemic (up to March 16, 2020). Then, gold lost its safe-haven feature in a later period (from March 17 to April 24, 2020). This finding indicates that the role of gold as safe-haven asset varies with time during different phases of pandemic. The existing literature demonstrates mixed results with respect to the safe-haven asset properties of gold during different stage of the COVID-19 pandemic. A number of reasons could be responsible for the failure of these studies to reach a consensus. For example, the difference in findings could be attributable to the use of different sample periods (or data frequencies), different methodologies, or the application of different economic conditions including different control variables to estimate the test equations. The variations in findings may also simply stem from spurious correlation.

While testing the safe-haven hypothesis that examines the gold/silver returns against stock market turmoil may depend on the control variables to be included, it can be more informative to focus on the uncertainty variables. Jubinski and Lipton (2013) report that ΔVIX_t has information content that positively predicts gold returns. Bomfim (2003) and

Caggiano *et al.* (2014) find that a change in EPU can increase stock market volatility, which causes change in gold prices. Jones and Sackley (2016) document that a worsening in EPU_t results in a rise in gold prices. Further evidence by Bilgin *et al.* (2018) indicates that gold prices are positively correlated with an upward shift in global EPU.

Extending this line of inquiry into uncertainty, researchers find that GPR plays a significant role in shaping investor behavior (Caldara and Iacoviello, 2019). The resulting fears are likely to drive investors to sell off their stocks, triggering a fly-to-quality phenomenon. Gozgor *et al.* (2019) find evidence that an increase of geopolitical risk significantly affects gold returns. Chiang (2021) documents that gold prices respond positively to an increase in GPR. Using multiple measures of uncertainty, Bouoiyour *et al.* (2018) report a positive correlation between gold returns and the uncertainty composite indicator during turmoil period.

Recent studies by Baker *et al.* (2020a, b), Yousef and Shehadeh (2020) and Yousef *et al.* (2021) also find that stock market volatility is associated with the COVID-19 pandemic, which in turn cause fears that spill over and impact gold prices. Koh and Baffes (2020) report that gold prices rise during the period of the COVID-19 pandemic crisis; Depren *et al.* (2021) find that gold price increases are associated with the number of confirmed cases and deaths in the pandemic period in Turkey. Sikiru and Salisu (2021) and Mahajan and Mahajan (2021) further confirm that gold serves as a safe-haven asset during periods of elevated COVID-19 pandemic. However, the evidence provided by Cheema *et al.* (2020) and Hassan *et al.* (2021) cannot find the support that gold can be serve as safe-haven asset during the time of COVID-19 pandemic.

Although silver was traditionally used as a medium of exchange as well as to store value in Chinese history (Chen, 1975), the current use of silver is mainly for industrial purposes, including its use in photovoltaic, electronics applications, railway infrastructure development, refrigeration and air-conditioning. Jewelry manufacture and home decoration are another source of demand for silver. Even though silver can be used for investment purpose, a weak speculative appetite among investors and falling prices of silver lead to lower activity from business participants. For this reason, silver shares a less significant role as a hedge against uncertainty under current market conditions [3]. This trend is consistent with the recent studies by Cheema *et al.* (2020) and Hassan *et al.* (2021), who cannot find evidence to support the hypothesis that silver was a safe-haven asset during the COVID-19 period.

3. Econometric model

3.1 The model

To incorporate the main arguments that explain gold/silver returns, we specify the equation as follow:

$$R_{i,t} = b_0 + b_1 R_{j,t} + b_2 \Delta p_t + b_3 \Delta y_t + b_4 \Delta \mathrm{FX}_t + b_5 \Delta \mathrm{EPU}_t + \; b_6 \Delta \mathrm{GPR}_t + \; b_7 \Delta V_{r,t} + b_8 \Delta V_{D,t-1} + \; u_t \tag{1}$$

where $b_1 = ?, b_2 > 0\, b_3 < 0, b_4 > 0 \;\; b_5 > 0, \;\; b_6 > 0, \; b_7 > 0\, b_8 > 0,$
$u_t | \mathrm{I}_{t-1} \backsim \mathrm{GED}(0, \sigma^2_{t-1}\;, \nu).$

$R_{i,t}$ is the asset i return, which refers to gold or silver return at time t ; $R_{j,t}$ denotes cross asset returns, $i \neq j$ and refers to stock market index return in the Chinese market for the dependent variable is $R_{i,t}$; Δp_t is the inflation rate; Δy_t is GDP growth rate measured by the growth of industrial production index; FX_t is Chinese yuan exchange rate, units of CNY per USD; EPU_t denotes economic policy uncertainty; GPR_t is geopolitical policy risk; $V_{r,t}$ is equity market volatility calibrated to interest rate changes; $V_{D,t}$ is equity market volatility attributed to disease infection, Δ is a change operator. All of the above are expressed in natural logarithms, except variables of $R_{i,t}$ and $R_{j,t}$, and u_t is an error series.

The variance equation is assumed to evolve with a GARCH (1,1) process as popularized by Bollerslev *et al.* (1992). The process is given by [4]:

$$\sigma_t^2 = \omega_0 + \omega_1 \varepsilon_{t-1}^2 + \omega_2 \sigma_{t-1}^2, \tag{2}$$

where σ_t^2 is conditional variance; ε_{t-1}^2 denotes a lagged shock squared term. Following Nelson (1991) and Li *et al.* (2005), the error series is assumed to follow the generalized error distribution (GED), since the GED can be used to handle the thickness of the tails of a distribution and has been demonstrated to have high flexibility in the estimation of financial time series (Li *et al.*, 2005; Mendoza-Velázquez and Galvanovskis, 2009).

3.2 Hypothesis

Equation (1) concisely summarizes variables that are pertinent to explaining gold and silver returns. Several underlying hypotheses are briefly discussed below.

3.2.1 Stock returns. Gold prices tend to appreciate as stocks tumble. This dynamic typically occurs when risk adverse investors encounter a persistent fall in stock prices. To avoid losses, investors tend to move funds from stock market o gold market. This behavior reflects an inverse relation between the gold return and stock return, that is, $b_1 < 0$. Baur and McDermott (2010) and Wen and Cheng (2018) find evidence that gold can be used to hedge against uncertainty from stock market downturn. However, this argument ignores the income/wealth effect, which holds as a stock return increases, the wealth effect may spill over to demand for gold as well, producing a positive relation, $b_1 > 0$.

3.2.2 Inflation rate. Theory predicts that a rise in inflation will bid up gold prices as households demand gold to preserve currency value or buy gold as an investment. This follows the notion of Worthington and Pahlavani (2007), who find that gold investment is an effective instrument for hedging against a rise in inflation. Thus, we expected that $b_2 > 0$.

3.2.3 Economic growth. During a recessionary period, which may be reflected in a slowdown of economic growth as implied by the Okun's law; uncertainty then rises, jeopardizing business activities. This slowdown will prompt fear among investors and induce them to purchase gold as a way to preserve wealth value. This market behavior leads to a negative relation between gold returns and income growth, that is, $b_3 < 0$. However, a rise in income may encourage investors or households to add gold or silver to their portfolios. This income effect may lead to. $b_3 > 0$.

3.2.4 Exchange rate. This variable is affected by the inflation rate. When the inflation rate of a country rises relatively to its trading partners, the country's currency value will depreciate. To hedge against losses from a depreciation in the country's currency value, domestic investors will typically buy gold to protect the purchasing power from losses in their domestic currency. This shift will lead to a positive relation between gold appreciation and CNY depreciation, that is, $b_4 > 0$. The sign might depend on whether the gold is in terms of USD or CNY. Studies of Sjaastad and Scacciavillani (1996) and Pukthuanthong and Roll (2011) find evidence to support a positive relationship for currency depreciation.

3.2.5 Uncertainty. Economic theory suggests that as uncertainty rises, businesses will delay investment decisions and households will postpone the purchase of luxury goods, which will create disruptions in business operations. This sluggish will prompt investors to buy gold to hedge against uncertainty. It is observed that uncertainty may come from a change in economic policy uncertainty ($\Delta \mathrm{EPU}_t$) (Baker *et al.*, 2016), an escalation of the geopolitical risk ($\Delta \mathrm{GPR}_t$) (Caldara and Iacoviello, 2019; Li *et al.*, 2021), a spillover of interest rate uncertainty onto financial market volatility, which in turn causes a spike in gold prices (Bouoiyour *et al.*, 2018; Yousef *et al.*, 2021). Uncertainty ($V_{D,t}$) may also arise from the coronavirus pandemic that stirs up social fears and generates economic losses. Baker *et al.* (2020b), Yousef *et al.* (2021). and Depren *et al.* (2021) find significant damaging effects from the uncertainty arising from the COVID-19 pandemic, which caused gold prices to rise (Wallace, 2020; Yousef and Shehadeh, 2020; Mahajan and Mahajan, 2021). These economic phenomena suggest that gold returns are positively correlated with deepening uncertainties of ΔEPU_t, ΔGPR_t, $\Delta V_{r,t}$ and $\Delta V_{D,t-1}$. That is, the coefficients for. $\{b_5, \ b_6, \ b_7, \text{ and } b_8\}$are positive.

4. Data

This study covers the sample period from January 2002 to August 2021. The data are monthly observations at the end of the month for gold and silver prices. Both gold and silver prices are expressed in the Chinese Yuan (CNY), $R^{\text{CNY}}_{G,t}$ and $R^{\text{CNY}}_{S,t}$, and the US dollar (USD), $R^{\text{USD}}_{G,t}$ and $R^{\text{USD}}_{S,t}$. The exchange rate is expressed as CNY/USD. The Chinese stock index obtained from Datastream, RI_t, is the return on stock index ($R_{I,t}$) adjusted for dividend yields denoted by $R_{m,t}$. The stock return is calculated by taking the first difference on natural logarithm of *RI* times 100. Table 1 provides a summary of $R^{\text{CNY}}_{G,t}$, $R^{\text{USD}}_{G,t}$, $R^{\text{CNY}}_{S,t}$, $R^{\text{USD}}_{S,t}$, $R_{I,t}$ and $R_{m,t}$. Interestingly, the gold return in USDs produces higher returns than the gold returns expressed by CNY, indicating an investment in gold expressed in USD outperforms that from stock and silver as noted by Wen and Cheng (2018). This simple calculation reflects a unique channel that Chinese investors/households could use USD to buy gold for hedging and/or investment purposes.

The inflation rate is obtained by taking the log-difference of CPI_t times 100; the GDP_t growth rate is achieved by taking the log-difference of industrial production index (IPI_t) times 100. The positive growth rate of GDP_t can be viewed as the inverse of a decline in the unemployment rate as implied by Okun's law. The foreign exchange rate, FX, is defined as the units of CNY per US dollar. The real effective exchange rate is defined as the nominal effective exchange rate divided by the GDP deflator. The implied volatility (VIX) is commonly treated as an expected risk factor (Whaley, 2009; Jubinski and Lipton, 2013), which is calculated using the expected S&P 100 index option volatility by the Chicago Board Options Exchange (CBOE). The CPI_t, IPI_t, FX_t, REER_t and VIX_t are obtained from *Economic Data* of the Federal Reserve Bank database of ST. Louis.

