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Continuous Wavelet Transform of Time-Frequency Analysis Technique to Capture the Dynamic Hedging Ability of Precious Metals

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Abstract: Exploring the hedging ability of precious metals through a novel perspective is crucial for better investment. This investigation applies the wavelet technique to study the complicated correlation between global economic policy uncertainty (GEPU) and the prices of precious metals. The empirical outcomes suggest that GEPU exerts positive influences on the prices of precious metals, indicating that precious metals could hedge against global economic policy uncertainty, which is supported by the inter-temporal capital asset pricing model (ICAPM). Among them, gold is better for long-term investment than silver, which is more suitable for the short run in recent years, while platinum's hedging ability is virtually non-existent after the global trade wars. Conversely, the positive influences from gold price on GEPU underline that the gold market plays a prospective role in the situation of economic policies worldwide, which does not exist in the silver market. Besides, the effects of platinum price on GEPU change from positive to negative, suggesting that the underlying cause of its forward-looking effect on GEPU alters from the investment value to the industrial one. In the context of the increasing instability of global economic policies, the above conclusions could offer significant lessons to both investors and governments.

Keywords: global economic policy uncertainty; precious metals; gold price; silver price; platinum price; wavelet technique

MSC: 91-10

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1. Introduction

This exploration aims to investigate the correlation between global economic policy uncertainty (GEPU) and the prices of precious metals and to further explore if precious metals could be considered as hedging assets to avoid the instability of economic policies worldwide. Against the background of an increasingly complex political and economic situation worldwide (Qin et al. [1]), a series of economic policies has been introduced frequently by governments around the world, which has led to an increase in GEPU (Davis [2]; Qin et al. [3]). This phenomenon could be obviously perceived during the Asian financial crisis in 1997, the global economic crisis in 2008, the European sovereign debt crisis in 2010, Brexit in 2016, the global trade wars in 2018, the Corona Virus Disease 2019 (COVID-19) in 2020, the Russian-Ukrainian war in 2022 and so on. High GEPU inevitably exacerbates the uncertainty about the global economic prospect, causing a rise in risk aversion (Su et al. [4,5]; Han and Li [6]). As investors are more willing to invest hedging assets to avert high GEPU (Qin et al. [7]; Kamal et al. [8]), the precious metals market may be a suitable choice (Cheng et al. [9]; Gençyürek and Ekinci [10]). When GEPU shows an upward trend, the demand for precious metals would increase to hedge the instability

of economic policies worldwide, boosting their prices to rise accordingly. For instance, the European sovereign debt crisis caused GEPU to increase sharply (Davis [2]) and the prices of precious metals also surged to hedge against potential uncertainties and risks. However, this view could not always be observed. On the one hand, the higher value of other assets (e.g., the U.S. dollar and cryptocurrency) makes precious metals less attractive (Su et al. [11]), even if GEPU is at a relatively high level. On the other hand, a rise in the prices of precious metals may be caused by other events without high GEPU, such as several geopolitical events (Qin et al. [12,13]). Therefore, the ability of precious metals to hedge against global economic policy uncertainty is complicated, which is a practical and significant topic that deserves further discussion.

Conversely, the prices of precious metals may also exert influences on GEPU. Firstly, the investment value of precious metals allows their prices to positively reflect GEPU, especially during periods of economic and political crises (Qin et al. [14]). Secondly, the rise in precious metals' prices might increase investment returns and reduce the market panic (Chiang [15]; Cui et al. [16]), which is conducive to ease GEPU. Thirdly, the industrial value of precious metals makes their prices dependent on industrial supply and demand. Thus, the economic and political crises may not only decrease precious metals' demand and prices, but also be related to high GEPU. Hence, the precious metals might be a forward-looking indicator for the situation of economic policies worldwide, which is currently overlooked by existing research. Further, this investigation selects three important and relatively common precious metals (gold, silver and platinum) to analyze their ability to hedge against high GEPU and then compare them. There is not only a high degree of correlation among gold, silver and platinum, but there are also several differences (Cheng et al. [9]). Specifically, gold is used primarily for investment, coinage (bars and coins) and jewelry (Su et al. [4,5]), while silver is similar to gold, but has more uses in industry (Sami [17]). Moreover, platinum is a special metal with an extremely high melting point, corrosion resistance and electrical conductivity (Gençyürek and Ekinci [10]; McCown and Shaw [18]), which means that it is versatile and more vulnerable to changes in industry. Therefore, the hedging ability among different precious metals is varied.

The hedging ability of precious metals has attracted considerable attention in the last few decades, and various opinions have been drawn from different perspectives. Some scholars discuss and compare the hedging ability of two kinds of precious metals, such as gold and silver, or gold and platinum. Dibooglu et al. [19] confirm the safe-haven property of gold and silver during the U.S.A's stressful financial periods, which could also be supported by Chen et al. [20]. Wei et al. [21] indicate that there are obvious impacts of cryptocurrency market uncertainties on the volatility of precious metal futures markets, highlighting that gold and silver futures on the New York Mercantile Exchange could hedge against cryptocurrency policy and price uncertainty. By comparison, Pierdzioch et al. [22] reveal that gold and silver are strong hedges against the depreciation of major exchange rates, while platinum is only a hedge against the Australian and Canadian dollars. McCown and Shaw [18] suggest that platinum could hedge against inflation, fluctuations in foreign exchange rates and the systematic risks of investments, which has a better ability to track the U.S. price level than gold. Salisu et al. [23] underline that silver is a better hedge than gold during periods of inflation and rare disasters adversely affected by the El Niño phenomenon. Shahzad et al. [24] imply that gold is a more stable asset than silver and serves as a hedge against geopolitical risks and financial instabilities.

Other scholars discuss and compare the hedging ability of three kinds of precious metals, including gold, silver and platinum. Mensi et al. [25] indicate that gold, silver and platinum could be used as strong hedges to avoid fluctuations in major currencies (including the U.S. foreign exchange rates of Australia, Canada, China, Eurozone, Japan, Switzerland and the United Kingdom). Su et al. [26] suggest that the COVID-19 pandemic is the most critical risk factor for market stability, which has a significant effect on the prices of precious metals (including GSP, SSP and PSP). Mensi et al. [27] have discovered that precious metals futures (including gold, silver and platinum futures) are diversifiers

for the U.S. stock market and safe havens in the short- and long-run periods. However, Jiang et al. [28] state that precious metals are more effective hedges for stock markets in India and China, but not in Brazil and Russia. Erdoğan et al. [29] show that precious metals such as gold, silver and platinum cannot be used to hedge against the downside risks of clean energy stock investment. Gençyürek and Ekinci [10] highlight that precious metals (gold, silver and platinum) are effective risk management tools, but not as hedges against the risks in stock markets of Brazil, Russia, India, China, South Africa and Turkey. Sephton [30] finds that apart from platinum and inflation shocks in Ghana, Morocco and Tanzania, there is little evidence to support that precious metals could counteract inflation shocks. By comparison, Mokni et al. [31] reveal that gold can be viewed as a dominant safe-haven asset in hedging market uncertainty caused by the COVID-19 pandemic, while silver and platinum have shown different responses. Cheng et al. [9] evidence that gold and silver are better hedging assets to avert geopolitical risks in the short and medium terms than platinum. Ahmed et al. [32] underline that gold is a safer asset than silver and platinum during the periods with oil price shocks. Das et al. [33] ascertain that gold could be considered as a weak hedge against contemporaneous oil volatility jumps, while silver and platinum do not show this feature; however, these two precious metals takeover gold in cases of lagged jumps and offer a strong hedge. Huang et al. [34] underline that gold acts as a weak safe haven and a strong hedge for the crude oil market, while silver is only a weak hedge, and platinum is neither a safe haven nor a viable hedge. Khaskheli et al. [35] prove that the fear-induced news during the COVID-19 pandemic can raise gold's return volatilities, but less influences are found on silver and platinum. Yıldırım et al. [36] state that those seeking portfolio diversification and hedging opportunities during the COVID-19 pandemic ought to consider investing in gold and silver rather than platinum assets.

