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Does global supply chain pressure motivate the gold market?

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ABSTRACT

Analyzing the gold market through a new perspective is crucial to forming a rational investment arrangement. This investigation utilizes the bootstrap full- and sub-sample techniques to probe the correlation between global supply chain pressure (GSCP) and the gold price (GP), further evidence of whether global supply chain pressure could motivate the gold market. The conclusions suggest that GSCP has positive and negative effects on GP. The positive influences indicate that intensifying GSCP might raise the safe-haven demand for gold to avert potential risks and uncertainties, underlining that global supply chain pressure could motivate the gold market, whereas low GSCP may decrease this incentive. However, the negative effect could not support the above opinion, which points out that the appreciation of U.S. dollars might weaken the hedging ability of gold. Conversely, GP negatively impacts GSCP, meaning that the gold bull market may stabilize the global supply chain, especially during economic crises. Against the aggravated Russia-Ukraine war and the severe global supply chain crisis, practical implications for consumers, investors, enterprises, and related economies could be put forward according to the above conclusions.

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1. Introduction

Since the outbreak of the Corona Virus Disease 2019 (COVID-19) in 2020, the disruption of the supply chain has become a severe challenge to the world economy (Qin et al., 2022a), which is meaningful to probe related issues from this perspective. The supply chain refers to the complete network of businesses and operations needed to produce products and deliver them to consumers (Brandao & Godinho-Filho, 2022). With the development of economic globalisation, transnational or trans-regional cooperation is increasingly closer, and the dependence between countries and regions

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around the world is also deeper (Liu et al., 2023), leading to the formation and maturation of the global supply chain. A global supply chain requires extending the supply chain system to the whole world from the perspective of globalisation (Qin et al., 2023). Thereupon, it can be perceived that the members of the global supply chain are all over the world, and the disruption at a production or logistics link may trigger the knock-on effect (Gamal et al., 2022; Kazancoglu et al., 2023), causing to an increase in global supply chain pressure (GSCP). The most notable instance is that during the outbreak of COVID-19, major manufacturing countries have been hit by this epidemic, and the international transport network has been disrupted, causing numerous breakpoints in the global supply chain and a spike in GSCP. This investigation employs GSCP to reflect the extent of damage to the global supply chain (Benigno et al., 2022), where higher GSCP represents more damage and vice versa.

Faced with the risks and uncertainties brought by intensifying GSCP, the demand for hedging assets would increase significantly (Oloko et al., 2021; Valadkhani et al., 2022). Gold has historically been considered a powerful hedge against risks or uncertainties, such as economic policy uncertainty, geopolitical risk and partisan conflict (Qin et al., 2020a, 2020b, 2020c). Then, a high GSCP may increase the demand for gold, which raises the gold price (GP). Also, high GSCP might directly disrupt the production and transportation of gold, which causes the gold supply to fall, further increasing GP. Then, it could be observed that global supply chain pressure could motivate the gold market. But this view can not always be supported, mainly due to the following two reasons: First, the hedging ability may be weakened during several periods, such as other more valuable assets (e.g., bitcoin and currencies) make gold less attractive (Ma et al., 2021; Su et al., 2020a), even during periods with high GSCP. Second, during periods with low GSCP, gold may be viewed as a hedge against risks from other events that exert little or no disruptions to the global supply chain (Su et al., 2022b, 2022c). Thus, whether global supply chain pressure could motivate the gold market is worth further discussion. In turn, the gold market's role in the global supply chain is also uncertain. On the one hand, the rise in GP might reflect high GSCP, which shows positive effects. On the other hand, the gold bull market may reduce losses and obtain returns, which is beneficial to restore supply and decrease GSCP, presenting a negative effect. Therefore, the correlation between GSCP and GP may be complicated and dynamic, which is an interesting and significant topic that provides valuable lessons to the public, enterprises and countries.