The EPU_t index was originally constructed by Baker *et al.* (2016). Davis (2016) extended the approach to construct the global indices, including China's EPU, which is published in *Economic*

Table 1. Summary statistics of gold, silver and stock price index returns in China

	$R^{\text{CNY}}_{G,t}$	$R^{\text{USD}}_{G,t}$	$R^{\text{CNY}}_{S,t}$	$R^{\text{USD}}_{S,t}$	$R_{I,t}$	$R_{m,t}$
Mean	0.6681	0.7674	0.2206	0.6523	0.3109	0.5557
Median	0.3508	0.8401	−0.2504	0.6279	0.1441	0.8469
Maximum	12.3668	13.0260	28.1297	26.6471	4.2903	24.3056
Minimum	−16.0295	−19.0951	−27.1220	−28.9372	−4.4824	−28.2016
Std. Dev	4.6014	4.9979	8.6832	8.9330	1.2965	7.5832
Skewness	−0.2524	−0.3476	−0.0827	−0.2798	0.0261	−0.5271
Kurtosis	3.6721	3.9274	4.6423	4.2042	3.4938	5.0646
Jarque-Bera	6.6234	12.5923	19.4122	14.9866	2.1886	50.3809
Observations	225	225	171	204	213	225

Note(s): $R^{\text{CNY}}_{G,t}$ is the gold return in Chinese Yuan (CNY), $R^{\text{USD}}_{G,t}$ is the gold return in U.S. dollars (USD), $R^{\text{CNY}}_{S,t}$ is the silver return in Chinese yuan, $R^{\text{USD}}_{S,t}$ is the gold return in USD, $R_{I,t}$ is the return of Chinese stock market index, $R_{m,t}$ is the stock market return plus dividend yield for Chinese stock index

Policy Uncertainty Index, and derived from terms: Economy, Policy and Uncertainty {E} and their variants in major newspapers. Baker *et al.* (2020a) also developed a newspaper-based Equity Market Volatility {E} index attributed to interest rate variations, V_r, and EMV index due to infectious disease, V_D. Both V_r and V_D are derived from counts of newspaper articles that involve E(economic), M (stock market), V (volatility), and ID (disease) and their variants across US newspapers (Backer *et al.*, 2020a) [5]. Following a similar procedure as that of Baker *et al.* (2016), Caldara and Iacoviello (2019) constructed a monthly index of GPR and updated the data by counting the occurrence of words involving geopolitical tensions from leading international newspapers [6]. The search identifies newspapers containing the words with geopolitical events: {military-related tensions, nuclear tensions, war threats, terrorist threats, terrorist acts or the beginning of a war}. The indices of EPU_t, GPR_t, V_r and V_D are downloaded from EPU website. A special feature of the news-based indices for EPU_t, GPR_t, V_r and V_D stems from their forward-looking approach, which reflects real time uncertainty as perceived and expressed by journalists. These variables differ from the risk variables that are derived from conditional variance (Bollerslev *et al.*, 1992; Bollerslev, 2010; Engle, 2009) or different measures of variability of stock returns proposed by Din *et al.* (1993).

5. Empirical evidence

5.1 Preliminary results

Using a simple regression model based on the GED-GARCH procedure, Equation (1) is estimated and the results are reported in Table 2. Most estimates are generally consistent with the theoretical predictions in the conventional analysis. Empirical evidence and the corresponding interpretation for each variable are given below.

First, the evidence indicates that the gold price appreciation rate is proportional to the inflation rate; the estimated positive coefficient, Δp_t, is statistically significant. This means that an increase in inflation will cause investors/households to buy gold as a way to hedge against a potential loss in financial wealth. This market phenomenon is consistent with the evidence documented by Worthington and Pahlavani (2007) in the US market.

Second, the parameter of income growth, Δy_t, is negative and significant, which implies that a positive change in the gold price is related to a rise in unemployment rate as suggested by Okun's law [7]. That is, an economic downturn and its ensuing higher unemployment rate would induce the public to move funds into gold in order to hedge against the rising uncertainty from an economic downturn.

Third, the evidence indicates the coefficient of $\Delta \mathrm{FX}_t$ is positive and statistically significant, meaning that a rise in depreciation of CNY will lead to an appreciation in gold price. This is essentially due to the fact that a depreciation of CNY could reflect a relative higher inflation rate, leading to a decline in CNY value; to hedge against a loss of CNY value, investors/households tend to buy gold and hence to bid up gold prices. This finding is consistent with results reported by Capie *et al.* (2005) and Pukthuanthong and Roll (2011), who find that a depreciation of a domestic currency leads to gold prices to increase.

Fourth, the evidence indicates a positive correlation between stock return and gold return as reflected in a significantly positive coefficient of $R_{m,t}$. This finding is in contrast to the literature that pertains to the US market, which usually shows a negative relation between stock and gold returns. Our result clearly contradicts the hypothesis that gold serves as a hedge against stock market downturn as indicated by Baur and Lucey (2010). Rather, our evidence of a positive coefficient for $R_{m,t}$ is consistent with the study documented by Hoang *et al.* (2015), who conclude that risk-averse investors prefer not to include gold in their portfolios to hedge against stock price movement in the Chinese market. The evidence of a gold-stock return relation is more in line with the wealth effect that holds as stock returns

Table 2. Simple regression estimates of gold returns in Chinese yuan associated with economic factors and uncertainty changes

	C	$R_{m,t}$	Δp_t	Δy_t	ΔFX_t	ΔEPU_t	ΔGPR_t	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	ω_0	ε^2_{t-1}	σ^2_{t-1}	R^2
$R^{\text{CNY}}_{G,t}$	0.6567	0.3515								2.1802	0.7346	0.7964	0.0109
	8.44	3.81								0.33	0.83	3.59	
$R^{\text{CNY}}_{G,t}$	0.3339		1.0938							1.9893	0.7652	0.8085	0.0176
	7.23		7.29							0.30	0.88	4.07	
$R^{\text{CNY}}_{G,t}$	0.7014			−0.1200						8.7017	1.8698	0.7595	0.0060
	19.37			−3.54						0.32	0.66	2.30	
$R^{CNY}_{G,t}$	0.7420				0.5108					9.6905	0.9379	0.7452	0.0070
	6.43				2.77					0.36	0.63	1.82	
$R^{\text{CNY}}_{G,t}$	0.6681					0.0049				2.7831	0.8279	0.7895	0.0059
	7.49					2.85				0.33	0.84	3.45	
$R^{\text{CNY}}_{G,t}$	0.6309						0.0083			2.1664	0.9194	0.7787	0.0005
	6.87						3.23			0.32	0.89	3.50	
$R^{\text{CNY}}_{G,t}$	0.4400							0.0068		0.9978	0.8470	0.8061	−0.0002
	6.72							4.43		0.24	0.98	4.66	
$R^{\text{CNY}}_{G,t}$	0.6318								0.0006	3.8629	1.2088	0.7841	0.0002
	8.67								2.10	0.32	0.78	3.15	

Note(s): Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. R^2 is the R-squared increase, investors/households are motivated to buy gold, which leads to an appreciation in its price. Therefore, the behavior of substituting gold for stocks is not so obvious in the Chinese market.

Fifth, the estimated coefficients of uncertainty variables involving $\{\Delta \mathrm{EPU}_t^{\mathrm{US}}, \Delta \mathrm{GPR}_t^{\mathrm{US}}, \Delta V_{r,t}, \text{and } \Delta V_{D,t-1}\}$ are positive and statistically significant for the gold return equation. These results indicate that investors/households are highly sensitive to reported news of uncertainty with respect to forward-looking indicators of EPU, GPR, and equity market volatility in relation to interest rate changes or COVID-19 spreads. Any upward shift of these uncertainties could bring about fears that lead stock prices to plummet, which would cause a flight-to-quality and demand for gold. The positive coefficient of the test results are consistent with Li and Lucey (2017), Beckmann *et al.* (2019) and Chai *et al.* (2019), who find ΔEPU has a significant impact on gold prices. Moreover, evidence is consistent with Brogaard *et al.* (2020), Bauer and Smales (2020), Li *et al.* (2021) and Chiang (2021) who document that a rise in ΔGPR causes gold prices to appreciate. Our results also conform with the literature pertaining to the volatility impact on gold prices due to interest rate innovations or the pandemic uncertainty (Baker *et al.*, 2020a, b; Yousef and Shehadeh, 2020; Sikiru and Salisu, 2021).

For comparison, we also estimate the result using the silver return as dependent variable. The results are reported in Table 3. With the exceptions of Δp_t and $\Delta \mathrm{GPR}_t$, all other estimated coefficients surprisingly exhibit inverse signs compared with those of the gold return equation. This result suggests that silver can be used to hedge against inflation and ΔGPR as well as a stock decline in China but not the other sources of uncertainties. This conclusion comes from the estimated results that Δp_t and $\Delta \mathrm{GPR}_t$ present positive signs and $R_{m,t}$ has a positive sign; while the other variables, including Δy_t, $\Delta \mathrm{FX}_t$, $\Delta \mathrm{EPU}_t$, $\Delta V_{r,t}$ and $\Delta V_{D,t-1}$, display opposite signs and are statistically significant. The evidence suggests that silver's ability to hedge against uncertainty is mixed. Even so, the evidence of a negative correlation between silver returns and stock returns is consistent with the notion that silver is an effective asset to hedge against a stock market downturn.

5.2 Multivariate analysis

Evidence derived from a simple regression model provides preliminary information for the parametric relation between two variables. However, this approach is likely to fall prone to partial equilibrium analysis and suffers from a missing variable problem. Thus, we utilize a multiple regression approach to estimate the gold and silver return equations (expressed in the Chinese yuan and US dollar). The results are reported in Table 4.

All the variables in Panel A on the right-hand side of the mean equation for $R_{G,t}^{\mathrm{CNY}}$ display the same sign as those in Table 2 and are statistically significant at the 5% level, suggesting stable and significant information content for various uncertainty measures. Similar findings are obtained from the $R_{G,t}^{\mathrm{USD}}$ equation. Differences occur in the coefficients of growth of income and exchange rate. The negative sign of $\Delta \mathrm{FX}_t$ shown in Table 4 (when the gold return is expressed in USD) is equivalent to a positive sign of $\Delta \mathrm{FX}_t$ in CNY. This is the case since a depreciation in CNY is equivalent to an appreciation of USD in a bilateral exchange rate conversion. Other estimates of the variables present very comparable qualitative results. The evidence leads us to the conclusion that gold is used as an asset to hedge against different sources of uncertainty as evidenced by positive coefficients of $\Delta \mathrm{EPU}_t$, $\Delta \mathrm{GPR}_t$, $\Delta V_{r,t}$ and $\Delta V_{D,t-1}$, which are statistically significant.

A review of the silver market estimations in Panel B (Table 4) indicates that with the exception of the coefficients of Δp_t, $\Delta \mathrm{EPU}_t$ and $\Delta \mathrm{GPR}_t$, all other coefficients present signs that are opposite from the estimates in gold market. Specifically, in addition to Δy_t and $\Delta \mathrm{FX}_t$, the coefficients of $\{\Delta V_{r,t}, \Delta V_{D,t-1}\}$ in $R_{S,t}^{\mathrm{CNY}}$ equation also show negative signs, indicating that an increase in these variables will have a negative impact on silver returns. This result

Table 3. Simple regression estimates of silver returns in Chinese yuan associated with economic factors and uncertainty changes

	C	$R_{m,t}$	Δp_t	Δy_t	$\Delta \mathrm{FX}_t$	$\Delta \mathrm{EPU}_t$	$\Delta \mathrm{GPR}_t$	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	ω_0	ε^2_{t-1}	σ^2_{t-1}	R^2
$R^{\mathrm{CNY}}_{S,t}$	0.1166	−0.4654								12.449	1.1038	0.6450	0.0015
	1.49	−7.56								0.74	1.08	2.77	
$R^{\mathrm{CNY}}_{S,t}$	−0.1792		2.8381							7.6131	0.8544	0.7142	0.0144
	−2.63		13.64							0.66	1.19	3.64	
$R^{\mathrm{CNY}}_{S,t}$	−0.2453			0.0546						24.083	3.6298	0.6152	−0.0006
	−8.63			3.63						0.56	0.93	2.31	
$R^{\mathrm{CNY}}_{S,t}$	−0.3131				−0.2355					11.455	1.0434	0.6761	−0.0015
	−4.22				−4.15					0.70	1.10	3.08	
$R^{\mathrm{CNY}}_{S,t}$	0.1985					−0.0230				9.8819	1.0867	0.6667	0.0170
	1.72					−6.32				0.68	1.08	3.00	
$R^{\mathrm{CNY}}_{S,t}$	−0.1034						0.0458			13.460	1.1422	0.6419	0.0079
	−8.59						6.79			0.75	0.99	2.58	
$R^{\mathrm{CNY}}_{S,t}$	−0.2352							−0.0112		8.0683	1.3711	0.6913	−0.0034
	−4.22							−9.34		0.59	1.06	3.11	
$R^{\mathrm{CNY}}_{S,t}$	0.7348								−0.0011	24.562	2.0569	0.8012	−0.0001
	10.47								−12.09	0.33	0.52	2.33	