In brief, there are abundant efforts in analyzing the hedging ability of various precious metals, but no study explores it from the perspective of GEPU. Although some studies only discuss the hedging ability of one kind of precious metal (mostly focusing on gold) and find that gold could hedge against GEPU during the periods with crises (Qin et al. [3]), few efforts have been made to compare the differences in hedging ability of various precious metals. In addition, few studies confirm the role of the precious metals market. Dibooglu et al. [19] evidence that extreme returns in gold and silver signal either calmer times or financial crises to come. Besides this, several studies apply the wavelet technique to conduct empirical analyses. Frimpong et al. [37] observe the heterogeneity of the agricultural market operation structure at different simultaneous frequency scales, which is more profound at high frequencies in terms of binary wavelet coherence. Then, they perform the partial wavelet coherence to analyze the time-frequency impact of GEPU on agricultural commodity prices and find that GEPU is a driver of agricultural commodity market connectedness. Agyei et al. [38] highlight that the use of wavelet transforms could decompose variables into time-frequency domain, which promotes the evaluation of the localized variation of power in the sequences. Since variables are featured by non-linearity and disorder, the wavelet technique is a reasonable method to reveal the underlying irregularity among time series. After that, they apply this method to investigate the co-movement between the exchange rate and stock returns during the COVID-19 pandemic by considering the time- and frequency-domain. Although the wavelet technique has certain advantages in analyzing complex interactions among economic variables, the previous studies have not applied this method to probe the time-varying and complex correlation between GEPU and precious metal prices, and this investigation attempts to fill these gaps.

The marginal contributions in this investigation are as follows: to begin with, the extant studies mainly pay attention to the ability of precious metals to hedge against inflation (Sephton [30]), the fluctuations in currencies (Mensi et al. [25]), the COVID-19 pandemic (Su et al. [26]; Mokni et al. [31]), oil volatility (Ahmed et al. [32]; Das et al. [33]) and financial stress (Dibooglu et al. [19]), or discuss the hedging ability of only one kind of precious metal, such as gold (Qin et al. [12–14]). However, there have been no effort to probe this ability of various precious metals from the perspective of GEPU. Therefore,

this investigation is a ground-breaking work that explores whether precious metals could hedge against high GEPU, and has chosen gold spot price (GSP), silver spot price (SSP) and platinum spot price (PSP) for analysis and comparison. Secondly, the extant efforts primarily focus on the one-sided impact (e.g., from GEPU to the prices of precious metals), the interaction between which few studies have considered, and which calls for further probing of the role of the precious metals market in the situation of economic policies worldwide. Thus, this investigation discusses the correlation between GEPU and the prices of precious metals (including GSP, SSP and PSP), in order to make the analysis on this subject more comprehensive. The empirical outcome refers to the fact that GEPU exerts positive influences on the prices of precious metals, highlighting their ability to hedge against high GEPU, and this conclusion is consistent with the ICAPM. In turn, the prices of precious metals have both positive and negative influences on GEPU, suggesting that taking the precious metals market into consideration could make GEPU prediction more reasonable. Besides, GEPU is differently correlated with GSP, SSP and PSP, showing that there are differences in the hedging ability of gold, silver and platinum. These conclusions not only help investors to avoid potential uncertainties and achieve maximum returns by investing in the precious metals market and forming an optimal precious metals portfolio, but also assist governments to promote the sustained and stable economic development through taking measures in advance to reduce possible uncertainties and avoid public panic. Thirdly, the correlation between GEPU and the prices of precious metals (including GSP, SSP and PSP) may be complicated and changeable, which has been ignored by the extant literature. Thereupon, this investigation performs the more advanced wavelet technique by taking time- and frequency-domains into account to capture this complex correlation. As an economic signal analysis technique, the wavelet analysis can be used as a "microscope" to observe time series. In the economic operation, there are many economic variables or indicators that change with time, such as GEPU and the prices of precious metals. Further, there are both periodic factors and random disturbances in these changes, and the application of the wavelet analysis could separate these different motivations. By performing the wavelet technique, the macro time series can be decomposed into time frequency components of different scales, and then we could identify the dynamic and complex interrelationship between GEPU and the prices of precious metals (including GSP, SSP and PSP).

The construction of this investigation is as follows. Section 2 elaborates the materials and methods. Sections 3 and 4 show the empirical results and discussions. The conclusions and suggestions are reported in Section 5.

2. Materials and Methods

2.1. Theoretical Mechanism

This investigation builds the inter-temporal capital asset pricing model (ICAPM) to gain the correlation of GEPU with the prices of precious metals (Cifarelli and Paladino [39]). The ICAPM assumes that there are rational and feedback investors in the precious metals market. Among them, the rational one's demand for precious metals depends on the systemic risk, but the feedback one would invest precious metals on the basis of their previous prices. In addition, the systemic risk refers to the risk that could not be dissipated through altering investment arrangement, such as global economic policy uncertainties. Thereupon, this investigation employs GEPU to reflect this systemic risk, and the rational one's demand for precious metals (taking gold as an example, and silver and platinum are the same) is written as:

$$RD_t = \frac{E_{t-1}(GSP_t) - GSP^f}{\mu(GEPU_t)} \quad (1)$$

where RD_t is the proportion of gold demand from the rational investor. The numerical value of $\mu(GEPU_t)$ is positive, which is also an increasing function. When there is only the rational investor in the market, $RD_t = 1$, and Equation (1) could be rewritten as the CAPM

introduced by Sharpe [40], that is, $E_{t-1}(GSP_t) = GSP^f + \mu(GEPU_t)$. Through constructing the CAPM, it can be perceived that the rise in GEPU would push GSP up.

Additionally, there exists the feedback investor, which determines the current demand for gold on the basis of the previous GSP. The proportion of gold demanded by the feedback investor could be defined as $FD_t = \varphi GSP_t$, where $\varphi > 0$. Considering both rational and feedback investors ($RD_t + FD_t = 1$), the ICAPM could be expressed as:

$$E_{t-1}(GSP_t) = GSP^f + \mu(GEPU_t) - \varphi\mu(GEPU_t)GSP_{t-1} \tag{2}$$

The coefficient of $\mu(GEPU_t)$ is $1 - \varphi GSP_t$, and its value exceeds 0 since $\varphi GSP_t = FD_t < 1$ (Qin et al. [12]). After that, we could perceive that GEPU still has a positive influence on GSP, indicating that the rise in GEPU may increase the hedging demand for gold to avoid potential uncertainties and risks, driving GSP to soar. Hence, we can offer a hypothesis from the ICAPM, that is, the high uncertainty of global economic policies could motivate the precious metals market, and the precious metals possess the ability to hedge against GEPU.

2.2. Empirical Technique

The preponderance in the wavelet analysis is mainly reflected in two sides. Firstly, this technique could conduct the local analysis and estimate the spectral features (Aguiar-Conraria and Soares [41]). Secondly, this technique can acquire estimations from the time-and frequency-domains (Qin et al. [26]), in order to explore the changeable correlation between GEPU and the prices of precious metals. In addition, there are two wavelet types: the discrete wavelet transform (DWT) and continuous wavelet transform (CWT). The former is applicable to the noise reduction and decomposition of variables, and this form is primarily for the analysis of economic variables. However, the latter could be applied to the information extraction and self-similarity detection, which is appropriate for analyzing noisy and complex series (Crowley [42]). In addition, this investigation explores the correlation between GEPU and the prices of precious metals (including GSP, SSP and PSP), which is more suitable for applying the CWT than DWT (Aguiar-Conraria and Soares [41]). Actually, the series of GSP, SSP and PSP are not stable, but the unit root and co-integration examinations could be neglected while performing the CWT (Qin et al. [27]). Then, the wavelet technique with CWT form can catch the correlation among the unstable sequences.