However, the above topic has yet to be thoroughly studied. Firstly, the previous studies mainly focus on the constant relationship between risks or uncertainties and the gold market, but the complicated and dynamic interrelation between variables is ignored (Byström, 2020; Chiang, 2022; Cui et al., 2022; 2023; Oloko et al., 2021; Triki & Maatoug, 2021). Secondly, the existing efforts pay more attention to gold's ability to hedge against economic uncertainties (Qin et al., 2020c), geopolitical risks (Qin et al., 2020a), inflation (Salisu et al., 2022; Valadkhani et al., 2022), stock market volatility (Ma et al., 2021; Zeinedini et al., 2022) and so on, but no investigation probes the hedging ability of gold from the global supply chain. Thirdly, the extant literature also neglects the role of the gold market in the global supply chain (Qin et al., 2020a, 2020b, 2020c). This investigation tries to fill these gaps and answer three research

questions: Does a dynamic correlation exist between GSCP and GP? If global supply chain pressure could motivate the gold market? What role does gold play in the global supply chain?

The marginal contributions in this investigation are summarised as follows: To begin with, this study is a pioneering effort to probe the hedging ability of gold from the global supply chain. Besides, we overcome the shortcoming of extant literature that only qualitatively analyses the global supply chain. This investigation selects the GSCP index, constructed by the Federal Reserve Bank of New York, to conduct quantitative research (Benigno et al., 2022). Secondly, this investigation also considers the effect of GP on GSCP to identify the role of gold in the global supply chain, which is also innovative in existing efforts. Also, in contrast to most previous studies that only discuss the one-side effect, we further consider the mutual influences and then comprehensively capture the interrelation between GSCP and GP. Thirdly, this investigation employs four parameter stability techniques to prove that the traditional full-sample approach is inapplicable and that GSCP has a time-varying correlation with GP. Therefore, we perform the more advanced sub-sample technique (Su et al., 2020a, 2020b, 2022a, 2022b) to identify the dynamic Granger causal relation between the two series systematically.

This investigation is structured as follows: Section 2 reviews the extant literature. Section 3 introduces the methodology, including research analysis techniques and the data. The estimated results and related discussions are presented in Section 4. Section 5 elaborates on the conclusions, including theoretical contributions, managerial implications, limitations, and future research directions.

2. Literature review

2.1. The overview of GSCP

The existing research pays more attention to the disruption of the global supply chain, primarily analysed from four perspectives. In terms of economic uncertainty, Blessley and Mudambi (2022) evidence that the trading dispute between China and the U.S. makes the U.S. Department of Agriculture move agricultural exports to food banks, which creates supply shocks of both magnitude and scope. Feng et al. (2022) confirm that trading uncertainties (including tariffs, quotas, and subsidies) may change the products' flow and interrupt supply chains. In terms of geopolitical risk, Su et al. (2021) find that such an event happening in oil producers might increase the price of oil, which raises the production and transportation costs, causing GSCP to intensify (Zhang et al., 2022). Qin et al. (2023) suggest that positive influences of higher geopolitical risk exist on GSCP in the short-run scenario, which could not be supported in the medium and long term. Regarding climate and natural disasters, Li et al. (2022) state that China's agri-food supply chain networks are frequently disrupted by extreme weather, which not only leads to huge losses but also adversely impacts people's everyday life. Rahman et al. (2022) point out that climate and natural disasters (including droughts, snowstorms, and shifting of seasons) may cause considerable damage to the overall supply chains. Qin et al. (2023) ascertain that the extreme climate drives GSCP to increase significantly, and La Nina phenomena exert

more profound and lasting impacts than El Nino events. In terms of public health, Nagurney (2021) suggests that as a critical resource in the supply chains from production to transportation, storage and distribution, labour illness, fear of contagion and morbidity during the COVID-19 might disrupt the supply chains network and make GSCP soar. Jomthanachai et al. (2022) point out that the epidemic has an adverse effect on the global trade supply chain, where Thailand's logistics and transport system is the most damaged among the six Association of Southeast Asian Nations (ASEAN) countries. Wang et al. (2022) reveal that the epidemic seriously disrupts the supply chains, where transportation industries have been hit harder than retail ones.

2.2. The hedging ability of gold

Although no study explores gold's hedging ability from the global supply chain, this attribute has received considerable attention from other perspectives. Some scholars state that gold is a powerful hedge to avoid uncertainties. Byström (2020) evidences that GP increases on particularly depressing days, which suggests that gold can be served as a hedge against extreme unhappiness. Qin et al. (2020b) ascertain that the U.S. partisan conflicts positively influence GP, revealing that factionalism can motivate the gold market. Triki and Maatoug (2021) demonstrate that gold is a powerful diversifier and a safe haven, especially during significant tensions. Chiang (2022) underlines that gold could be served as a safe haven asset to avert uncertainties, including economic policy uncertainty, geopolitical risk, interest rate variation and equity market volatility. Su et al. (2022b) suggest that there exist positive effects of world uncertainty on GP, indicating that gold remains the uncertainty-hedging aura during periods of economic and political crises. Cui et al. (2023) prove that gold could be considered a safe haven asset during COVID-19 in the short and long runs.