Note(s): Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. R^2 is the R-squared

Table 4.
Estimates of gold and silver returns in CNY and USD in response to changes in economic factors and changes in uncertainty

	C	$R_{m,t}$	Δp_t	Δy_t	$\Delta \mathrm{FX}_t$	$\Delta \mathrm{EPU}_t$	$\Delta \mathrm{GPR}_t$	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	ω_0	ε_{t-1}^2	σ_{t-1}^2	$\overline{R}^2$
Panel A. Gold market													
$R_{G,t}^{\mathrm{CNY}}$	0.2941	0.1067	1.2083	−0.0079	0.3777	0.6930	0.0020	0.0070	0.0013	5.2255	0.5292	0.8228	0.02
	2.56	8.45	8.80	−2.09	3.31	2.71	4.27	3.81	5.25	0.30	0.56	2.52	
$R_{G,t}^{\mathrm{USD}}$	0.3588	0.1104	1.1447	0.0624	−0.6285	0.2454	0.0057	0.0018	0.0012	10.0848	0.6947	0.8113	0.04
	3.89	10.91	9.54	2.34	−5.92	1.41	1.38	1.71	1.85	0.41	0.53	2.62	
Panel B. Silver market													
$R_{S,t}^{\mathrm{CNY}}$	0.0443	−0.1140	1.6112	−0.0501	−0.1853	1.6722	0.0113	−0.0047	−0.0111	9.8908	0.9270	0.7110	0.03
	2.42	−5.37	8.45	−5.71	−1.56	2.16	1.63	−1.73	−5.77	0.65	1.02	3.06	
$R_{S,t}^{\mathrm{USD}}$	0.3452	−0.0205	1.9177	−0.0215	0.1166	0.9664	−0.0045	−0.0072	−0.0055	15.3390	1.0787	0.7639	0.01
	3.29	−2.31	9.40	−1.92	1.17	0.88	−2.19	−3.54	−3.40	0.51	0.94	3.46	

Note(s): The estimated equation is: $R_{G(S),t} = C + \beta_1 R_{m,t} + \beta_2 \Delta p_t + \beta_3 \Delta y_t + \beta_4 \Delta \mathrm{FX}_t + \beta_5 \Delta \mathrm{EPU}_t + \beta_6 \Delta \mathrm{GPR}_t + \beta_7 \Delta V_{r,t} + \beta_8 \Delta V_{D,t-1} + \varepsilon_t$
$R_{G,t}^{\mathrm{CNY}}$ ($R_{S,t}^{\mathrm{CNY}}$) is the gold (silver) return in terms of Chinese yuan. $R_{m,t}$ = domestic stock market index return, Δp_t = inflation rate, Δy_t = income growth, $\Delta \mathrm{FX}_t$ = change in exchange rate (RMB per USD), $\Delta \mathrm{EPU}_t$ = change in economic policy uncertainty, $\Delta \mathrm{GPR}_t$ = change in geopolitical policy risk, $\Delta V_{r,t}$ = equity market volatility calibrating interest rate, and $\Delta V_{D,t}$ = equity market volatility calibrating disease infection. The ω_0, ε_{t-1}^2 and σ_{t-1}^2 are constant, lagged shock squared, and lagged variance for GARCH(1,1) specification. Numbers in the first row are the estimated coefficients, the second row contains the *t*-statistics. The critical values of *t*-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. $\overline{R}^2$ is the adjusted *R*-squared

suggests that silver does not have the ability to hedge against these uncertainties. Similar to the gold market, the coefficient of $\Delta\mathrm{FX}_t$ shows an opposite sign in the $R_{S,t}^{\mathrm{USD}}$ equation vs. the $R_{S,t}^{\mathrm{CNY}}$ equation, and by so doing, demonstrates that an appreciation of the USD is equivalent to a depreciation of RMB; with the exception of Δp_t, $\Delta\mathrm{FX}_t$ and $\Delta\mathrm{EPU}_t$, the independent variables for $\{\Delta\mathrm{GPR}_t,\ \Delta V_{r,t}$, and $\Delta V_{D,t-1}\}$ display negative signs, providing no evidence that silver is capable of hedging against these risk/uncertainty. However, the negative correlation between the silver return and stock market return confirms the ability of silver to hedge against a stock downturn.

5.3 Test for safe-haven hypothesis

Literature (Baur and McDermott, 2010; Cheema *et al.*, 2020) suggests that the safe-haven hypothesis can be examined with the coefficient of stock return at normal times as well the coefficient under extreme market conditions. To perform the test, it is convenient to rewrite equation (1) as:

$$\begin{aligned} R_{G(S),t} \;&= C + \beta_1(1-D)\Delta R_{m,t} + \beta_2\Delta p_t + \beta_3\Delta y_t + \beta_4\Delta\mathrm{FX}_t + \beta_5\Delta\mathrm{EPU}_t + \ \beta_6\Delta\mathrm{GPR}_t \\ &\quad + \ \beta_7\Delta V_{r,t} + \ \beta_8\Delta V_{D,t-1} + \beta_9 D\cdot R_{m,t} + \varepsilon_t \end{aligned} \tag{3}$$

where β_1 is the parameter for hedge effect that measures the relation between the gold return and the stock return during time period in the data prior to the outbreak of COVID-19; β_9 is an incremental effect that highlights the extreme market conditions that apply during the time of COVID-19. The total effect is the sum of $(\beta_1 + \beta_9)$, D is the dummy variable, which sets to unity for the times during the COVID-19 pandemic (January of 2020 to the end of sample) and otherwise zero. If the coefficients of β_1 and β_9 are negative and statistically significant, the evidence favors of safe-haven hypothesis. On the other hand, if the coefficients of uncertainty variable for $\{\Delta p_t,\ (-\Delta y_t),\ \Delta\mathrm{FX}_t,\ \Delta\mathrm{EPU}_t,\ \Delta\mathrm{GPR}_t,\ \Delta V_{r,t}$and $\Delta V_{D,t-1}\}$ are positive and statistically significant, the evidence implies that gold is an asset to hedge against the uncertainties, since a rise in these uncertainty parameters will give rise to a damaging effect on financial assets or portfolios and induce investors to sell assets and switch to gold for hedging the financial loses.

Estimated results are reported in Table 5. The results in Panel A suggest that both safe-haven coefficients, β_1 and β_9 (and the total sum, $\beta_1 + \beta_9$) in gold return equation, are positive and statistically significant. Thus, evidence indicates that gold fails to act as a COVID-19 safe-haven asset against stock market losses in the Chinese market whether the gold return is measured by CNY (or USD) in tranquil or COVID-19 period. The evidence is consistent with the findings by Cheema *et al.* (2020) and Hasan *et al.* (2021) for testing gold returns and S&P500 returns.

A review of the silver market in Panel B shows that silver can be used to hedge against stock market losses during relatively tranquil period of uncertainty prior to COVID, since the estimated coefficients β_1 are negative and highly significant. However, the incremental coefficients β_9 are insignificant although the signs are negative, suggesting that silver's ability to act as a safe-haven asset during the COVID-19 crisis was weak. The evidence is consistent with the findings by Cheema *et al.* (2020) and Hasan *et al.* (2021), who fail to find that silver can serve as a safe-haven asset during the COVID-19 pandemic.

With respect to the estimated coefficients for the uncertainty variables, $\{\Delta\mathrm{EPU}_t,\ \Delta\mathrm{GPR}_t,\ \Delta V_{r,t}$and $\Delta V_{D,t-1}\}$, the estimated coefficients are positive and statistically significant for the gold market, supporting the notion that gold is an effective asset against uncertainty. However, the evidence from the silver market cannot achieve the same performance.

Table 5.
Robustness test of estimates of gold and silver returns in response to changes in economic factors, change in exchange rate, change in uncertainty and hedge for stock risk during COVID-19

	C	$R_{m,t}$	Δp_t	Δy_t	$\Delta \mathrm{FX}_t$	$\Delta \mathrm{EPU}_t$	$\Delta \mathrm{GPR}_t$	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	$D \cdot R_{m,t}$	ω_0	ε^2_{t-1}	σ^2_{t-1}	$\overline{R}^2$
Panel A. Gold market														
$R^{\mathrm{CNY}}_{G,t}$	0.3631	0.0822	1.0608	−0.0630	0.5769	0.6474	0.0044	0.0107	0.0039	0.5890	8.5185	0.6245	0.7977	0.04
	3.30	5.45	7.02	−2.58	6.07	3.81	3.90	5.50	4.80	5.87	0.30	0.51	1.91	
$R^{\mathrm{USD}}_{G,t}$	0.3545	0.0937	1.2713	0.0931	−0.1339	0.2697	0.0138	0.0072	0.0010	1.0867	15.1719	0.2775	0.9258	0.03
	6.35	14.47	12.35	4.06	−1.96	2.31	2.31	3.39	2.31	11.91	0.43	0.20	5.19	
Panel B. Silver market														
$R^{\mathrm{CNY}}_{S,t}$	0.3658	−0.1683	2.3911	0.4557	0.6648	−1.8310	0.0068	−0.0144	−0.0115	−0.1703	26.5902	1.6120	0.7551	0.05
	3.58	−6.28	9.99	7.71	5.98	−5.14	11.33	−3.87	−6.96	−1.26	0.44	0.68	2.42	
$R^{\mathrm{USD}}_{S,t}$	0.2954	−0.0883	1.7915	0.4628	−1.4815	−0.5333	−0.0122	−0.0101	−0.0081	−0.1403	33.2267	0.3852	0.8984	0.02
	3.26	−13.97	14.39	11.91	−8.54	−4.76	−3.56	−3.71	−8.09	−1.20	0.47	0.43	4.71	

Note(s): The estimated equation is: $R_{G(S),t} = C + \beta_1(1-D)\cdot R_{m,t} + \beta_2\Delta p_t + \beta_3\Delta y_t + \beta_4\Delta\mathrm{FX}_t + \beta_5\Delta\mathrm{EPU}_t + \beta_6\Delta\mathrm{GPR}_t + + \beta_7\Delta V_{r,t} + \beta_8\Delta V_{D,t-1} + \beta_9 D\cdot R_{m,t} + \varepsilon_t$ $R^{\mathrm{CNY}}_{G,t}$ ($R^{\mathrm{CNY}}_{S,t}$) is the gold (silver) return in terms of Chinese yuan. $R_{m,t}$ = domestic stock market index return, Δp_t = inflation rate, Δy_t = income growth, $\Delta\mathrm{FX}_t$ = change in exchange rate (RMB per USD), $\Delta\mathrm{EPU}_t$ = change in economic policy uncertainty, $\Delta\mathrm{GPR}_t$ = change in geopolitical policy risk, $\Delta V_{r,t}$ = equity market volatility calibrating interest rate, and $\Delta V_{D,t}$ = equity market volatility calibrating disease infection. D is a dummy variable, which sets to unity for the COVID-19 period starting from January 2020 to the end of the sample, otherwise zero, and ε_t is an error term. The ω_0, ε^2_{t-1} and σ^2_{t-1} are constant, lagged shock squared, and lagged variance for GARCH(1,1) model. Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. $\overline{R}^2$ is the adjusted R-squared

5.4 Interaction between EPU and infectious disease

It is conceivable that investors' attitude toward $\Delta\mathrm{EPU}_t$ may interact with the arrival of an infectious disease. To demonstrate, we write:

$$b_5 = c_0 + c_1 \Delta V_{D,t-1} + e_t \tag{4}$$

Substituting (4) into (1) and reparameterizing yields

$$\begin{aligned} R_{G(S),t} &= C + \beta_1 R_{m,t} + \beta_2 \Delta p_t + \beta_3 \Delta y_t + \beta_4 \Delta \mathrm{FX}_t + \beta_5 \Delta \mathrm{EPU}_t + \beta_6 \Delta \mathrm{GPR}_t + \beta_7 \Delta V_{r,t} \\ &\quad + \beta_8 \Delta V_{D,t-1} + \beta_9 \Delta \mathrm{EPU}_t \cdot \Delta V_{D,t-1} + \varepsilon_t \end{aligned} \tag{5}$$

where equation (5) is arrived by assuming that the coefficient of b_5 is a linear function of $\Delta V_{D,t-1}$. By substituting (4) into (1) and rearranging some terms, [8] we obtain a nonlinear term, $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1}$, which indicates an interaction between $\Delta\mathrm{EPU}_t$ and $\Delta V_{D,t-1}$. Thus, an increase in $\Delta V_{D,t-1}$, given $\Delta V_{D,t-1} > 0$, shows a widening spread of COVID-19 which exacerbates the $\Delta\mathrm{EPU}_t$, inducing a greater effect on gold returns.