2.2.1. The Form of CWT

Introducing a sequence $y(t) \in L^2(R)$ that is written as:

$$y(t) = \frac{1}{C_\varphi}\int_0^{+\infty}\left[\int_{-\infty}^{+\infty}\frac{1}{\sqrt{n}}\varphi\left(\frac{t-m}{n}\right)W_y(m,n)dm\right]\frac{dn}{n^2} \tag{3}$$

where $0 < C_\varphi = \int_0^{+\infty}\frac{(|\varphi(f)|^2)}{f}df < +\infty$, complying with what is called admissibility conditions. This requirement allows refactoring from the CWT, and $W_y(m,n)$ could be expressed as:

$$W_y(m,n) = \int_{-\infty}^{+\infty} y(t)\varphi^*_{m,n}(t)dt = \frac{1}{\sqrt{n}}\int_{-\infty}^{+\infty} y(t)\varphi^*\left(\frac{t-m}{n}\right)dt \tag{4}$$

Additionally, the CWT remains the power of $y(t)$, which could be acquired by Equation (5). After that, this investigation could identify the wavelet coherence that measures the magnitude of local correlations between GEPU and the prices of precious metals (including GSP, SSP and PSP).

$$\|y\|^2 = \frac{1}{C_\varphi}\int_0^{+\infty}\left[\int_{-\infty}^{+\infty}\left|W_y(m,n)\right|^2 dm\right]\frac{dn}{n^2} \quad n > 0 \tag{5}$$

2.2.2. Wavelet Coherence

According to Torrence and Webster [43,44], the wavelet coherency could be estimated on the basis of the CWT and the power of $y(t)$. After that, the cross wavelet transform between GEPU and the prices of precious metals (taking GSP as an example, and SSP and PSP are the same) could be written as:

$$W_{GEPU,GSP}(m,n) = W_{GEPU}(m,n)W^{*}_{GSP}(m,n) \tag{6}$$

where * refers to the application of complicated conjugation. $W_{GEPU}(m,n)$ and $W_{GSP}(m,n)$ point out the CWT of GEPU and GSP. Then, we could obtain the cross wavelet power, that is $|W_{GEPU,GSP}(m,n)|$. Furthermore, the wavelet coherence underlines regions where sequences change together and may not have higher powers. Equation (7) is the squared wavelet coherence coefficient, where N is the smoothing operator.

$$R^{2}_{GEPU,GSP}(m,n) = \frac{\left|N\left(n^{-1}|W_{GEPU,GSP}(m,n)|\right)\right|^{2}}{N\left(n^{-1}|W_{GEPU}(m,n)|^{2}\right)N\left(n^{-1}|W_{GSP}(m,n)|^{2}\right)} \tag{7}$$

2.2.3. Wavelet Partial Coherence and Phase-Difference

The prices of precious metals are also obviously affected by the geopolitical events and the value of the U.S. dollar (Qin et al. [13,14]), which might bring significant influences to the correlation between GEPU and the prices of precious metals (including GSP, SSP and PSP). Thus, this investigation takes geopolitical risk (GPR) and the U.S. dollar index (USDI) into account, making GPR and USDI control series. The squared wavelet partial coherency (also taking GSP as an example, where SSP and PSP are the same) is expressed as:

$$R^{2}_{GEPU,GSP|GPR,USDI}(m,n) = \frac{\left|R_{GEPU,GSP}(m,n) - R_{GEPU,GPR,USDI}(m,n)R^{*}_{GSP,GPR,USDI}(m,n)\right|^{2}}{\left(1-\left(R_{GEPU,GPR,USDI}(m,n)\right)^{2}\right)\left(1-\left(R_{GSP,GPR,USDI}(m,n)\right)^{2}\right)} \tag{8}$$

where $R^{2}_{GEPU,GSP|GPR,USDI}(m,n) = 1$ is evaluated from the time- and frequency-domains. In addition, this investigation performs the Monte Carlo technique to probe the significance (Grinsted et al. [45]; Qin et al. [26,27]). The phase-difference indicates that there are three cases: GEPU leads GSP, GSP leads GEPU and GEPU synchronizes with GSP. Besides, the positive or negative effects between GEPU and GSP could also be defined as:

$$\theta_{GEPU,GSP|GPR,USDI}(m,n) = tan^{-1}\left(\frac{\delta\left(\rho_{GEPU,GSP|GPR,USDI}(m,n)\right)}{\gamma\left(\rho_{GEPU,GSP|GPR,USDI}(m,n)\right)}\right) \tag{9}$$

In Equation (9), $\rho_{GEPU,GSP|GPR,USDI}(m,n)$ refers to the complicated wavelet partial coherency; δ and γ indicate the theoretical section and real part of CWT. To better understand $\theta_{GEPU,GSP|GPR,USDI}(m,n)$, we depict Figure 1.

It can be observed that $\theta_{GEPU,GSP|GPR,USDI}(m,n) \in [-\pi,\pi]$ refers to the correlation between GEPU and GSP, under the control of GPR and USDI. When $\theta_{GEPU,GSP|GPR,USDI}(m,n) \in \left[0,\frac{\pi}{2}\right]$, GEPU positively leads GSP, and when $\theta_{GEPU,GSP|GPR,USDI}(m,n) \in \left[-\pi,-\frac{\pi}{2}\right]$, GEPU negatively leads GSP. Similarly, when $\theta_{GEPU,GSP|GPR,USDI}(m,n) \in \left[-\frac{\pi}{2},0\right]$, GSP positively leads GEPU, and when $\theta_{GEPU,GSP|GPR,USDI}(m,n) \in \left[\frac{\pi}{2},\pi\right]$, GSP negatively leads GEPU. Besides, if $\theta_{GEPU,GSP|GPR,USDI}(m,n) = 0$, GEPU moves synchronously with GSP.

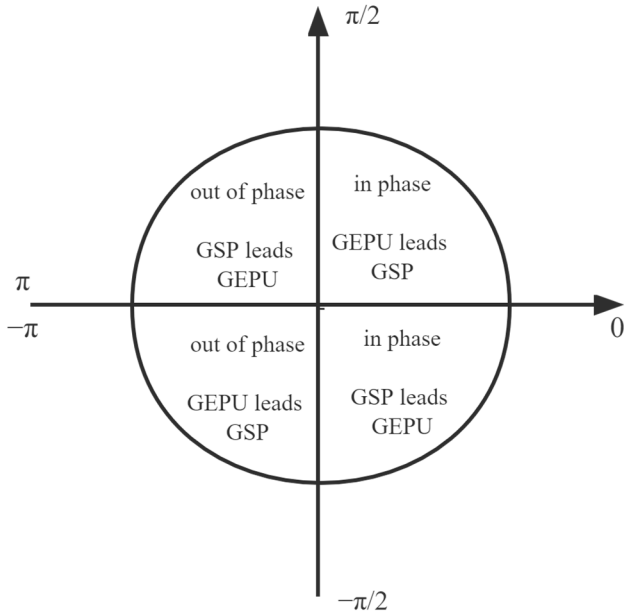

Figure 1. The phase-difference circle.