However, some scholars confirm that gold is not a powerful hedge. Salisu and Adediran (2020) reveal that gold is not a hedge against oil price volatility, regardless of the nature of the fluctuations and the empirical techniques applied. Thampanya et al. (2020) state that adding gold to a stock portfolio would not improve its risk-adjusted returns. Ma et al. (2021) imply that the government bond is more powerful than gold in hedging stock market volatility, particularly in periods of turbulence. Choudhury et al. (2022) highlight that gold is a weaker safe haven for stock market investors during the COVID-19 period, while U.S. treasuries are the safest, followed by Japanese sovereign bonds. Naeem et al. (2022) point out that oil has higher hedge effectiveness than gold before the global economic crisis. Salisu et al. (2022) find silver a more powerful hedge than gold during inflation and climate disasters caused by the El Niño phenomenon. Zeinedini et al. (2022) show that there is an insignificant effect of the stock price in Iran on GP, meaning that gold is not a hedge against stock market volatility.

Further, other scholars explain these two contrasting views and believe that the hedging ability of gold possesses time-varying characteristics. Chai et al. (2019) state that economic policy uncertainty positively affects GP during the global economic crisis, but there is a negative influence during the European debt crisis, which presents

positive and adverse impacts alternately during the Donald J. Trump campaign. Qin et al. (2020a) highlight that geopolitical risks have a positive and negative effect on GP, revealing that gold could not always be reserved in a chaotic era. Qin et al. (2020c) underline that gold could be considered a hedge during crises, but this view can not be supported in non-crisis periods. Su et al. (2020a) suggest that bitcoin may undermine the hedging ability of gold during several periods, but this ability persists at other times. Su et al. (2022c) indicate that world uncertainties exert positive and adverse impacts on GP, meaning that gold's hedging ability cannot always be shown. Valadkhani et al. (2022) discover that gold exhibits an obvious response to inflation if monthly inflation in the U.S. exceeds 0.55%, which keeps it non-responsive if inflation is moderate or low.

2.3. The effect of GP on uncertainty

Although no investigation probes the role of gold in the global supply chain, the influence of GP on other uncertainties has drawn obvious attention and yielded different conclusions. On the one hand, Qin et al. (2020a) reveal that GP exerts positive influences on geopolitical risks, underlining that the gold market could be a powerful barometer of the geopolitical environment. On the other hand, Su et al. (2022b) have evidence of a negative influence of GP on world uncertainties (also Qin et al., 2020b). In addition, this effect is not unchangeable. Oloko et al. (2021) point out that the influence of gold price shock on the persistence of inflation rates in developing countries is long-term, while this effect is short-term in developed countries. Cui et al. (2022) highlight that GP negatively affects the stock market in China, while GP volatility has a positive influence on it in the long term.

3. Methodology

3.1. Research analysis techniques

3.1.1. Bootstrap full-sample technique

Although the traditional vector auto-regressive (VAR) approach can probe the correlation among time series, these variables and the VAR system should conform to the standard normal distribution (Qin et al., 2022b). If this distribution can not be obeyed, the correctness of the traditional VAR approach might be degraded accordingly (Su et al., 2020a, 2020b). To cope with this difficulty, Shukur and Mantalos (1997) introduce a critical value of the residual-based bootstrap (*RB*) approach, which could be applied to the Granger causality test that does not follow a standard normal distribution. In addition, the *RB* technique is also suitable for small samples (Su et al., 2022a). Further, the likelihood ratio (*LR*) approach is then introduced by Shukur and Mantalos (2000), which can be modified by power and size characteristics. We employ the *RB*-based revised-*LR* technique to explore the causal relationship between GSCP and GP. Equation (1) reveals the VAR (j) system.