The test results for equation (5), which are reported in Table 6, clearly indicate that the coefficients of $R_{m,t}$, Δp_t, Δy_t, $\Delta\mathrm{FX}_t$, $\Delta\mathrm{EPU}_t$, $\Delta\mathrm{GPR}_t$, and $\Delta V_{r,t}$ exhibit comparable signs to the results we reported in Tables 4 and 5 in $R^{\mathrm{CNY}}_{G,t}$ equation and are statistically significant. The evidence is consistent with the risk premium hypotheses for increases in $\Delta\mathrm{EPU}_t$, $\Delta\mathrm{GPR}_t$ and/or. $\Delta V_{r,t}$.

Focusing on the effects of Δ COVID-19 pandemic in Panel A of Table 6, evidence shows that the coefficients of both $\Delta V_{D,t-1}$ and $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1}$ are positive and statistically significant. The significantly positive coefficient of $\Delta V_{D,t-1}$ exhibits the direct impact from a change of COVID-19 in time t–1, showing a flight-to-quality (gold). The evidence is consistent with the findings reported by Yousef and Shehadeh (2020), Akhtaruzzaman *et al.* (2021), and Mahajan and Mahajan (2021), who find gold returns are higher during periods when the number of global coronavirus cases are increasing.

The positive sign for the product term, $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1}$, reflects the impact of investors' rising fears as the volatility of COVID-19 intensifies ($\Delta V_{D,t-1} > 0$). This volatility interacts with $\Delta\mathrm{EPU}_t$ (Chiang, 2022), creating an indirect effect on gold returns. Moreover, an examination of the restriction of $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1} = 0$ produces a Chi-squared statistic of 125.06, which is significant at the 1% level, prompting us to reject the null. Thus, evidence confirms, from both an economic rationale and our statistical results, that investors perceive gold as an effective asset during times of elevated COVID-19 pandemic uncertainty.

5.5 Robustness test for different measures of exchange rate

In the literature, the US real effective exchange rate (REER) is a commonly used to explain gold prices [9]. An increase in REER implies a stronger currency value, which signifies a promising economic prospect with an expectation of low inflation or rise in asset prices. Under this circumstance, investors tend to short gold holdings, resulting in a decline in gold price. Thus, it is anticipated a negative correlation between gold returns and a rise in REER. On the basis of this observation, the $\Delta\mathrm{FX}_t$ is replaced by the US $\Delta\mathrm{REER}_t$ in the test equation. The estimated results are reported in Table 7. Evidence from the coefficients of $\Delta\mathrm{REER}_t$ presents negative signs, which are statistically significant, whether the coefficient is measured in gold returns or silver returns in CNY or USD. The negative relation for the slope of $\Delta\mathrm{REER}_t$ is consistent with the positive sign of the slope of $\Delta\mathrm{FX}_t$ as shown in Table 6 since an appreciation of USD is equivalent to a depreciation of CNY. The result of a rise in REER_t tends to boost the economy and other asset prices, which in turn depress gold price returns. The evidence is in line with findings documented by Pukthuanthong and Roll (2011) and Chiang (2022). Note that the evidence of $\Delta\mathrm{REER}_t$ and $\Delta\mathrm{GPR}_t$ is consistent with the results of

Table 6. Estimates of nonlinear estimates of gold and silver returns in CNY and USD in response to changes in economic factors, change in exchange rate, change in uncertainty and nonlinear interacting between uncertainties: Sample period: 2002.M2 – 2021M8

	C	$R_{m,t}$	Δp_t	Δy_t	$\Delta \mathrm{FX}_t$	$\Delta \mathrm{EPU}_t$	$\Delta \mathrm{GPR}_t$	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	$\Delta \mathrm{EPU}_t \cdot \Delta V_{D,t-1}$	ω_0	ε^2_{t-1}	σ^2_{t-1}	$\overline{R}^2$
Panel A. Gold market														
$R^{\mathrm{CNY}}_{G,t}$	0.2854	0.0971	0.8123	−0.1313	0.2637	0.7602	0.0060	0.0089	0.0014	0.0004	7.7810	1.2692	0.8211	0.03
	3.31	10.52	4.57	−3.12	4.77	4.66	1.89	3.49	2.23	11.18	0.24	0.54	2.48	
$R^{\mathrm{USD}}_{G,t}$	0.3660	0.1081	1.1338	0.0785	−0.6696	0.1041	0.0098	0.0051	0.0013	−0.003	9.9495	0.6152	0.8248	0.03
	5.19	10.72	9.63	3.69	−6.75	4.52	2.23	2.60	2.00	−1.52	0.42	0.51	2.78	
Panel B. Silver market														
$R^{\mathrm{CNY}}_{S,t}$	0.3225	−0.0982	2.7388	0.6002	−0.1446	−2.362	0.0008	−0.008	−0.0135	0.0009	16.1884	1.5821	0.7536	0.03
	2.13	−5.76	14.29	8.51	−1.84	−5.69	0.15	−2.75	−12.55	0.55	0.47	0.82	2.94	
$R^{\mathrm{USD}}_{S,t}$	0.4958	0.0217	2.4786	0.4701	−0.4895	−0.8874	−0.0134	0.0081	−0.0098	−0.0066	46.7454	0.1500	0.6001	0.03
	4.76	1.67	12.33	11.73	−3.04	−3.45	−2.10	2.98	−12.66	−3.67	0.48	0.47	0.79	

Note(s): The equation is: $R_{G(S),t} = C + \beta_1 R_{m,t} + \beta_2 \Delta p_t + \beta_3 \Delta y_t + \beta_4 \Delta \mathrm{FX}_t + \beta_5 \Delta \mathrm{EPU}_t + \beta_6 \Delta \mathrm{GPR}_t + \beta_7 \Delta V_{r,t} + \beta_8 \Delta V_{D,t-1} + \beta_9 \Delta \mathrm{EPU}_t \cdot \Delta V_{D,t-1} + \varepsilon_t$
$R^{\mathrm{CNY}}_{G,t}$ ($R^{\mathrm{CNY}}_{S,t}$) is the gold (silver) return in terms of Chinese yuan. $R_{m,t}$ = domestic stock market index return, Δp_t = inflation rate, Δy_t = income growth, $\Delta \mathrm{FX}_t$ = change in exchange rate (RMB per USD), $\Delta \mathrm{EPU}_t$ = change in economic policy uncertainty, $\Delta \mathrm{GPR}_t$ = change in geopolitical policy risk, $\Delta V_{r,t}$ = equity market volatility calibrating interest rate, and $\Delta V_{D,t}$ = equity market volatility calibrating disease infection. The ω_0, ε^2_{t-1} and σ^2_{t-1} are constant, lagged shock squared, and lagged variance for GARCH(1,1) specification. Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. $\overline{R}^2$ is the adjusted R-squared

Table 7. Robustness test of nonlinear estimates of gold and silver returns in response to changes in economic factors, change in real effective exchange rate, change in uncertainty and nonlinear interacting between uncertainties: Sample period: 2002.M2 – 2021M8

	C	$R_{m,t}$	Δp_t	Δy_t	ΔREER_t	ΔEPU_t	ΔGPR_t	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	$\Delta \text{EPU}_t \cdot \Delta V_{D,t-1}$	ω_0	ε^2_{t-1}	σ^2_{t-1}	$\overline{R}^2$
Panel A. Gold market														
$R^{\text{CNY}}_{G,t}$	0.2450	0.0666	0.5155	−0.1151	−0.8324	1.0427	0.0088	0.0092	0.0038	0.0001	2.7765	0.5252	0.8422	0.07
	2.29	4.67	3.79	−4.13	−6.50	4.41	1.87	3.37	3.36	3.30	0.29	0.63	3.53	
$R^{\text{USD}}_{G,t}$	0.3864	0.0622	0.9737	0.0240	−1.0108	0.6287	0.0187	0.0086	0.0028	0.0005	4.9367	0.4980	0.9183	0.09
	5.31	8.46	9.28	15.29	−16.43	4.76	3.22	6.36	3.20	9.87	0.31	0.44	6.01	
Panel B. Silver market														
$R^{\text{CNY}}_{S,t}$	0.4057	−0.1780	2.0869	0.6223	−1.2323	−2.1686	0.0067	−0.0083	−0.0088	−0.0025	15.2181	1.2355	0.7897	0.05
	3.43	−11.13	17.11	11.26	−10.95	−5.05	1.90	−2.95	−8.25	−0.87	0.44	0.82	3.30	
$R^{\text{USD}}_{S,t}$	0.5051	−0.0568	2.1278	0.4484	−1.7521	−0.5522	−0.0054	−0.0027	−0.0063	−0.0058	25.8005	0.6042	0.8750	0.08
	4.10	−6.57	10.98	8.86	−21.22	−2.20	−1.06	−0.81	−7.18	−2.41	0.47	0.59	4.44	

Note(s): The equation is: $R_{G(S),t} = C + \beta_1 R_{m,t} + \beta_2 \Delta p_t + \beta_3 \Delta y_t + \beta_4 \Delta \text{REER}_t + \beta_5 \Delta \text{EPU}_t + \beta_6 \Delta \text{GPR}_t + \beta_7 \Delta V_{r,t} + \beta_8 \Delta V_{D,t-1} + \beta_9 \Delta \text{EPU}_t \cdot \Delta V_{D,t-1} + \varepsilon_t$
$R^{\text{CNY}}_{G,t}$ ($R^{\text{CNY}}_{S,t}$) is the gold (silver) return in terms of Chinese yuan. The superscript USD means US dollar. $R_{m,t}$ = domestic stock market index return, Δp_t = inflation rate, Δy_t = income growth, ΔREER_t = change in US real effective exchange rate, ΔEPU_t = change in economic policy uncertainty, ΔGPR_t = change in geopolitical policy risk, $\Delta V_{r,t}$ = equity market volatility calibrating interest rate, and $\Delta V_{D,t}$ = equity market volatility calibrating disease infection. The ω_0, ε^2_{t-1} and σ^2_{t-1} are constant, lagged shock squared, and lagged variance for GARCH(1,1) specification. Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. $\overline{R}^2$ is the adjusted R-squared

Gozgor *et al.* (2019) who utilize Bayesian graphical structural vector autoregression model. With respect to the other variables, the estimated equation in Table 7 produces very comparable results as those obtained from Table 6.

5.6 Robustness test for using stock implied volatility (VIX) as an alternative measure

Whaley (2009) observes that the VIX spikes during times of stock market turmoil. Bilgin *et al.* (2018) and Chai *et al.* (2021) uncover that VIX has a positive impact on gold prices. This happens since a rise in the VIX creates fears, which drive risk averse investors to short stock and long gold. Thus, it is expected that a rise in gold prices is positively correlated with an increase in VIX. As a point of comparison to approaches taken in the literature, this section conducts a robustness test by replacing the $\Delta\mathrm{EPU}_t$ with the US market implied volatility, $\Delta\mathrm{VIX}_t^{\mathrm{US}}$. In practice, market participants perceive that information of $\Delta\mathrm{VIX}_t^{\mathrm{US}}$ appears to be more visible, which is often viewed as a fear index in world financial markets given the dominant role of the US position (Rapach *et al.*, 2013; Chiang, 2019, 2020). The estimates estimated by replacing $\Delta\mathrm{VIX}_t^{\mathrm{US}}$ in the test equation are reported in Table 8.