2.3. Data

This investigation selects the monthly series (to examine the robustness, this exploration also probes the relation between GEPU and the prices of precious metals with quarterly data and the outcomes are coincident with the monthly series) during the period of January 1997 to November 2022, in order to answer whether the precious metals could hedge against global economic policy uncertainty. In 1997, Thailand abandoned its fixed exchange rate system, and this economic policy triggered a financial storm across Asia. Specifically, currencies in Thailand, Indonesia, South Korea and other countries fell sharply, and the most major Asian stock markets plummeted. Further, the closure of numerous large enterprises, the huge unemployment of workers, as well as the social and economic depression, eventually caused the Asian financial crisis and even political crisis in several countries (e.g., Thailand and Indonesia). In order to cope with this crisis, relevant countries implemented new economic policies (e.g., the prudent fiscal and monetary policies, the policies to increase foreign exchange reserves) to remedy the flaws that led to the financial crisis and the damage it caused, making global economic policy more uncertain. Since then, multiple events have further aggravated this uncertainty, such as the September 11 attacks in 2001, the global economic crisis in 2008, the European sovereign debt crisis in 2010, Brexit in 2016, the global trade wars in 2018, the COVID-19 pandemic in 2020 and the Russian-Ukrainian war in 2022. Thereupon, we choose the global economic policy uncertainty (GEPU) index introduced by Davis (2016), to represent the situation of economic policies worldwide, which can be taken from the Economic Policy Uncertainty database. According to the gross domestic product (GDP) data from the International Monetary Fund (IMF), this indicator is calculated by using a GDP-weighted average of the EPU indices for 21 countries. The national EPU indices reflect the frequencies of national newspaper articles that include three aspects related to economy, policy and uncertainty (Qin et al. [3]). Meanwhile, the Asian financial crisis in 1997 not only made GEPU rise, but also motivated the precious metals market. The hedging demand for precious metals increased accordingly, which drove their prices to rise. This phenomenon could also be observed in other high GEPU time periods, thus, the precious metals market may be intimately related to the situation of economic policies worldwide. After that, we choose the gold spot price (GSP), silver spot price (SSP) and platinum spot price (PSP) in the U.S. dollars to represent the fluctuations of precious metals market, which are obtained from the World Gold Council and the IMF (Cheng et al. [9]). Then, we can identify the correlation between GEPU and the prices of

precious metals (including GSP, SSP and PSP), and further probe whether precious metals could hedge against global economic policy uncertainty. Further, this investigation could also compare the hedging ability among gold, silver and platinum.

The trends and wavelet power spectra of GEPU, GSP, SSP and PSP are depicted in Figure 2. From Figure 2, the trends of GEPU, GSP, SSP and PSP are revealed in the left column. To begin with, we discuss the correlation between GEPU and GSP. The Asian financial crisis in 1997 led to an increase in GEPU (from 64.27 in July 1997 to 106.75 in December 1997) and GSP was also at a relatively high level. After this crisis dissipated, both GEPU and GSP have declined slightly. The September 11 attacks in 2001 and the Iraq war in 2003 made GEPU soar, and GSP also showed an upward trend due to the rise in gold demand to avoid GEPU and geopolitical risks. Moreover, the global economic crisis caused a rise in both GEPU and the hedging demand for gold and this phenomenon could also be observed during the European sovereign debt crisis. After these crises subsided, the global economic policies have stabilized, which reduces the demand for hedges (e.g., gold), thus significantly decreasing GSP. The global trade wars made GEPU rise from 123.86 in February 2018 (the lowest level during 2018–2019) to 315.38 in August 2019 (the highest level during 2018–2019), which grew by more than 150%. In order to hedge against GEPU, the gold demand and its price also present an upward momentum. In 2020, the COVID-19 pandemic broke out around the world, making GEPU reach its highest level in May (430.26), and GSP also moved in the same direction (from 1584.2 dollars per troy ounce in January to 1728.7 dollars per troy ounce in May, which grew by nearly 10%). Similarly, the Russian-Ukrainian war has caused GEPU to soar from 189.46 in February 2022 to 329.95 in March 2022 (a growth by more than 70%), and GSP exploded to nearly 2000 dollars per troy ounce. Through the above discussion, it could be observed that the correlation between GEPU and GSP is not unchangeable but intricate.

Then, we consider the silver and platinum markets. On the one hand, the trends of SSP and PSP are similar to GSP to a certain extent, indicating that the correlation between GEPU and SSP (or PSP) is also complicated. On the other hand, there are differences among various precious metals. First, SSP appreciates and depreciates faster than GSP, which causes the relation between GEPU and SSP to be slightly different from that of GSP. For instance, the European sovereign debt crisis led GEPU to increase, while GSP remained at a high level for longer than SSP. Secondly, PSP obviously varies from GSP and SSP, indicating that their relations with GEPU are also quite different. For instance, PSP shows that the most volatility during the period with high GEPU was caused by the global economic crisis, but it presented the lowest fluctuations during the COVID-19 pandemic. Therefore, we can observe that the interrelation between GEPU and the prices of precious metals is changeable and complex, and there are similarities and differences among GSP, SSP and PSP.

The wavelet power spectra of GEPU, GSP, SSP and PSP is presented in the right column. GEPU presents high power from 2008 to 2022, particularly in the past seven years, indicating that Brexit, the global trade wars, the COVID-19 pandemic and the Russian-Ukrainian war significantly intensified the uncertainty of economic policies worldwide. GSP appears similar to GEPU, which means that there is a certain correlation between these two data. Although SSP is similar to GSP, the power of the former has declined slightly after the COVID-19 pandemic. Unlike GSP and SSP, the high power of PSP is concentrated around the global economic crisis. Besides, the geopolitical events and the values of the U.S. dollar are closely related to the correlation between GEPU and the precious metals market. For example, the September 11 attacks in 2001 not only increased GEPU, but also raised the hedging demand for precious metals to avert potential risks caused by this geopolitical event. Furthermore, the prices of precious metals (including GSP, SSP and PSP) are priced in the U.S. dollar and the depreciation of the latter (e.g., the quantitative easing) may push the former up. After that, we choose the geopolitical risk (GPR) index and the U.S. dollar index (USDI) as control variables (Caldara and Iacoviello [46]; Qin et al. [14]), to ensure the rationality of the empirical analysis. Thereupon, we could further perceive the perplexed

interaction between GEPU and the prices of precious metals, as well as the similarities and differences among GSP, SSP and PSP, which were also affected by GPR and USDI. Hence, we employ the more advanced wavelet analysis to identify this complicated correlation between GEPU and the prices of precious metals (including GSP, SSP and PSP) through considering the time- and frequency-domains.

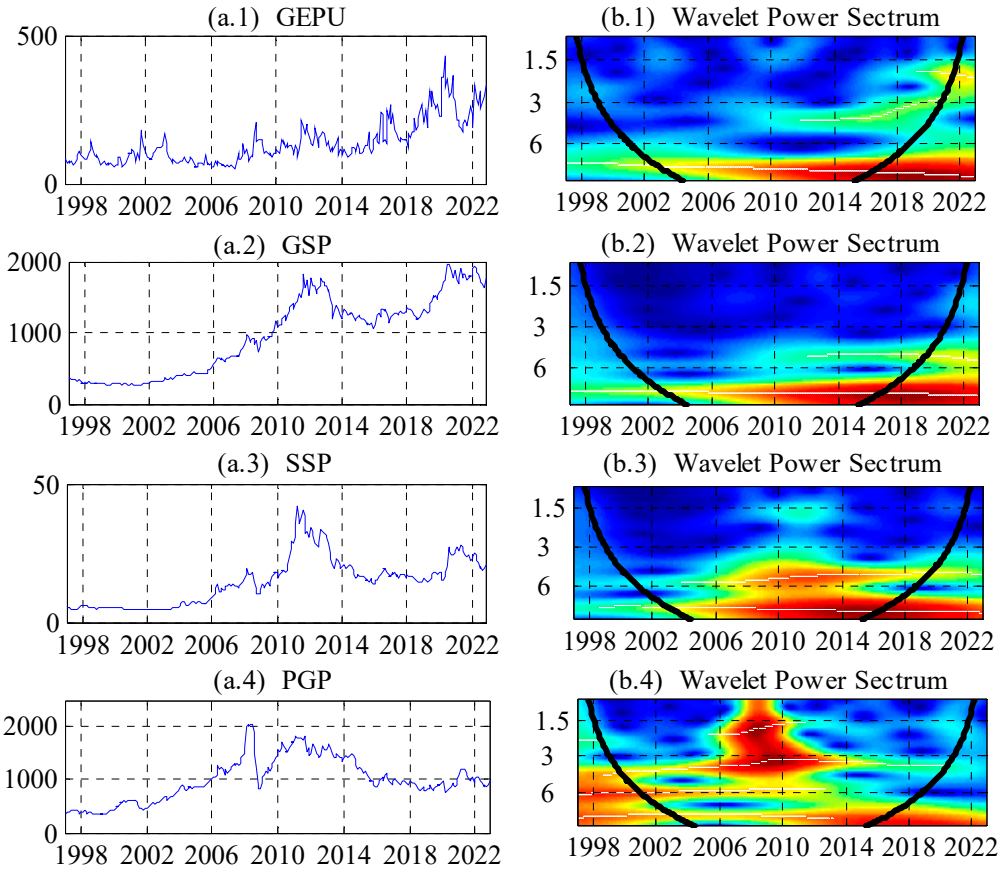

Figure 2. The trends and wavelet power spectra of GEPU, GSP, SSP and PGP. Notes: (**a.1**–**a.4**) reveal the trends of GEPU and the prices of precious metals; (**b.1**–**b.4**) show the wavelet power spectra of GEPU, GSP, SSP and PGP. The cones of influences are depicted with thick black curves in the right column, indicating the regions impacted by edge effects; the scopes of color are from lower (blue) powers to higher (red) powers.