$$Z_t = \chi_0 + \chi_1 Z_{t-1} + \ldots\ldots + \chi_j Z_{t-j} + \mu_t \tag{1}$$

where j is chosen through Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC), and these two ways can be applied to acquire the optimising lag order (Su et al., 2022b). Moreover, Z can be further represented as $Z_t = (\mathrm{GSCP}_t, \mathrm{GP}_t)'$. Since GP is priced in the U.S. dollar, which might impact the correlation between GSCP and GP (Qin et al., 2020a, 2020b; 2021). Hence, this investigation makes the U.S. dollar index (USDI) control series, and Equation (1) could be rewritten as follows:

$$\begin{bmatrix} \mathrm{GP}_t \\ \mathrm{GSCP}_t \end{bmatrix} = \begin{bmatrix} \chi_{10} \\ \chi_{20} \end{bmatrix} + \begin{bmatrix} \chi_{11}(L) & \chi_{12}(L) & \chi_{13}(L) \\ \chi_{21}(L) & \chi_{22}(L) & \chi_{23}(L) \end{bmatrix} \begin{bmatrix} \mathrm{GP}_t \\ \mathrm{GSCP}_t \\ \mathrm{USDI}_t \end{bmatrix} + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \end{bmatrix} \tag{2}$$

According to the above VAR (j) process, the original assumption that GSCP is not a Granger cause of GP ($\chi_{12,k} = 0$) can be confirmed. This supposition ought to be rejected if GSCP exerts obvious influences on GP. By analogy, the original assumption that GP is not a Granger cause of GSCP ($\chi_{21,k} = 0$) could be rejected if GP significantly impacts GSCP.

3.1.2. Parameter stability tests

The above technique assumes the coefficients are fixed, but this supposition can not always be established in reality (Qi et al., 2022; Su et al., 2020a). Applying the full-sample technique is not reasonable if the coefficients have structural mutations. In order to guarantee the robustness of estimated results, we utilise the *Sup-F*, *Ave-F* and *Exp-F* techniques produced by Andrews (1993) and Andrews and Ploberger (1994). The first technique captures structural mutations in every series and the VAR (j) system, and the latter two techniques recognise whether coefficients alter gradually over time. Additionally, this investigation also uses the L_c statistics technique, introduced by Nyblom (1989) and Hansen (1992), to provide proof of the random walk of the coefficients. If sudden structural changes exist, the causal relation between GSCP and GP is changeable. Therefore, the full-sample technique is inapplicable, and we ought to perform the more advanced sub-sample one to identify the dynamic interrelation.

3.1.3. Bootstrap sub-sample technique

The sub-sample technique is introduced by Balcilar et al. (2010) to recognise the changeable character of the correlation between two series. This technique separates the entire data into small ones based on the rolling window width and then makes all the small ones roll from start to finish constantly. But confirming an appropriate rolling window width is not easy because a smaller width might cause an inaccurate estimated outcome, and a larger one may decrease frequency. To cope with this difficulty, Pesaran and Timmermann (2005) ascertain that this width ought to exceed or equal to 20 while coefficients in the VAR (j) system are changeable. The specific procedure can be summarised as: Firstly, assuming that the length of the whole data is M and the width is set as n, and the end of every small part is n, $n+1, \ldots \ldots, M$. Secondly, every small section can obtain a correlation through performing the *RB*-based revised-*LR* technique. Thirdly, we could acquire the estimated outcomes of this

sub-sample technique by chronologically computing the p-values and LR statistics. Furthermore, the mean values of estimated outcomes ($N_b^{-1}\sum_{k=1}^{j}\hat{\chi}_{12,k}^{*}$ and $N_b^{-1}\sum_{k=1}^{j}\hat{\chi}_{21,k}^{*}$) refer to the impact of GSCP on GP and the effect of GP on GSCP. In addition, based on Balcilar et al. (2010), this investigation uses the 90% confidence interval with lower (the fifth quantile of $\hat{\chi}_{12,k}^{*}$ and $\hat{\chi}_{21,k}^{*}$) and upper (the ninety-fifth quantile of $\hat{\chi}_{12,k}^{*}$ and $\hat{\chi}_{21,k}^{*}$) bounds (Su et al., 2022a).