Consistent with the estimator of China's $\Delta\mathrm{EPU}_t$, the coefficient of $\Delta\mathrm{VIX}_t^{\mathrm{US}}$ displays negative sign and is statistically significant. This finding is consistent with the market behavior that arise in $\Delta\mathrm{VIX}_t^{\mathrm{US}}$ will produce fears that cause investors to sell stocks and move to gold as a way to hedge risk. Thus, we observe the positive relation between gold return and $\Delta\mathrm{VIX}_t^{\mathrm{US}}$. This finding is in line with the evidence provided by Jublinski and Lipton (2013). Checking other variables, we find the estimates are comparable. Thus, the model is robust using different measures of market uncertainty and different exchange rate information [10].

By comparing the estimated results from Tables 6–8, several empirical findings are worth of noting. First, using $\Delta\mathrm{REER}_t$ in estimating gold return equation produces a compatible result as that for $\Delta\mathrm{FX}_t$, since the estimated result, which presents a negative sign for $\Delta\mathrm{REER}_t$ is equivalent to an estimated result with a positive sign for $\Delta\mathrm{FX}_t$. Second, the performance of $\Delta\mathrm{EPU}_t$ has a comparable result to that for $\Delta\mathrm{VIX}_t^{\mathrm{US}}$, since an increase in these variables tends to produce fears that would cause risk aversion investors to shift to gold, driving up its demand and biding up gold prices. Third, the estimated results suggest that a change in COVID-19 pandemic as proxied by $\Delta V_{D,t-1}$ has a direct effect on gold returns; yet evidence also shows an indirect effect via its interaction with the uncertainty/risk variable. The revelation of this indirect effect goes beyond the findings in the existing literature (Akhtaruzzaman *et al.*, 2021; Chai *et al.*, 2021; Yousef *et al.*, 2021).

5.7 Stock returns, gold/silver returns and uncertainties

The reverse relation between gold returns and stock returns (while holding the other variables unchanged) is an interesting phenomenon to examine (Gao and Zhang, 2016). Following the spirit of equation (5), the stock return equations are estimated twice – restricted and unrestricted equations. The restriction is the interactive term: $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1} = 0$. The results are reported in Part A of Table 9. The Chi-squared statistics for testing the restriction of $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1} = 0$ is 14.64, which is rejected at the 1% level. This indicates the specification of including an interacting term is appropriate in the unrestricted stock return equation. Focusing on the unrestricted equation, the estimated coefficients, including $\{\Delta\mathrm{FX}_t,\ \Delta\mathrm{EPU}_t,\ \Delta\mathrm{GPR}_t,\ \Delta V_{r,t},\ \Delta V_{D,t-1}$ and $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1}\}$ present negative signs and exhibit opposite signs as compared with the $R_{G,t}^{\mathrm{CNY}}$ equation in the first row of Table 6. This evidence suggests that stock and gold returns generally respond to uncertainty variables $\{\Delta\mathrm{FX}_t,\ \Delta\mathrm{EPU}_t,\ \Delta\mathrm{GPR}_t,\ \Delta V_{r,t},\ \Delta V_{D,t-1}$ and $\Delta\mathrm{EPU}_t \cdot \Delta V_{D,t-1}\}$, in the opposite directions. This evidence of negative coefficients for the arguments of $\{\ldots\}$ in the stock return equation

Table 8. Robustness test of nonlinear estimates of gold and silver returns in response to changes in economic factors, change in US real effective exchange rate, change in US implied volatility and nonlinear interacting between uncertainties: Sample period: 2002.M2 – 2021M8

	C	$R_{m,t}$	Δp_t	Δy_t	ΔREER_t	$\Delta \text{VIX}_t^{\text{US}}$	ΔGPR_t	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	$\Delta \text{VIX}_t^{\text{US}} \cdot \Delta V_{D,t-1}$	ω_0	ε_{t-1}^2	σ_{t-1}^2	$\overline{R}^2$
Panel A. Gold market														
$R_{G,t}^{\text{CNY}}$	0.6713	0.0587	0.2700	−0.0379	−0.8373	0.0294	0.0066	0.0046	0.0035	0.0002	10.9690	0.5981	0.7470	0.04
	9.53	5.18	3.33	−2.88	−9.87	6.07	2.16	2.29	4.78	2.08	0.36	0.55	1.56	
$R_{G,t}^{\text{USD}}$	0.4655	0.0687	1.0060	0.1574	−1.0090	0.0117	0.0171	0.0071	0.0020	0.0000	12.8975	0.4089	0.8694	0.08
	6.28	4.98	6.97	4.37	−15.22	3.00	4.42	3.72	3.47	6.39	0.44	0.32	3.10	
Panel B. Silver market														
$R_{S,t}^{\text{CNY}}$	0.4057	−0.1780	2.0869	0.6223	−1.2323	−2.1686	0.0067	−0.0083	−0.0088	−0.0025	15.2181	1.2355	0.7897	0.05
	3.43	−11.13	17.11	11.26	−10.95	−5.05	1.90	−2.95	−8.25	−0.87	0.44	0.82	3.30	
$R_{S,t}^{\text{USD}}$	0.1241	−0.1558	2.1961	0.4583	−1.3409	−0.0101	0.0033	−0.0118	−0.0084	0.0002	10.8590	1.6547	0.7627	0.05
	1.59	−11.64	13.34	4.20	−14.22	−3.50	9.93	−3.05	−6.11	2.06	0.36	0.86	3.17	

Note(s): The equation is: $R_{G(S),t} = C + \beta_1 R_{m,t} + \beta_2 \Delta p_t + \beta_3 \Delta y_t + \beta_4 \Delta \text{REER}_t + \beta_5 \Delta \text{VIX}_t^{\text{US}} + \beta_6 \Delta \text{GPR}_t + \beta_7 \Delta V_{r,t} + \beta_8 \Delta V_{D,t-1} + \beta_9 \Delta \text{VIX}_t^{\text{US}} \cdot \Delta V_{D,t-1} + \varepsilon_t$
$R_{G,t}^{\text{CNY}}$ ($R_{S,t}^{\text{CNY}}$) is the gold (silver) return in terms of Chinese yuan. The superscript USD means US dollar. $R_{m,t}$ = domestic stock market index return, Δp_t = inflation rate, Δy_t = income growth, ΔREER_t = change in US real effective exchange rate, $\Delta \text{VIX}_t^{\text{US}}$ = change in implied volatility in US mark, ΔGPR_t = change in geopolitical policy risk, $\Delta V_{r,t}$ = equity market volatility calibrating interest rate, and $\Delta V_{D,t}$ = equity market volatility calibrating disease infection. The ω_0, ε_{t-1}^2 and σ_{t-1}^2 are constant, lagged shock squared, and lagged variance for GARCH(1,1) specification. Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. $\overline{R}^2$ is the adjusted R-squared

Table 9.
Estimates of stock returns in response to gold (silver) return, economic factors and uncertainties: Sample period: 2002.M2 – 2021M8

	C	$R_{G,t}^{CNY}$	Δp_t	Δy_t	$\Delta \mathrm{FX}_t$	$\Delta \mathrm{EPU}_t$	$\Delta \mathrm{GPR}_t$	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	$\Delta \mathrm{EPU}_t \cdot \Delta V_{D,t-11}$	ω_0	ε_{t-1}^2	σ_{t-1}^2	$\overline{R}^2$
Panel A. Gold market														
$R_{m,t}$	0.1615	0.2921	0.9801	0.1973	−0.8844	−1.5393	−0.0050	−0.0257	−0.0042	–	5.4638	0.4904	0.8076	0.06
	1.11	8.94	3.82	2.98	−7.56	−6.06	−2.24	−8.24	−3.83	–	0.48	0.93	4.25	
$R_{m,t}$	0.2010	0.2854	1.1865	0.1953	−0.8383	−1.7698	−0.0035	−0.0232	−0.0040	−0.0001	5.5917	0.4677	0.8028	0.05
	1.49	10.22	5.17	3.80	−10.67	−5.23	−4.41	−6.68	−2.40	−3.45	0.49	0.96	4.17	
Panel B. Silver market														
$R_{m,t}$	−0.0240	−0.0528	0.5330	0.4505	−0.9752	−3.0439	−0.0118	−0.0281	−0.0002	–	4.6075	0.4785	0.7807	0.05
	−1.88	−3.28	2.10	5.38	−7.61	−8.19	−1.11	−6.89	−3.42	–	0.45	0.88	3.61	
$R_{m,t}$	0.0204	−0.0832	0.8178	0.4387	−0.9105	−3.2621	−0.0152	−0.0321	0.0002	0.0097	5.3545	0.3978	0.7799	0.05
	2.91	−4.23	2.42	3.42	−7.68	−5.40	−1.73	−8.10	3.07	3.22	0.50	0.87	3.44	

Note(s): The equation is: $R_{m,t} = C + \beta_1 R_{G(S),t} + \beta_2 \Delta p_t + \beta_3 \Delta y_t + \beta_4 \Delta \mathrm{FX}_t + \beta_5 \Delta \mathrm{EPU}_t + \beta_6 \Delta \mathrm{GPR}_t + \beta_7 \Delta V_{r,t} + \beta_8 \Delta V_{D,t-1} + \beta_9 \Delta \mathrm{EPU}_t \cdot \Delta V_{D,t-1} + \varepsilon_t$
$R_{m,t}$ = domestic stock market index return, $R_{G,t}^{\mathrm{CNY}}$ ($R_{S,t}^{\mathrm{CNY}}$) = the gold (silver) return in terms of Chinese yuan; gold (silver) returns in CNY, $R_{G(S),t}^{\mathrm{CNY}}$, Δp_t = inflation rate, Δy_t = income growth, $\Delta \mathrm{FX}_t$ = change in exchange rate (CNY per USD), $\Delta \mathrm{EPU}_t$ = change in economic policy uncertainty, $\Delta \mathrm{GPR}_t$ = change in geopolitical policy risk, $\Delta V_{r,t}$ = equity market volatility calibrating interest rate, and $\Delta V_{D,t}$ = equity market volatility calibrating disease infection. The ω_0, ε_{t-1}^2 and σ_{t-1}^2 are constant, lagged shock squared, and lagged variance for GARCH(1,1) specification. Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. $\overline{R}^2$ is the adjusted R-squared

implies that a rise in currency depreciation or an escalation in uncertainty will result in a plunge in stock returns, causing a flight-to-quality and demand for gold.

Turning to the $R_{m,t}$ equation in Panel B, where the independent variable $R_{G,t}$ is replaced with $R_{S,t}$, we obtain comparable qualitative results, with the exception of the coefficient of variable $R_{S,t}$ which displays a significant negative sign, implying silver and stock can be combined to form a diversity portfolio.

6. Implication: dynamic correlation with uncertainty

Although the above evidence leads us to conclude that the gold-stock returns are positively correlated, and silver-stock returns are negatively correlated, these results are based on a procedure derived from a static regression model. In practice, the parametric relations vary with time, especially under extreme market conditions. To examine the dynamic relations between gold/silver and stock returns, a dynamic conditional correlation (DCC) procedure is used for measuring the two asset returns, which are denoted by $\rho_{ij,t}$. The DCC model was developed by Engle (2002, 2009) and then applied by Chiang *et al.* (2007a) and Chiang (2021). To illustrate, $\rho_{ij,t} = \frac{h_{ij,t}}{\sqrt{h_{i,t}}\sqrt{h_{j,t}}}$, where $h_{ij,t}$ is specified as a 2×2 time-varying covariance matrix of ε_t, and the unconditional variance matrix of ε_t is the standardized residuals of asset returns (gold and silver) [11]. The time-varying conditional dynamic correlations for gold-silver and gold-stock returns (vertical axis) over time (horizontal axis) expressed in CNY are depicted in Figures 1 and 2, respectively. Obviously, these two sets of correlations for asset returns exhibit different time paths due to the fact they respond differently to the related state variables.