3. Results

3.1. Descriptive Statistics

Table 1 presents the statistics of GEPU, GSP, SSP, PSP, GPR and USDI. The averages of these six sequences are concentrated on 135.363, 958.761, 14.650, 993.464, 100.228 and 92.296 levels. The significant differences between the maximum and minimum of GEPU, GSP, SSP and PSP evidence that these variables fluctuate wildly. The skewness is positive in GEPU, GSP, SSP, PSP, GPR and USDI, which means that all of them obey the right-skewed distributions. The kurtosis of GEPU and GPR exceeds three, indicating that these two sequences possess a feature of fat-tail, while GSP, SSP, PSP and USDI satisfy the platykurtic distributions. Furthermore, the Jarque-Bera test confirms that these six sequences could reject the null hypothesis at the significant levels of 1% (GEPU, GSP, SSP, PSP and GPR) or 5% (USDI), proving that none of them satisfy the standard normal distribution.

Table 1. Descriptive statistics for GEPU, GSP, SSP, PSP, GPR and USDI.

	GEPU	GSP	SSP	PSP	GPR	USDI
Observations	311	311	311	311	311	311
Mean	135.363	958.761	14.650	993.464	100.228	92.296
Median	113.204	1061.900	14.940	947.410	89.140	93.040
Maximum	430.259	1964.900	41.970	2052.450	512.530	120.240
Minimum	48.877	254.800	4.120	342.600	39.050	71.840
Standard Deviation	72.499	543.567	8.640	413.234	51.782	10.990
Skewness	1.312	0.099	0.659	0.342	4.259	0.342
Kurtosis	4.316	1.605	2.908	2.436	29.342	2.605
Jarque-Bera	111.654 ***	25.704 ***	22.624 ***	10.187 ***	9932.029 ***	8.078 **
Probability	0.000	0.000	0.000	0.006	0.000	0.018

Notes: ** and *** denote significance at the 5% and 1% levels.

3.2. The Correlation between GEPU and GSP

The wavelet partial coherency and phase-difference between GEPU and GSP are depicted in Figure 3. Among them, Figure 3(a.1)–(a.3) ignore the influences of other factors on the relations between GEPU and GSP, which may cause errors in the results. To cope with this problem, Figure 3(b.1)–(b.3) plot the relations between GEPU and GSP after controlling GPR and USDI, making the results more accurate. Thereupon, Figure 3(b.1)–(b.3) would be emphatically discussed in the following analysis. In the long run, GEPU would positively affect GSP in 2011–2022, where GSP positively led GEPU in 1998-2000, and GEPU moved synchronously with GSP in 1997.

From 2011–2022, the rise of GEPU was mainly concentrated in six periods. First, the European Union has adopted currency devaluation, fiscal tightening and monetary easing during the European sovereign debt crisis (Davis [2]), making GEPU rise to 214.31 in August 2011. Second, Brexit has thrown more uncertainty into economic policies worldwide (Qin et al. [3]), causing GEPU to soar to 242.04 in June 2016. Third, Donald Trump advocated tax cuts and trade protectionism during his presidential campaign, which inevitably drove GEPU to 264.08 after his inauguration January 2017 (Qin et al. [14]). Fourth, the global trade wars made national trade policies unpredictable (Su et al. [4]), pushing GEPU up to 315.38 in August 2019. Fifth, the outbreak of COVID-19 has forced countries or regions to adopt new policies to prevent infection (e.g., the stoppage of production and the reshoring of manufacturing) and revive their economies (Qin et al. [47]), and GEPU surged to 430.26 in May 2020. Sixth, economic sanctions caused by the Russian-Ukrainian war caused GEPU to rise to 329.95 in March 2022 (Qin et al. [1]). The positive influences of high GEPU on GSP could be interpreted by three sides. From the perspective of investors, high GEPU leads to an increasing risk aversion in the market (Chiang [15]; Su et al. [5]; Cui et al. [16]) and then they are more willing to invest in the hedging assets (e.g., gold), triggering gold demand and its price to increase. From the perspective of enterprises, high GEPU makes their development face more unknown, and they have to purchase more stable assets to avoid potential losses or even bankruptcy, making gold a suitable choice (Qin et al. [14]). From the perspective of countries, high GEPU may be accompanied by economic risks or even crises, and central banks around the world would increase their gold reserves (Su et al. [11]), further causing GSP to rise. By analogy, low GEPU caused by the dissipation of the above events could positively affect GSP through the decline in hedging demand of investors, enterprises and countries. Hence, we could demonstrate that GEPU positively affected GSP during the period of 2011–2022.

From 1998–2000, GSP showed a downward trend, which corresponded to a relatively low level of GEPU. Since gold possesses an investment value, the positive effects of GSP on GEPU indicate that GSP is an effective instrument to predict GEPU, which highlights that the gold market plays a prospective role in the situation of economic policies worldwide (Qin et al. [14]). In 1997, the synchronization of GEPU and GSP indicated that the gold market is not only a safe haven that hedges against high GEPU caused by the Asian financial

crisis, but also a forward-looking indicator that reflects the condition of economic policies in the world.