3.2. Data

This investigation selects the monthly time series of December 2000 to November 2022 to explore whether global supply chain pressure could motivate the gold market. Since December 2000, the La Nina phenomenon has brought extreme weather worldwide, increasing the pressure on the global supply chain. For instance, parts of Asia, Europe and North America have been hit by severe cold temperatures and snow storms, causing damage to transportation and heating facilities that maintain supply chain stability. Also, parts of South America, Oceania and Africa (especially Argentina, Australia, Bolivia and Mozambique) have been hit by heavy rains and storms that severely destroy communications, power and human capital. After that, numerous events destroyed the global supply chain, and these can be summarised as climate (e.g., the La Nina and El Nino phenomena), economic (e.g., the global economic crisis in 2008 and global trade wars from 2017), geopolitical (e.g., the Russia-Ukraine war in 2022), public health (e.g., the COVID-19 in 2020) and other (e.g., the March 11 Japan earthquake in 2011) events. Then, we choose the global supply chain pressure (GSCP) index to represent the magnitude of disruptions acquired in the Federal Reserve Bank of New York (Benigno et al., 2022). This index integrates considerable commonly used indicators to provide a comprehensive summary of potential supply chain disruptions, including indicators that reflect global transportation costs and supply chain-related components in the Purchasing Managers' Index. The values of GSCP are higher than 0, revealing that the global supply chain is distinctly tight, and more intensifying GSCP points out more pressure and vice versa. In the face of disruptions to the global supply chain, the public has become significantly more risk-averse and sought safe havens to avoid potential risks, such as the gold market. For instance, the Russia-Ukraine war in 2022 severely disrupts the global supply chain (including food, energy, semiconductors, etc.) and made the gold market more attractive to investors, resulting in a rise in gold demand and its price. Thereby, the gold market might be intimately linked to the global supply chain, and this paper selects the gold price in U.S. dollar (GP) to explore this relevance (Qin et al., 2020a, 2020b), which is acquired in the World Gold Council. We could capture the correlation between GSCP and GP and explore if global supply chain pressure could motivate the gold market. The trends of GSCP and GP are depicted in Figure 1.

From Figure 1, it can be perceived that GP is not always in a similar direction as GSCP. The La Nina phenomenon occurred in 2000–2001, making GSCP rise slightly, but its values are less than 0. During this time, the willingness to invest in gold to avoid GSCP is low, hence, the demand for gold and GP does not show an obvious upward trend. In 2004, as the oil price continued to rise, GSCP increased accordingly, and its

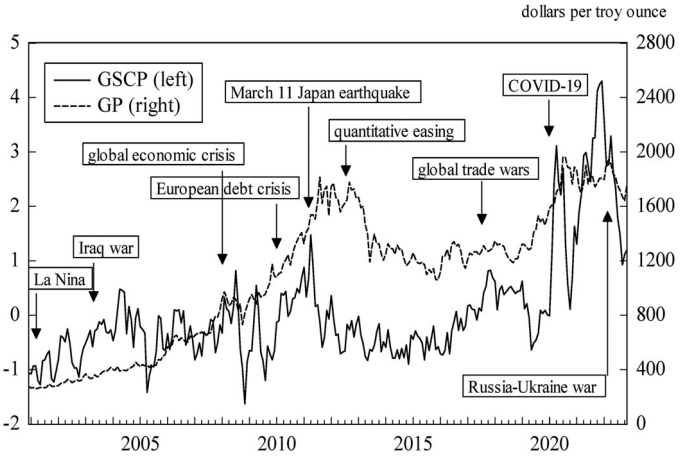

Figure 1. The trends of GSCP and GP.
Source: Authors' calculation.