To explain the time-varying relations, it is relevant to estimate the model by linking the time-varying correlation coefficient series to a set of explanatory variables as given by equation (6).

$$\widehat{\rho}_{ij,t}^{\text{CNY}} = \phi_0 + \phi_1 \Delta FX_t + \phi_2 \Delta \text{EPU}_t + \phi_3 \Delta \text{GPR}_t + \phi_4 \Delta V_{r,t} + \phi_5 \Delta V_{D,t} + \varepsilon_t \tag{6}$$

where $\widehat{\rho}_{ij,t}^{\text{CNY}}$ is the conditional correlation of asset returns i and j in terms of CNY. A Fisher transformation of the correlation series (Chiang *et al.*, 2007a; Chiang, 2021) of asset i and j is obtained by using $\widehat{\rho}_{ij,t}^{\text{CNY}} = \frac{1}{2}\left(\ln\left[\frac{1+\widehat{\rho}_{ij,t}}{1-\widehat{\rho}_{ij,t}}\right]\right)$. This transformation is used because there are

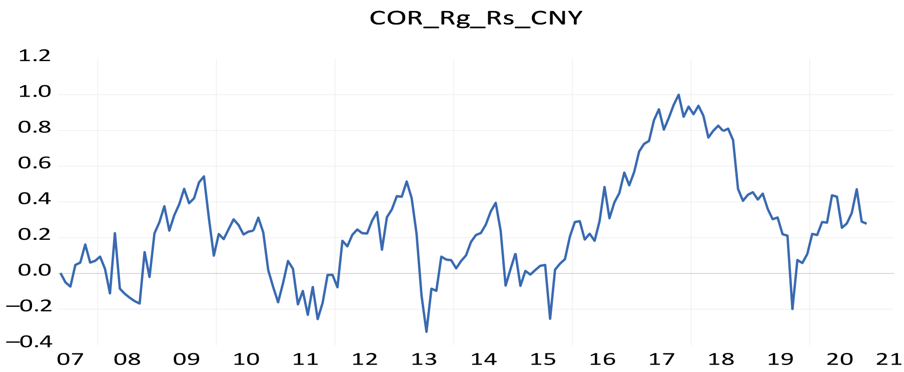

Figure 1. Conditional dynamic correlations between gold return and silver return (vertical axis) over time (horizontal axis) in CNY

negative values in $\widehat{\rho}_{ij,t}$ series as shown in Figures 1 and 2. The GARCH(1,1) estimates of equation (5), which includes an AR(1) term, are contained in Table 10.

Evidence from the $\widehat{\rho}^{\,CNY}_{GS,t}$ equation indicates that the coefficients of $\Delta \mathrm{FX}_t$ and $\Delta \mathrm{GPR}_t$ are positively and statistically significant, indicating a comovement of the gold-silver return correlation in response to a depreciation in CNY and heightened GPR; however, the coefficients of $\Delta \mathrm{EPU}_t$, $\Delta V_{r,t}$, and $\Delta V_{D,t-1}$ display negative signs. The outcomes are consistent with the evidence in Table 6, where $R^{CNY}_{G,t}$ and $R^{CNY}_{S,t}$ are estimated with the same set of variables but have opposite signs in their results.

For the $\widehat{\rho}^{\,CNY}_{GM,t}$ equation, the evidence indicates that the coefficients of $\Delta \mathrm{FX}_t$ and $\Delta V_{r,t}$ are positively significant and consistent with the comovement between gold return and stock return in response to a positive change in $\Delta \mathrm{FX}_t$ and $\Delta V_{r,t}$. Nevertheless, a negative sign presents in the coefficients of $\Delta \mathrm{EPU}_t$, $\Delta \mathrm{GPR}_t$, and $\Delta V_{D,t-1}$, indicating a decoupling behavior in reaction to a rise in uncertainty from $\Delta \mathrm{EPU}_t$, $\Delta \mathrm{GPR}_t$ and $\Delta V_{D,t-1}$ [12]. It is clear that the correlation differentials for the two sets of asset returns respond differently to $\Delta \mathrm{GPR}_t$ and $\Delta V_{r,t}$. This implies that market participants can identify the nature of uncertainty due to gold prices expressed in different currencies, which allows them to manage their portfolios in different way.

7. Conclusions

This paper presents evidence regarding changes in gold and silver prices respond to the economic and uncertainty factors in the Chinese market. The study examines gold and silver return behavior expressed both in RMB and USD. Since prices in USD are broadly influenced by the world market, testing results by using CNY are more consistent. This paper documents several empirical findings. First, the gold return is negatively associated with output growth, Δy_t. As such, a higher gold return is positively related to a rise in the unemployment rate or with deteriorating economic conditions, which would induce an increased demand for gold by the public in order to hedge against the economic downturn. The evidence is in line with the observation by Koh and Baffes (2020).

Second, the evidence shows that a gold price appreciation in China is positively related to the inflation rate. In this case, rising inflation will induce investors/households to buy gold, which is used as a hedge against real losses in financial assets. The finding is consistent with the evidence in advanced markets as reported by Worthington and Pahlavani (2007) and observed by Jia (2019) in Chinese market.

Third, the evidence indicates that an increase in gold return is positively correlated with a depreciation of the CNY. This finding is consistent with a loss in value of RMB resulting from

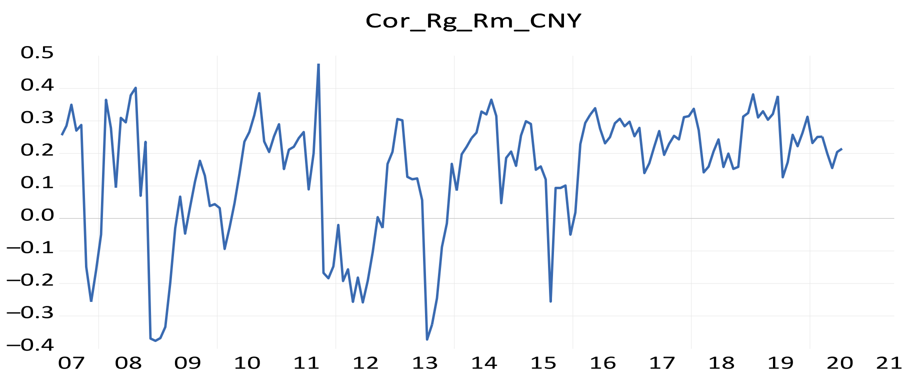

Figure 2.
Conditional dynamic correlations between gold return (vertical axis) and stock market return over time (horizontal axis) in CNY

Table 10. Estimates of dynamic correlation for gold-silver return and gold-stock return in response to uncertainties

Dept. Var	C	ΔFX_t	ΔEPU_t	ΔGPR_t	$\Delta V_{r,t}$	$\Delta V_{D,t-1}$	AR(1)	δ	ε^2_{t-1}	σ^2_{t-1}	$\overline{R}^2$
$\widehat{\rho}^{CNY}_{GS,t}$	0.2431	0.0182	−0.0006	0.0003	−0.0006	−0.0001	0.9038	0.0413	0.7170	0.2983	0.77
	5.72	10.26	−9.69	3.24	−9.46	−4.04	97.31	0.45	0.38	0.23	
$\widehat{\rho}^{CNY}_{GM,t}$	0.1409	0.0201	−0.0002	−0.0001	0.0033	−0.0092	0.7909	0.0347	0.1900	−0.0841	0.49
	18.71	10.06	−9.76	−4.25	10.71	−4.60	57.39	0.68	0.40	−0.06	

Note(s): $\widehat{\rho}^{CNY}_{GS,t}$ ($\widehat{\rho}^{USD}_{GS,t}$) = the conditional correlation coefficient between gold and silver returns in terms of Chinese yuan (US dollar). $\widehat{\rho}^{CNY}_{GM,t}$ ($\widehat{\rho}^{USD}_{GM,t}$) = the conditional correlation coefficient between gold and stock returns in terms of Chinese yuan (US dollar). ΔFX_t = change in exchange rate (CNY per USD), ΔEPU_t = change in economic policy uncertainty, ΔGPR_t = change in geopolitical policy risk, $\Delta V_{r,t}$ = equity market volatility calibrating interest rate, and $\Delta V_{D,t}$ = equity market volatility calibrating disease infection, AR(1) = an autoregressive term. The δ, ε^2_{t-1} and σ^2_{t-1} are constant, lagged shock squared, and lagged variance for GARCH(1,1) model. Numbers in the first row are the estimated coefficients, the second row contains the t-statistics. The critical values of t-distribution at the 1, 5, and 10% levels of significance are 2.63, 1.98, and 1.66, respectively. $\overline{R}^2$ is the adjusted R-squared heightened inflation as well as the findings provided by Beckmann *et al.* (2015), who report that a depreciation in a domestic currency tends to result in a gold price appreciation. The test result is robust when the exchange rate is replaced by the real effective exchange rate.

Fourth, this study demonstrates a positive relation between stock returns and gold returns whether it is in times of normalcy or in times of turmoil. This finding is in contrast to the literature in US market, which shows a negative relation between stock and gold returns. Thus, the evidence runs counter to the hypothesis that gold can serve as a safe-haven asset for hedging against a downturn in stock prices in the US market as documented by Baur and Lucey (2010) and Bialkowski *et al.* (2015). The evidence of a positive coefficient for $R_{m,t}$ indicates that gold does not act as a safe haven for the Chinese equity market. Rather, gold more or less presents a wealth effect as seen by gold price appreciation when stock return increases. Therefore, a complementary behavior exists between stocks and gold in the Chinese market. Nevertheless, the silver return is negatively correlated with the stock return and hence displays hedging characteristics against downside stock market risk. Yet, the test result is not statistically significant for the data during the COVID-19 period, suggesting that silver acted as a weak safe-haven asset during the COVID-19 pandemic.

Fifth, this study provides new evidence by finding a positive relation between gold returns and uncertainty variables with $\{\Delta \text{EPU}_t,\ \Delta \text{GPR}_t,\ \Delta V_{r,t}\}$. Our results indicate that investors/households are highly sensitive to news of uncertainty with respect to forward-looking indicators as reported by journalists for EPU, GPR and interest-rate-induced volatility. Evidence supports the notion that an upward shift of any of these uncertainties could spur market fears and lead market participants to bid up gold prices, resulting in a flight-to-quality. In this sense, gold is a hedge asset against uncertainty. The evidence is in line with the results reported by Bauer and Smales (2020), Li *et al.* (2021) and Chiang (2021). The robustness test suggests that the same result is achieved when ΔEPU_t is replaced by $\Delta \text{VIX}_t^{\text{US}}$; the result is consistent with the finding by Basher and Sadorsky (2016). In contrast, silver returns are negatively related to this set of uncertainty variables, implying silver cannot be used to hedge against these uncertainties.

Sixth, the positive relation between gold returns and volatility associated with the COVID-19 pandemic suggests the need to include a measure for infectious diseases uncertainty, which helps to improve the gold equation. This finding supports the hypothesis that gold is used as a hedging instrument against the uncertainty of the COVID-19 pandemic. The evidence is in line with Baker *et al.* (2020a, b), Mahajan and Mahajan (2021) and Sikiru and Salisu (2021). In addition, this study finds evidence of an interacting effect, which captures the movement of gold returns as investors show a propensity to react to changes in economic policy uncertainty arising from infected disease escalation. This market behavior is indeed producing an indirect impact on the gold return as the pandemic intensifies. Thus, this model has more information content that goes beyond the existing models (Akhtaruzzaman *et al.*, 2021; Sikiru and Salisu, 2021) to describe the effects of COVID-19 on gold returns.

Seventh, although silver possesses many features, such as being positively correlated with inflation rate and exchange rate depreciation, silver in the Chinese market does not have much capacity to hedge against uncertainty as evidenced by its negative correlation with a rise in EPU, upward shift in volatility from interest rate innovation or an upsurge in the COVID-19 pandemic.