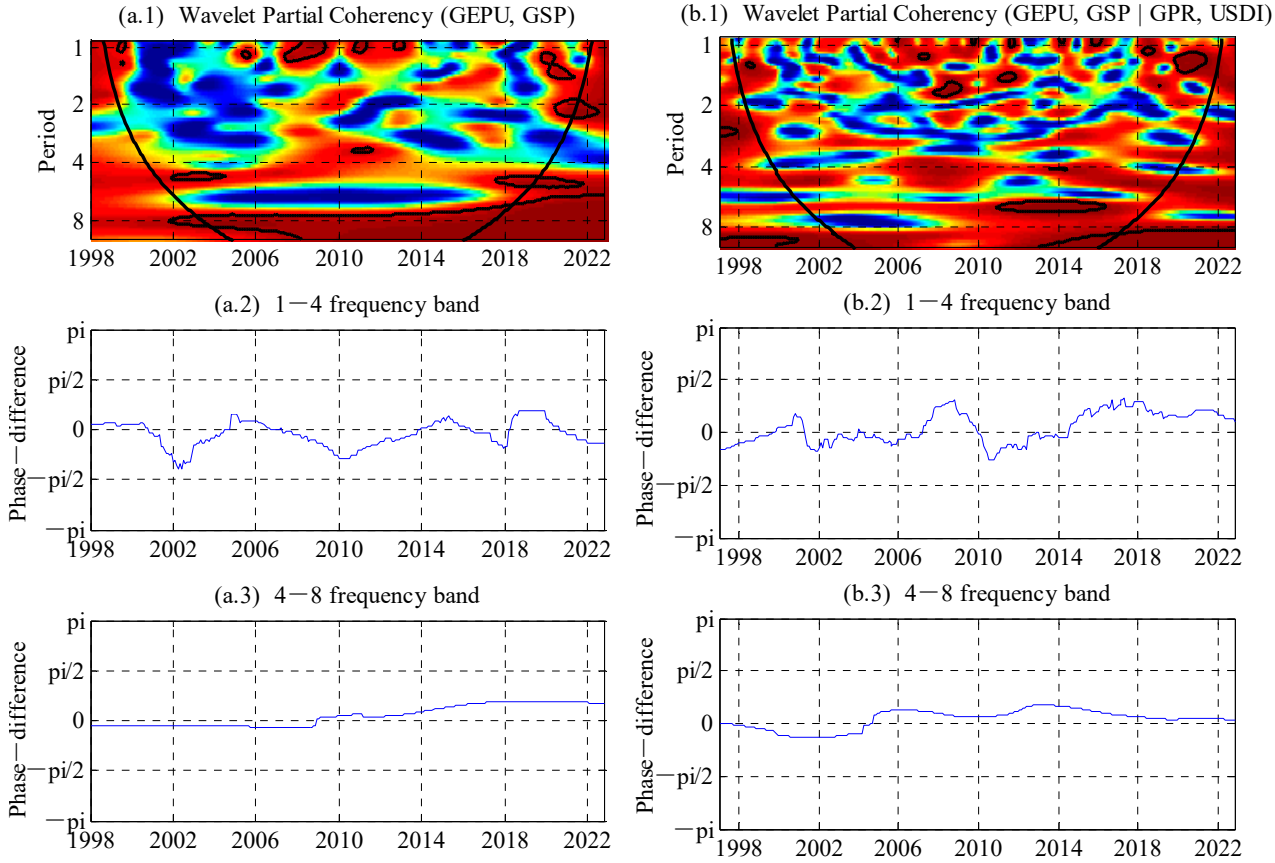

Figure 3. The wavelet partial coherency and phase-difference between GEPU and GSP. Notes: (**a.1**) refers to the wavelet partial coherency between GEPU and GSP without controlling GPR and USDI; (**b.1**) points out the wavelet partial coherency between GEPU and GSP, and GPR and USDI are control series; (**a.2**,**a.3**,**b.2**,**b.3**) reveal the phase-difference between GEPU and GSP. The black contours report the 5% significance level, and these results are obtained by performing the Monte Carlo simulations with 10,000 iterations.

In the medium and short terms, GEPU positively influenced GSP in 2008 and 2020, while GSP positively led GEPU in 1997 and 2011. To begin with, we consider the positive effects of GEPU on GSP, which has only been shown in the short term. In 2008, the global economic crisis destabilized economic policies around the world, such as financial rescue plans, loose monetary and fiscal policies and the reform of financial regulatory systems (Qin et al. [1]; Davis [2]), driving GEPU to 204.59 in October. The underlying causes behind the positive influence from GEPU to GSP can be made clear by three ways. Firstly, high GEPU makes people pessimistic about the economic prospects, and they are inclined to store gold as a hedge against possible risks and uncertainties (Chiang [15]; Cui et al. [16]). Thereafter, the rising demand for gold inevitably leads to an increase in GSP. Secondly, high GEPU accompanied by the loose monetary policy causes the U.S. dollar to depreciate in anticipation. On the one hand, the decline in the U.S. dollar's value makes people reduce their holdings of it, referring to invest in other assets (e.g., gold) that are more valuable (Su et al. [11]). On the other hand, as gold is denominated in the U.S. dollar, the depreciation of it would certainly lift GSP (Qin et al. [14]). Thirdly, the rise in GSP has shown gold's ability to hedge against severe crisis and high GEPU, which attracts more investors to the gold market, causing its price to climb further. Thus, the positive effect of GEPU on GSP in 2008 could be evidenced. In addition, the positive influence from GEPU to

GSP in 2020 can also be explained by the similar transmission mechanism during the above period of 2011–2022. These positive effects are consistent with the ICAPM, underlining that gold can hedge against global economic policy uncertainty.

Then, we consider the positive impacts of GSP on GEPU, which was revealed in both short and medium terms. In 1997, GSP was at a relatively high level, while GEPU also showed an upward trend during the Asian financial crisis. Thus, GSP can be viewed as an indicator to reflect GEPU in advance (Qin et al. [12]), indicating that the gold market can be used to predict the situation of economic policies around the world. In 2011, the quantitative easing led to a depreciation in the U.S. dollar (Su et al. [4,5]), which gave GSP a boost from 1327 dollars per troy ounce in January to 1813.5 dollars per troy ounce in August, growing by nearly 40%. Meanwhile, GEPU also increased from 110.19 to 214.31 during the European sovereign debt crisis (Davis [2]). The positive effect of GSP on GEPU highlights that the gold market plays a forward-looking role in the situation of economic policies worldwide. Besides, the slight decline in GSP (from 1813.5 dollars per troy ounce to 1531 dollars per troy ounce, which decreased by about 15%) and GEPU (from 214.31 to 181.43, which reduced by around 15%) from August to December further emphasizes this predictive role of the gold market. Hence, the positive influences GSP exerted upon GEPU in 1997 and 2011 could be confirmed.

3.3. The Correlation between GEPU and SSP

The wavelet partial coherency and phase-difference between GEPU and SSP are depicted in Figure 4. Similar to the relations between GEPU and GSP, Figure 4(b.1)–(b.3) will be primarily discussed in the following analysis. GEPU positively led SSP during 2006–2008, 2013–2015 and 2017–2022, where the first two periods are shown below in the long term and the last one is presented in the medium and short terms. These outcomes are supported by the ICAPM, suggesting that silver could also be a hedging asset to avoid global economic policy uncertainty.

From 2006–2008, the U.S. subprime crisis and the ensuing global economic crisis led to an increase in GEPU (Davis [2]), which positively affected SSP from two aspects. On the one hand, high GEPU leads to a surge in risk aversion (Qin et al. [3]), making the demand for silver increase to hedge against potential uncertainties (Gençyürek and Ekinci [10]). As SSP continues to rise, more investors realize the haven value of silver, further driving its demand and price to rise. On the other hand, high GEPU is associated with the depreciation of the U.S. dollar during this time, which not only makes it less attractive (Su et al. [4,5]), but also causes a rise in the U.S. dollar-denominated price of silver. Thus, we can ascertain that GEPU exerted positive influences on SSP during 2006–2008. From 2013–2015, with the risks from the global economic crisis and the European sovereign debt crisis dissipating gradually, GEPU was in the lower range. At the same time, SSP decreased from 31.11 dollars per troy ounce in January 2013 to 14.05 dollars per troy ounce in December 2015, which reduced by more than 50%. The positive influence from GEPU to SSP could be explained as follows: low GEPU takes the edge off risk aversion in the market, causing the demand for hedges such as silver to decrease accordingly, which leads to a decline in SSP. In addition, the withdrawal of quantitative easing in the U.S. inevitably strengthens the U.S. dollar (USDI increases from 79.24 in January 2013 to 98.67 in December 2015, which grew by nearly 25%), making it a more attractive asset than silver, which further decreases SSP. Hence, the positive effect of GEPU on SSP during 2013–2015 could be proven. The transmission mechanism behind the positive effect of GEPU on SSP from 2017–2022 is similar to the above discussions: high GEPU caused by the inauguration of the Trump administration, the global trade wars, the COVID-19 pandemic and the Russian-Ukrainian war increases the hedging demand for silver in the short run, which pushes SSP up.