values were significantly greater than 0, making GP move in the same direction to hedge potential uncertainties. Since 2008, the global economic crisis has caused GSCP and GP to fluctuate sharply in the same direction. But this phenomenon did not hold since April 2009; GSCP has decreased sharply, while GP has raised from 883.25 dollars per troy ounce in April 2009 to 1175.75 dollars per troy ounce in November 2009, which grew by more than 30%. The European debt crisis in 2010 and the Japan earthquake in 2011 have strained the global supply chain, causing GSCP and GP to rise dramatically. After 2011, GSCP is gradually relieved, and GP is also downward. Since Donald Trump took office as President of the U.S., the frequent global trade wars aggravated GSCP, leading to an increase in risk aversion and GP. However, GP moves in an opposite direction in the second half of 2018, even if the values of GSCP are higher than 0. The outbreak of COVID-19 in 2020 has had a significant adverse impact on the global supply chain, causing the interruption of the leading players worldwide (e.g., production, logistics and transportation), intensifying GSCP. During this time, the gold market can be considered a safe haven, driving GP to soar from 1584.2 dollars per troy ounce in January 2020 to 1964.9 dollars per troy ounce in July 2020, which increases by nearly 25%. However, as the economic recovery, global demand has outstripped supply, making GSCP surge from 0.11 in October 2020 to 4.3 in December 2021, while GP shows no clear upward trend. During the Russia-Ukraine war in 2022, this geopolitical event and related sanctions resulted in a significant increase in GSCP and the requirement for hedging assets (such as gold), GP moved in the same direction as GSCP. With the gradual reduction of GSCP, GP also falls from 1942.15 dollars per troy ounce in March 2022 to 1639 dollars per troy ounce in October 2022, which decreases by more than 15%. Furthermore, GP is priced in the U.S. dollar, which might impact the correlation between GSCP and GP, such as U.S. withdrawal of quantitative easing can cause GP to decline, and vice versa. Thereupon, we choose the U.S. dollar index (USDI) as the control series, which is taken from the Wind Database (Qin et al., 2021). Based on the above analyses, the interrelation between GSCP and GP is not unchanging but complicated and affected by USDI. The traditional full-sample technique could not

Table 1. Descriptive statistics for GSCP, GP and USDI.

	GSCP	GP	USDI
Observations	264	264	264
Mean	0.063	1076.805	90.714
Median	−0.200	1203.475	90.110
Maximum	4.300	1964.900	120.240
Minimum	−1.630	257.700	71.840
Standard Deviation	1.050	505.567	10.953
Skewness	1.880	−0.164	0.606
Kurtosis	6.679	1.817	2.943
Jarque-Bera	304.327***	16.571***	16.183***

Notes: ***denotes the significance at a 1% level.
Source: Authors' calculation.

recognise this intricate causality between these two variables. Therefore, it is robust to perform the more advanced sub-sample technique to catch this dynamic correlation, and the issue of whether global supply chain pressure could motivate the gold market could also be answered.

From Table 1, the average of GSCP indicates that this series is concentrated on 0.063 levels, revealing that the overall performance of the global supply chain in 2000–2022 is under pressure. Besides, GP and USDI are concentrated at 1076.805 and 90.714 levels. The dramatic difference between the maximum and minimum values of GSCP and GP proves that these two-time series fluctuate significantly. The skewness is positive in GSCP and USDI, referring to the fact that they conform to the right-skewed distributions, whereas GP obeys the left-skewed one. GSCP possesses higher peak and fat tail characteristics, but GP and USDI conform to the platykurtic distributions. Moreover, the Jarque-Bera test provides evidence that the null hypothesis of standard normal distribution in GSCP, GP and USDI could be rejected at a 1% level. Hence, applying the Granger causality test based on the traditional VAR system is unreasonable, and we ought to implement the *RB*-based revised-*LR* technique to cope with this difficulty. Furthermore, this investigation also performs the more advanced sub-sample technique to capture the changeable Granger causal relation between GSCP and GP. Besides, we transform GP and USDI by making the natural log compress the variable scale and eliminate the heteroscedasticity.

4. Empirical results and discussions

In order to avert the 'spurious regression' in the VAR (j) process, this investigation employs the Augmented Dickey-Fuller (ADF, 1981) and Phillips-Perron (PP, 1988) techniques to examine the existence of unit roots in GSCP, GP and USDI. Table 2 reveals the relevant outcomes; it can be observed that the level of GSCP could reject the null hypothesis of the appearance of unit roots in ADF and PP techniques, indicating that this sequence is stable. But the levels of GP and USDI can not reject the null hypothesis, while their first differences are stationary at the significance level of 1%. Hence, this investigation uses the level of GSCP and the first differences between GP and USDI to conduct empirical analyses.

Based on Equation (2), we build the traditional VAR (j) system to carry out the bootstrap full-sample analysis and then recognise the correlation between GSCP and GP. This investigation selects the optimising lag order as 1 based on AIC and SIC.

Table 2. The outcomes of unit root tests.