Eighth, the opposite signs displayed by the parameters of gold-stock returns and silver-stock returns reflect the different roles that gold and silver play in response to a plunge in the stock market. When we reverse the dependent and independent variables in the test equations, making the stock return the dependent variable and gold/silver returns the independent variables, the evidence achieves the same signs. That is, the stock and gold returns are positively related and stock and silver returns are negatively related; both statistics are significant. Moreover, evidence of uncertainty variables of $\{\Delta \mathrm{FX}_t, \Delta \mathrm{EPU}_t, \Delta \mathrm{GPR}_t, \Delta V_{r,t}, \Delta V_{D,t-1}, \Delta \mathrm{EPU}_t \cdot \Delta V_{D,t-1}\}$ in the stock return equation shows negative signs, indicating they have an adverse effect on stock returns. These results are consistent with the findings reported by Caldara and Iacoviello (2019) and Baur and Smales (2020).

Ninth, testing of the dynamic correlations for gold-silver return, $\widehat{\rho}^{\mathrm{CNY}}_{GS,t}$, and gold-stock return, $\widehat{\rho}^{\mathrm{CNY}}_{GM,t}$, suggests that $\widehat{\rho}^{\mathrm{CNY}}_{GS,t}$ is negatively correlated with $\Delta \mathrm{EPU}_t$, $V_{r,t}$ $V_{D,t-1}$, but positively related to $\Delta \mathrm{GPR}_t$ However, $\widehat{\rho}^{\mathrm{CNY}}_{GM,t}$ is negatively correlated with $\Delta \mathrm{EPU}_t$, $\Delta \mathrm{GPR}_t$ $\Delta V_{D,t-1}$, but positively correlated with $\Delta V_{r,t}$. The difference in response depends on the reaction of market participants to various changes in uncertainty news.

Finally, this study has important policy implications regarding asset choices that can be used to form portfolios to hedge against uncertainty. Specifically, this study presents empirical evidence on gold and silver return behavior and finds that gold returns are positively associated with heightened GPR, an increase in market volatility attributable to interest rate changes or widespread rates of infectious disease. Thus, gold is a safe-haven asset that can hedge against uncertainty arising from changes in FX, VIX, EPU, GPR, V_r and V_D. However, silver can be viewed as an asset to hedge against stock downturn but does not function well as an asset to hedge against other uncertainties.

Moreover, unlike the evidence that has been presented in the US and European markets, gold returns in China are positively correlated with stock returns; this comovement behavior diminishes the effectiveness of an investment strategy that uses a combination of stock and gold to form a diversified portfolio in the Chinese market.

Notes

1. Patel (2019) reported that at a country level, China was the largest producer in the world in 2020, accounting for around 11 per cent (or 368.3 tons) of total global production.
2. Baur and Lucey (2010) classify a safe-haven asset as "an asset that is uncorrelated with another asset or portfolio in times of market stress or turmoil," and define a hedge as "an asset that is uncorrelated or negatively correlated with another asset or portfolio on average."
3. See Metals Focus (2018) for further discussions. The link is as follows: https://www.silverinstitute.org/wpcontent/uploads/2018/09/ChineseSilverMarket20182.pdf
4. Bollerslev *et al.* (1992) observe that the use of GARCH(1,1) is the best way to describe the variance process. No asymmetric term is included for the lagged shock value due to insignificant for most times.
5. Baker *et al.* (2020a) use the following terms (or term variants) to derive EMV: E: {economic, economy, financial}; M: {"stock market", equity, equities, "Standard and Poors"}; V: {volatility, volatile, uncertain, uncertainty, risk, risky}; ID:{epidemic, pandemic, virus, flu, disease, coronavirus, mers, sars, ebola, H5N1, H1N1}.
6. The GPR index is obtained from the link: https://www.policyuncertainty.com/all_country_data.html (Caldara and Iacoviello (2019).
7. Okun's law (1962) examines an empirical relation between a country's unemployment rate and the growth rate of its national product. Okun's law suggests how much of a country's GDP may be lost when the unemployment rate goes beyond the natural rate, implying an inverse relation between GDP growth and unemployment rate.
8. $(c_0 + c_1 \cdot \Delta V_{D,t-1} + e_t)\ \Delta \mathrm{EPU}_t = c_0 \Delta \mathrm{EPU}_t + c_1 \Delta \mathrm{EPU}_t \cdot \Delta V_{D,t-1} + e_t \cdot \Delta \mathrm{EPU}_t$; the parameters in equation (5) are: $C = c_0,\ \beta_1 = b_1, \beta_2 = b_2,\ \beta_3 = b_3,\ \beta_4 = b_4,\ \beta_5 = c_0,\ \beta_6 = b_6,\ \beta_7 = b_7,\ \beta_8 = b_8,\ \beta_9 = c_1,\ \varepsilon_t = u_t + e_t \cdot \Delta \mathrm{EPU}_t$.
9. The real effective exchange rate (REER) is a measure of the value of a national currency against a weighted average of several foreign currencies divided by a price deflator. An increase in REER

indicates an appreciation of the local currency against the weighted basket of currencies for its trading partners. Takáts (2012) and Chiang (2022) provide a formula.

10. Estimations in this paper are limited to aggregate data due to space constraint. The same approach can be applied to sectoral data to test and variations among different sectors (see Chiang, 2019).
11. Similarly, a rolling regression procedure is used by Chiang (1988) to obtain the dynamic correlation coefficient. However, Chiang *et al.* (2007b) noted that the using DCC model tend to outperform the rolling regression method.
12. The negative coefficient for stock and gold return correlation ($\hat{\rho}_{GM,t}^{CNY} = -0.0002$) in response to ΔEPU_t is consistent with the evidence in literature (Gao and Zhang, 2016). This study finds that a negative sign also applies to a rise in uncertainties associated with ΔGPR_t and $\Delta V_{D,t-1}$.

References

Akhtaruzzaman, M., Boubaker, S., Lucey, B.M. and Sensoy, A. (2021), "Is gold a hedge or a safe-haven asset in the COVID–19 crisis?", *Economic Modelling*, Vol. 102, September, 10558, doi: 10.1016/j.econmod.2021.105588.

Baker, S.R., Bloom, N. and Davis, S. (2016), "Measuring economic policy uncertainty", *Quarterly Journal of Economics*, Vol. 131, pp. 1593-1636.

Baker, S.R., Bloom, N., Davis, S.J. and Terry, S.J. (2020a), "COVID-induced economic uncertainty", NBER Working Paper, No. 26983.

Baker, S.R., Bloom, N., Davis, S.J., Kost, K.J., Sammon, M.C. and Viratyosin, T. (2020b), "The Unprecedented stock market impact of COVID-19", NBER Working Paper, No. 26945.

Basher, S. and Sadorsky, P. (2016), "Hedging emerging market stock prices with oil, gold, VIX, and bonds: a comparison between DCC, ADCC and GO-GARCH", *Energy Economics*, Vol. 54, February, pp. 235-247.

Batten, J.A., Ciner, C. and Lucey, B.M. (2014), "On the economic determinants of the gold-inflation relation", *Resources Policy*, Vol. 41, pp. 101-108.

Baur, D.G. and Lucey, B.M. (2010), "Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold", *Financial Review*, Vol. 45, pp. 217-229.

Baur, D.G. and McDermott, T.K. (2010), "Is gold a safe haven? International evidence", *Journal of Banking and Finance*, Vol. 34, pp. 1886-1898.

Baur, D.G. and Smales, L.A. (2020), "Hedging geopolitical risk with precious metals", *Journal of Banking and Finance*, Vol. 117, 105823, doi: 10.1016/j.jbankfin.2020.105823.

Beckmann, J., Czudaj, R. and Pilbeam, K. (2015), "Causality and volatility patterns between gold prices and exchange rates", *The North American Journal of Economics and Finance*, Vol. 34, pp. 292-300.

Beckmann, J., Berger, T. and Czudaj, R. (2019), "Gold price dynamics and the role of uncertainty", *Quantitative Finance*, Vol. 19, pp. 663-681.

Bekiros, S., Boubaker, S., Nguyen, D.K. and Uddin, G.S. (2017), "Black swan events and safe havens: the role of gold in globally integrated emerging markets", *Journal of International Money and Finance*, Vol. 73, pp. 317-334.

Bialkowski, J., Bohl, M.T., Stephan, P.M. and Wisniewski, T.P. (2015), "The gold price in times of crisis", *International Review of Financial Analysis*, Vol. 41, pp. 329-339.

Bilgin, M.H., Gozgor, G., Lau, C.K. and Sheng, X. (2018), "The effects of uncertainty measures on the price of gold", *International Review of Financial Analysis*, Vol. 58, pp. 1-7.

Bollerslev, T. (2010), "Glossary to ARCH (GARCH)", in Bollerslev, T., Russell, J. and Watson, M. (Eds), *Volatility and Time Series Econometrics: Essays in Honor of Robert Engle*, Oxford University Press, Oxford.

Bollerslev, T., Chou, R.Y. and Kroner, K.F. (1992), "ARCH modeling in finance: a review of the theory and empirical evidence", *Journal of Econometrics*, Vol. 52, pp. 5-59.

Bomfim, A. (2003), "Pre-announcement effects, news effects, and volatility: monetary policy and the stock market", *Journal of Banking and Finance*, Vol. 27, pp. 133-151.

Bouoiyour, J., Selmi, R. and Wohar, M.E. (2018), "Measuring the response of gold prices to uncertainty: an analysis beyond the mean", *Economic Modeling*, Vol. 75, pp. 1-12.

Brogaard, J., Dai, L., Ngo, P.T.H. and Zhang, B. (2020), "Global political uncertainty and asset prices", *Review of Financial Studies*, Vol. 33, pp. 1737-1780, doi: 10.1093/rfs/hhz087.

Caggiano, G., Castelnuovo, E. and Groshenny, N. (2014), "Uncertainty shocks and unemployment dynamics in U.S. recessions", *Journal of Monetary Economics*, Vol. 67, pp. 78-92.

Caldara, D. and Iacoviello, M. (2019), "Measuring geopolitical risk", available at: https://www2.bc.edu/matteo-iacoviello/gpr_files/GPR_PAPER.pdf.

Capie, F., Mills, T.C. and Wood, G. (2005), "Gold as a hedge against the dollar", *Journal of International Financial Markets, Institutions and Money*, Vol. 15, pp. 343-352.

Chai, G., You, D. and Chen, J. (2019), "Dynamic response pattern of gold prices to economic policy uncertainty", *Transactions of Nonferrous Metals Society of China*, Vol. 29, pp. 2667-2676, doi: 10.1016/s1003-6326(19)65173-3.

Chai, J., Zhao, C., Hu, Y. and Zhang, Z.G. (2021), "Structural analysis and forecast of gold price returns", *Journal of Management Science and Engineering*, Vol. 6, pp. 135-145.

Cheema, M.A., Faff, R. and Szulczyk, K. (2020), "The 2008 Global financial crisis and COVID-19 pandemic: how safe are the safe haven assets?", *Covid Economics*, Vol. 34, pp. 88-115.

Chen, C.-N. (1975), "Flexible bimetallic exchange rates in China, 1650-1850: a historical example of optimum currency areas", *Journal of Money, Credit and Banking*, Vol. 7 No. 3, pp. 359-376.

Chiang, T.C. (1988), "The forward rate as a predictor of the future spot rate - a stochastic coefficient approach", *Journal of Money, Credit and Banking*, Vol. 20, pp. 210-232.

Chiang, T.C. (2019), "Financial risk, uncertainty and expected returns: evidence from Chinese equity markets", *China Finance Review International*, Vol. 9 No. 4, pp. 425-454.

Chiang, T.C. (2020), "US policy uncertainty and stock returns: evidence in the US and its spillovers to European Union, China, and Japan", *Journal of Risk Finance*, Vol. 21 No. 5, pp. 621-657, doi: 10.3934/QFE.2020020.

Chiang, T.C. (2021), "Geopolitical risk, economic policy uncertainty and asset returns in Chinese financial markets", *China Finance Review International*, Vol. 11 No. 4, pp. 474-501, doi: 10.1108/CFRI-08-2020-0115.