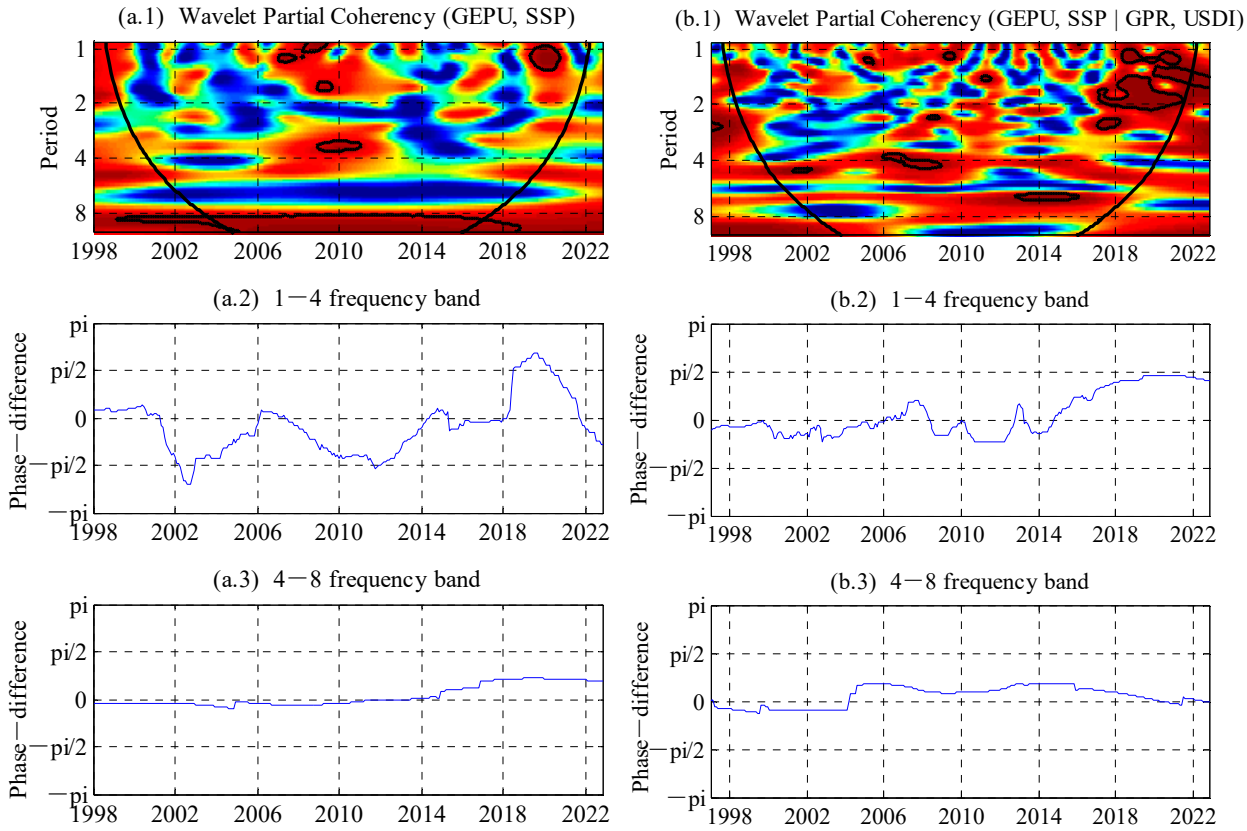

Figure 4. The wavelet partial coherency and phase-difference between GEPU and SSP. Notes: (**a.1**) refers to the wavelet partial coherency between GEPU and SSP without controlling GPR and USDI; (**b.1**) points out the wavelet partial coherency between GEPU and SSP, and GPR and USDI are control series; (**a.2**,**a.3**,**b.2**,**b.3**) reveal the phase-difference between GEPU and SSP. The black contours report the 5% significance level, and these results are obtained by performing the Monte Carlo simulations with 10,000 iterations.

3.4. The Correlation between GEPU and PSP

The wavelet partial coherency and phase-difference between GEPU and PSP are depicted in Figure 5. Similarly, Figure 5(b.1)–(b.3) would be mainly discussed in the following analysis. GEPU had positive influences on PSP during 2014–2015 (in the long run) and 2016–2017 (in the medium and short terms), which is also consistent with the ICAPM. Besides, the underlying causes of these positive effects are similar to the transmission mechanism from GEPU to SSP (or GSP) during the same periods, indicating that platinum can also be considered as an asset to hedge against the instability of global economic policies.

There are both positive and negative influences from PSP to GEPU during 2007–2009 (in the long run, positive), 2008–2009 and 2010–2013 (in the medium run, positive), 2018–2022 (in the short run, negative). Similar to the gold market, due to platinum's investment value (Cheng et al. [9]; Gençyürek and Ekinci [10]), the positive effects of PSP on GEPU highlight that the platinum market could play a forward-looking role in the situation of economic policies worldwide. The adverse effect of PSP on GEPU could also reflect this role, but the underlying cause is different, which is mainly affected by platinum's industrial value rather than its investment one. To be specific, since platinum is an important industrial raw material (Zheng et al. [48]), the economic downturns caused by the global trade wars, the COVID-19 pandemic and the Russian-Ukrainian war has decreased the demand for platinum, resulting in the decline in PSP. At the same time, low PSP accompanied by the economic downturns also increased GEPU, in order to reverse depressions. Similarly, the economic recovery in 2021 led to an increase in PSP and a fall in GEPU. Thus, the negative effect exerted by PSP upon GEPU during 2018–2022 could be ascertained.