		ADF	PP
GSCP		−3.058 (1)**	−2.809 [5]*
GP	Level	−2.013 (1)	−1.900 [6]
	First difference	−13.002 (1)***	−18.078 [3]***
USDI	Level	−1.798 (1)	−1.840 [5]
	First difference	−10.498 (1)***	−15.461 [4]***

Notes: The number in parentheses points out optimal lag order chosen by SIC.
The number in brackets reveals optimal bandwidth selected by Bartlett Kernel (Newey-West test, 1987).
*, ** and *** indicate significance at 10%, 5% and 1% levels.
Source: Authors' calculation.

Table 3. The outcomes of bootstrap full-sample method.

H_0: GSCP is not the Granger cause of GP		H_0: GP is not the Granger cause of GSCP	
Statistic	*p*-value	Statistic	*p*-value
0.279	0.600	0.128	0.750

Notes: This investigation calculates *p*-values through employing 10,000 bootstrap repetitions.
Source: Authors' calculation.

Table 4. The outcomes of parameter stability techniques.

	GSCP		GP		VAR (*j*) process	
Tests	Statistics	*p*-values	Statistics	*p*-values	Statistics	*p*-values
Sup-F	28.521***	0.001	34.266***	0.000	47.889***	0.000
Ave-F	18.143***	0.000	9.609**	0.033	25.827***	0.000
Exp-F	11.272***	0.000	11.936***	0.000	19.101***	0.000
L_c					6.053***	0.005

Notes: ** and *** denote the significance at 5% and 1% levels.
Source: Authors' calculation.

Table 3 shows the related outcome, indicating that GSCP is not a cause of GP and vice versa, which is inconsonant with the existing literature (Byström, 2020; Chiang, 2022; Cui et al., 2023; Oloko et al., 2021; Su et al., 2022b; Triki & Maatoug, 2021; Valadkhani et al., 2022).

The above bootstrap full-sample technique assumes the coefficients are unchangeable, and just a Granger causal relation can be observed throughout the entire period (Balcilar & Ozdemir, 2013). However, the outcomes in Table 3 are not robust if the series and VAR (*j*) process have structural mutations, underlining that the correlation between GSCP and GP is dynamic (Su et al., 2020a). Thereupon, this investigation applies the *Sup-F*, *Ave-F*, *Exp-F*, and L_c statistics techniques to examine the parameter stability. The outcomes of these four techniques are shown in Table 4.

From Table 4, the *Sup*-and *Exp-F* techniques indicate that GSCP, GP and the VAR (*j*) process could reject the null assumption at a 1% level, highlighting that they possess structural mutations. The *Ave-F* technique ascertains GSCP, and the VAR (*j*) process can reject the null hypothesis at a 1% level, while GP significantly changes over time at a 5% level. Besides, the L_c statistics technique points out that the alternative hypothesis could be accepted at the significance level of 1%, confirming that the VAR (j) process does not conform to the random walk process. Consequently, the above four techniques indicate that GSCP has a time-varying correlation with GP. This investigation employs the more advanced sub-sample technique to recognise this

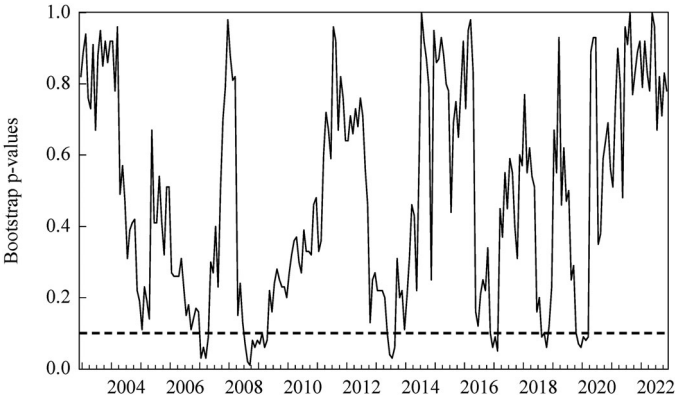

Figure 2. Examining the null hypothesis that GSCP does not Granger cause GP.
Source: Authors' calculation.

dynamic relation between GSCP and GP. To enhance the accuracy of the estimated conclusions, we choose the rolling window width of 24-months[1] (Qi et al., 2022; Su et al., 2022a). After that, we could clarify if the alternative hypothesis that GSCP Granger causes GP (or GP Granger causes GSCP) can be significantly accepted or rejected. Further, the directions of the influences from GSCP to GP (or the effects of GP on GSCP) could be estimated.