Chiang, T.C. (2022), "The effects of economic uncertainty, geopolitical risk and pandemic upheaval on gold prices", *Resource Policy*, Vol. 76, June, 102546, doi: 10.1016/j.resourpol.2021.102546.

Chiang, T.C., Jeon, B.N. and Li, H. (2007a), "Dynamic correlation analysis of financial contagion: evidence from Asian markets", *Journal of International Money and Finance*, Vol. 26, pp. 1206-1228.

Chiang, T.C., Tan, L. and Li, H. (2007b), "Empirical analysis of dynamic correlations of stock returns: evidence from Chinese A-Share and B-share markets", *Quantitative Finance*, Vol. 7, pp. 651-667.

Chkili, W. (2016), "Dynamic correlations and hedging effectiveness between gold and stock markets: evidence for BRICS countries", *Research in International Business and Finance*, Vol. 38, pp. 22-34.

Christie-David, R., Chaudhry, M. and Koch, T.W. (2000), "Do macroeconomics news releases affect gold and silver prices?", *Journal of Economics and Business*, Vol. 52, pp. 405-421.

Davis, S.J. (2016), "An index of global economic policy uncertainty", NBER Working Paper, No. 22740, available at: http://faculty.chicagobooth.edu/steven.davis/pdf/GlobalEconomic.pdf.

Depren, O., Kartel, M.T. and Deprin, S.K. (2021), "Changes of gold prices in COVID-19 pandemic: daily evidence from Turkey's monetary policy measures with selected determinants", *Technological Forecasting and Social Changes*, Vol. 170, 120884.

Dhawan, S. (2019), "Factors that affect gold price", *The Economic Time*, available at: https://economictimes.indiatimes.com/wealth/invest/factors-that-affect-gold-price/articleshow/64464960.cms?from=mdr (assessed 8 June 2021).

Ding, Z., Granger, C.W.J. and Engle, R.F. (1993), "A long memory property of stock market returns and a new model", *Journal of Empirical Finance*, Vol. 1, pp. 83-106.

Engle, R.F. (2002), "Dynamic conditional correlation: a simple class of multivariate generalized autoregressive conditional heteroskedasticity models", *Journal of Economic Statistics*, Vol. 20 No. 3, pp. 339-350.

Engle, R.F. (2009), *Anticipating Correlations: A New Paradigm for Risk Management*, Princeton University Press, Princeton, NJ.

Fortune, J.N. (1987), "The inflation rate of the price of gold, expected prices and interest rates", *Journal of Macroeconomics*, Vol. 9, pp. 71-82.

Gao, R. and Zhang, B. (2016), "How does economic policy uncertainty drive gold–stock correlations? Evidence from the UK", *Applied Economics*, Vol. 48, pp. 3081-3087.

Gozgor, Gi., Lau, C.K.M., Sheng, X. and Yarovaya, L. (2019), "The role of uncertainty measures on the returns of gold", *Economics Letters*, Vol. 185, 108680, doi: 10.1016/j.econlet.2019.108680.

Güris, B. and Kiran, B. (2014), "The price of gold and the exchange rate: evidence from threshold cointegration and threshold granger causality analyses for Turkey", *Acta Oeconomica*, Vol. 64, pp. 91-101, available at: https://www.jstor.org/stable/24857673.

Hasan, M.B., Hassan, M.K., Rashid, Md.M.M. and Alhenawi, Y. (2021), "Are safe haven assets really safe during the 2008 global financial crisis and COVID-19 pandemic?", *Global Finance Journal*, Vol. 50 C, doi: 10.1016/j.gfj.2021.100668.

Hoang, T., Wong, W.-K. and Zhu, Z. (2015), "Is gold different for risk-averse and risk-seeking investors? An empirical analysis of the Shanghai Gold Exchange", *Economic Modelling*, Vol. 50, pp. 200-211.

Ji, Q., Zhang, D. and Zhao, Y. (2020), "Searching for safe-haven assets during the COVID-19 pandemic", *International Review of Financial Analysis*, Vol. 71, 101526.

Jia, R. (2019), "Gold, inflation and pork in China. Goldhub blog", available at: https://www.gold.org/goldhub/gold-focus/2019/10/gold-inflation-and-pork-china (accessed 1 August 2021).

Jones, A.T. and Sackley, W.H. (2016), "An uncertain suggestion for gold-pricing models: the effect of economic policy uncertainty on gold prices", *Journal of Economics and Finance*, Vol. 40, pp. 367-379.

Jubinski, D. and Lipton, A.F. (2013), "VIX, gold, silver, and oil: how do commodities react to financial market volatility?", *Journal of Accounting and Finance*, Vol. 13, pp. 70-88.

Koh, W.C. and Baffes, J. (2020), "Gold shines bright throughout the COVID-19 crisis", World Banks Blogs, available at: https://blogs.worldbank.org/opendata/gold-shines-bright-throughout-covid-19-crisis (assessed 8 July 2021).

Kumar, D. (2014), "Return and volatility transmission between gold and stock sectors: application of portfolio management and hedging effectiveness", *IIMB Management Review*, Vol. 26, pp. 5-16.

Li, X. (2011), "The paradoxical effect of silver in the economics and Ming and Qing China", *Chinese Studies in History*, Vol. 45 No. 1, pp. 84-99.

Li, S. and Lucey, B.M. (2017), "Reassessing the role of precious metals as safe havens–What colour is your haven and why?", *Journal of Commodity Markets*, Vol. 7, pp. 1-14.

Li, Y., Huang, J. and Chen, J. (2021), "Dynamic spillovers of geopolitical risks and gold prices: new evidence from 18 emerging economies", *Resources Policy*, Vol. 70, p. 101938, available at: https://www.sciencedirect.com/science/article/abs/pii/S0301420720309685.

Li, Q., Yang, J., Hsiao, C. and Chang, Y. (2005), "The relationship between stock returns and volatility in international stock markets", *Journal of Empirical Finance*, Vol. 12, pp. 650-665.

Mahajan, S. and Mahajan, P. (2021), "Impact of COVID-19 on stock market and gold returns in India", *Eurasian Journal of Business and Economics*, Vol. 14 No. 27, pp. 29-46, doi: 10.17015/ejbe.2021.027.02.

Mendoza-Velázquez, A. and Galvanovskis, E. (2009), "Introducing the GED-copula with an application to financial contagion in Latin America", MPRA Paper, No. 46669, available at: https://mpra.ub.uni-muenchen.de/46669/.

Metals Focus (2018), *Prospects for the Chinese Silver Market*, The Silver Institute, London, available at: https://www.silverinstitute.org/wpcontent/uploads/2018/09/ChineseSilverMarket20182.pdflow (assessed 25 September 2021).

Okun, A.M. (1962), "Potential GNP: its measurement and significance", *Proceedings of the Business and Economics Statistics Section of the American Statistical Association*, pp. 98-104.

Nelson, D. (1991), "Conditional heteroskedasticity in asset returns: a new approach", *Econometrica*, Vol. 59, pp. 347-370.

O'Connor, F.A., Lucey, B.M., Batten, J.A. and Baur, D.G. (2015), "The financial economics of gold – a survey", *International Review of Financial Analysis*, Vol. 41, pp. 186-205.

Patel, S. (2019), "Why China is the world's largest gold consumer", *TheStreet*, (accessed 11 February 2022).

Pukthuanthong, K. and Roll, R. (2011), "Gold and the dollar (and the euro, pound, and yen)", *Journal of Banking and Finance*, Vol. 35, pp. 2070-2083.

Rapach, D.E., Strauss, J.K. and Zhou, G. (2013), "International stock return predictability: what is the role of the United States?", *Journal of Finance*, Vol. 68, pp. 1633-1622.

Raza, S.A., Shab, N. and Shahbaz, M. (2018), "Does economic policy uncertainty influence gold prices? Evidence from a nonparametric causality-in-quantiles approach", *Resources Policy*, Vol. 57, pp. 61-68.

Shahzad, S., Bouri, E., Roubaud, D. and Kristoufek, L. (2020), "Save haven, hedge and diversification for G7 stock markets: gold versus bitcoin", *Economic Modelling*, Vol. 87, pp. 212-224.

Sikiru, A.A. and Salisu, A.A. (2021), "Assessing the hedging potential of gold and other precious metals against uncertainty due to epidemics and pandemics", *Qual and Quant*, Vol. 6, pp. 1-16, doi: 10.1007/s11135-021-01214-7.

Sjaastad, L. and Scacciavillani, F. (1996), "The price of gold and the exchange rate", *Journal of International Money and Finance*, Vol. 15, pp. 879-897.

Takáts, E. (2012), "Real effective exchange rates - the bis methodology, bank for international settlements", Basel, available at: https://www.bis.org/ifc/events/6ifcconf/takats_pres.pdf (assessed 19 May 2021).

Toraman, C., Basarir, Ç. and Bayramoglu, M.F. (2011), "Determination of factors affecting the price of gold: a study of MGARCH model", *Business and Economics Research Journal*, Vol. 2, p. 37.

Wallace, J. (2020), "Why gold prices are hitting all-time highs", *Bangkok Post*, available at: https://www.bangkokpost.com/business/1963543/why-gold-prices-are-hitting-all-time-highs.

Wang, K.-M., Lee, Y.-M. and Thi, T.-B.N. (2011), "Time and place where gold acts as an inflation hedge: an application of long-run and short-run threshold model", *Economic Modelling*, Vol. 28, pp. 806-819.

Wen, X. and Cheng, H. (2018), "Which is the safe haven for emerging stock markets, gold or the US dollar?", *Emerging Markets Review*, Vol. 35, pp. 69-90. doi: 10.1016/j.ememar.2017.12.006.

Whaley, R.E. (2009), "Understanding the VIX", *Journal of Portfolio Management*, Vol. 35, pp. 98-105.

Worthington, A.C. and Pahlavani, M. (2007), "Gold investment as an inflationary hedge: cointegration evidence with allowance for endogenous structural breaks", *Applied Financial Economics Letters*, Vol. 3, pp. 259-262, doi: 10.1080/17446540601118301.

Yousef, I. and Shehadeh, E. (2020), “The impact of COVID-19 on gold price volatility”, *International Journal of Economics and Business Administration*, Vol. 8, pp. 353-364.

Yousef, I., Bouri, E., Ali, S. and Azoury, N. (2021), “Gold against Asian stock markets during the COVID-19 outbreak”, *Journal of Risk and. Financial Management*, Vol. 14, p. 186, doi: 10.3390/jrfm14040186.

Further reading

Arouri, M.E., Lahiani, A. and Nguyen, D.K. (2015), “World gold prices and stock returns in China: insights for hedging and diversification strategies”, *Economic Modelling*, Vol. 44, pp. 273-282.

Balcilar, M., Gupta, R. and Pierdzioch, C. (2016), “Does uncertainty move the gold price? New evidence from a nonparametric causality-in-quantiles test”, *Resources Policy*, Vol. 49, pp. 74-80.

Bhattarai, S., Chatterjee, A. and Park, W.Y. (2020), “Global spillover effects of US uncertainty”, *Journal of Monetary Economics*, Vol. 114, pp. 71-89.

Catão, L.A.V. (2007), “Why real exchange rates?”, *Finance and Development*, Vol. 44 No. 3, pp. 46-47, available at: https://www.imf.org/external/pubs/ft/fandd/2007/09/basics.htm (assessed 17 May 2021).

Chen, K. and Wang, M. (2017), “Does gold act as a hedge and a safe haven for China’s market?”, *International Journal of Financial Study*, Vol. 5, p. 18.

Ghosh, D., Levin, J., Macmillan, P. and Wright, E. (2004), “Gold as an inflation hedge?”, *Studies in Economics and Finance*, Vol. 22, pp. 1-25.

Kenourgios, D., Samitas, A. and Paltalidis, N. (2011), “Financial crises and stock market contagion in a multivariate time-varying asymmetric framework”, *Journal of International Financial Markets, Institutions and Money*, Vol. 21, pp. 92-106.

Levin, E.J., Montagnoli, A. and Wright, R.E. (2006), “Short-run and long-run determinants of the price of gold”, *Strathprints*, Report, University of Strathclyde.

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