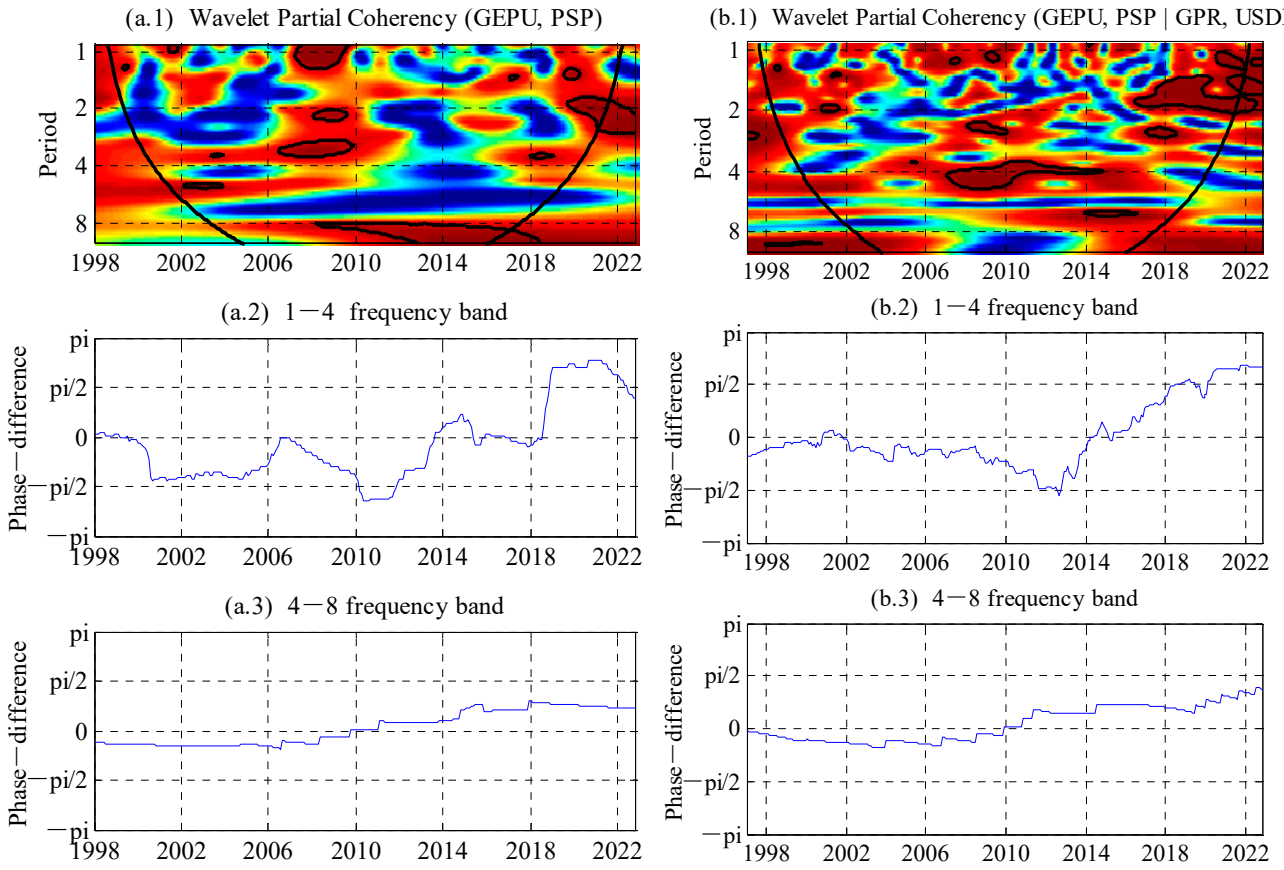

Figure 5. The wavelet partial coherency and phase-difference between GEPU and PSP. Notes: (**a.1**) refers to the wavelet partial coherency between GEPU and PSP without controlling GPR and USDI; (**b.1**) points out the wavelet partial coherency between GEPU and PSP, and GPR and USDI are control series; (**a.2**,**a.3**,**b.2**,**b.3**) reveal the phase-difference between GEPU and PSP. The black contours report the 5% significance level and these results are obtained by performing the Monte Carlo simulations with 10,000 iterations.

4. Discussion

To compare the relations between GEPU and the prices of precious metals (including GSP, SSP and PSP) more clearly, we further summarize Figures 3–5 in Table 2.

By comparing SSP with GSP, we discover that gold is better for the long-term investment in recent years, while silver is more suitable for the short-term one. The primary reasons for this phenomenon are as follows on the one hand, SSP grows faster and larger than GSP, suggesting that silver could respond more rapidly to high GEPU in recent years, thus, investing in the silver market in the short term would hedge against risks more timely; however, SSP also declines more quickly and dramatically than GSP, which makes silver less valuable than gold for long-term investment. On the other hand, as silver plays an increasingly significant role in industry, SSP is more vulnerable to supply and demand in the industrial sector, further undermining silver's hedging ability in the long run. Additionally, gold plays a dual role in hedging and predicting GEPU, while silver only possesses the hedging ability. The underlying causes are as follows: first, since SSP fluctuates faster and larger than GSP, silver's indicative effect on the situation of economic policies is severely weakened; and second, silver's industrial value does not cancel out its ability to hedge against high GEPU in the short run, but it counteracts the forward-looking power created through its investment value. By comparing PSP with GSP and SSP, we find that platinum's hedging ability is virtually non-existent after the global trade wars. The main reason is that, as platinum plays an increasingly important role in industry, this industrial value offsets the returns on its safe-haven ability. Further, PSP has an adverse effect on GEPU and this

phenomenon is not shown in GSP and SSP because the underlying impetus of platinum's indicative effect on GEPU changes from the investment value to the industrial one.

Table 2. Correlations between GEPU and GSP, SSP, PSP.

Variables	Terms of Correlations	Time Periods	Lead-Lag Relations
GEPU—GSP	Long term	1997	Synchronous (+)
		1998–2000	GSP leads GEPU (+)
		2011–2022	GEPU leads GSP (+)
	Medium term	1997	GSP leads GEPU (+)
	Short term	2011	GSP leads GEPU (+)
		2008, 2020	GEPU leads GSP (+)
GEPU—SSP	Long term	2006–2008, 2013–2015	GEPU leads SSP (+)
	Medium term	2017	GEPU leads SSP (+)
	Short term	2017–2022	GEPU leads SSP (+)
GEPU—PSP	Long term	2007–2009	PSP leads GEPU (+)
		2014–2015	GEPU leads PSP (+)
	Medium term	2008–2009, 2010–2013	PSP leads GEPU (+)
		2017	GEPU leads PSP (+)
	Short term	2016–2017	GEPU leads PSP (+)
		2018–2022	PSP leads GEPU (−)

Notes: The correlations between GEPU and GSP, SSP and PSP are obtained through taking GPR and USDI as control series. "+" and "−" in parentheses refer to the influences are positive and negative respectively.

To sum up, it could be observed from the trends and wavelet power spectra of GEPU, GSP, SSP and PSP that the relation between GEPU and the prices of precious metals is complex and that there are similarities and differences among GSP, SSP and PSP. To identify this complicated correlation between GEPU and the prices of precious metals (including GSP, SSP and PSP), this investigation employs the more advanced wavelet technique that considers the time- and frequency-domains. Besides, we also make GPR and USDI control series, to guarantee the robustness of this investigation. Empirical outcomes indicate that GEPU exerts positive influences on the prices of precious metals, suggesting that precious metals could hedge against global economic policy uncertainty, which is supported by the ICAPM. Among them, gold is better for the long-term investment, while silver is more suitable for the short-term one in recent years, but platinum's hedging ability is virtually non-existent after the global trade wars. In turn, GSP has positive effects on GEPU, highlighting that the gold market plays a forward-looking role in the situation of economic policies worldwide. However, silver does not possess this ability, mainly due to the larger volatility in SSP and the fact that the industrial value of silver offsets its prospective effect on GEPU. In addition, there are both positive and negative influences from PSP to GEPU, primarily due to platinum's industrial value being more dominant than its investment value in predicting GEPU after the global trade wars.

5. Conclusions

This investigation probes the correlation between the instability of global economic policy and the prices of precious metals, further exploring whether precious metals could hedge against global economic policy uncertainty and how their prices (including GSP, SSP and PSP) react in many ways to GEPU. Since this correlation might be changeable and perplexed, we apply the wavelet technique to capture it, which also considers GPR and USDI as control sequences. The empirical conclusion suggests that there are positive impacts of GEPU on the prices of precious metals, which coincides with the ICAPM, highlighting that precious metals can be viewed as hedging assets to avert the instability of global economic policies. Conversely, the prices of precious metals exert positive and negative influences on GEPU, indicating that taking the precious metals market into account might make GEPU prediction more comprehensive. By comparing the prices of precious metals, we can conclude that gold plays a dual role in hedging and forecasting GEPU, while

silver only possesses the hedging ability, and gold is better for the long-term investment in recent years than silver, which is more suitable in the short run. Moreover, platinum's hedging ability is almost non-existent after the global trade wars, and the underlying cause of platinum's indicative effect on GEPU changes from the investment value to the industrial one. By investigating the complicated interrelation between GEPU and the prices of precious metals (including GSP, SSP and PSP), we can conclude that precious metals could hedge against global economic policy uncertainty during several instances, but there are differences in the hedging ability of gold, silver and platinum.

On the basis of the above conclusions, we could offer meaningful insights for both investors and governments. On the one hand, since precious metals can be viewed as hedging assets to avert global economic policy uncertainty during several periods, investors could evaluate the values of precious metals according to GEPU. If there is a rise in GEPU, they should invest in the precious metals market in order to avoid potential uncertainties and risks. Furthermore,, the hedging ability of different precious metals is various, thus, investors should form an optimal precious metals portfolio based on GEPU to achieve maximum returns. To be specific, they ought to invest more in silver in the short term, and hold more gold in the long term, but platinum should be stored less due to its unapparent safe-haven status in the current economic situation. Moreover, governments could reserve relevant assets (e.g., increase gold reserves) to hedge national economy against the risks caused by frequent changes in global economic policies. At the same time, they should also take active measures to prevent enormous fluctuations or even potential bubbles in the precious metal market, in order to ensure its healthy operation. On the other hand, since precious metals could also be considered as an asset to predict the situation of economic policies worldwide during several instances, governments ought to make a more comprehensive evaluation of GEPU based on the precious metals market (especially the gold and platinum markets). After that, they should take measures in advance to reduce possible uncertainties and avoid public panic, which is beneficial in promoting a sustained and stable economic development. In future research, we would apply the copula dynamic conditional correlation method based on the daily data to further investigate the hedging ability of precious metals.

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