Figures 2 and 3 depict the *p*-values and coefficients of GSCP on GP. GSCP significantly Granger causes GP at a 10% level during the periods of January 2007 to April 2007, July 2008 to April 2009, May 2013 to August 2013, December 2016 to February 2017, August 2018 to October 2018, and October 2019 to March 2020. In addition, both positive effects (January 2007 to April 2007, July 2008 to April 2009, May 2013 to August 2013, December 2016 to February 2017, and October 2019 to March 2020) and adverse influence (August 2018 to October 2018) exist from GSCP to GP during the above six periods.

The positive effects of GSCP to GP could prove that global supply chain pressure may motivate the gold market and vice versa. From January 2007 to April 2007, the

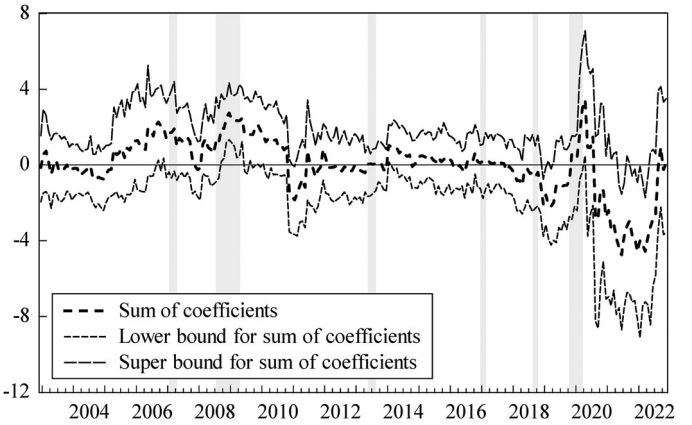

Figure 3. The coefficients of the influence from GSCP to GP.
Source: Authors' calculation.

average of GSCP is about −0.7, which indicates that the global supply chain is relatively stable. At the same time, GP presents no significant increase and remains at a low range; the underlying causes behind this positive effect from GSCP to GP can be clarified from three sides. Firstly, less GSCP reduces the risk aversion of the public, and their demand for hedges (e.g., gold) to hedge against possible uncertainties is correspondingly lower (Chiang, 2022; Qin et al., 2020a, 2020b; Triki & Maatoug, 2021), making GP at a relatively low level. Secondly, less GSCP is accompanied by low oil prices (Benigno et al., 2022), which causes a decline in demand for gold to avert the costs caused by potential inflation (Oloko et al., 2021; Shahzad et al., 2022; Valadkhani et al., 2022), resulting in a lower level of GP. Thirdly, the easing of the Iranian nuclear issue creates a stable geopolitical environment for the development of a global supply system (Caldara & Iacoviello, 2017, 2021), which promotes the overall demand for gold to remain steady, leading GP to maintain a low level of volatility (Su et al., 2020a, 2022b). Thus, we could evidence that low stress in the global supply chain reduces the incentive for the gold market, and GSCP exerted positive influence on GP from January 2007 to April 2007.

From July 2008 to April 2009, GSCP showed a trend of plummeting first and then skyrocketing; thereupon, we will discuss the positive influence of GSCP on GP from two stages. In the first stage, GSCP fell sharply from 0.82 in July 2008 to −1.63 in November 2008, and GP also decreased from 918 dollars per troy ounce to 730.75 dollars per troy ounce (reduces by more than 20%), the positive influence from GSCP to GP could be interpreted as follows: Although the global economic crisis has weakened production and supply capacity around the world (Qin et al., 2020c, 2021), the collapse in oil prices (the Brent oil price plummets from 132.72 dollars per barrel in July 2008 to 52.45 dollars per barrel in November 2008, which decreases by more than 60%) has eased GSCP. Then, the demand for gold as a hedge against GSCP and potential inflation has sharply reduced, leading to a downward trend in GP (Chiang, 2022; Qin et al., 2020a, 2020b; Valadkhani et al., 2022). In addition, the rise of USDI from 73.2 in July 2008 to 86.55 in November 2008 also makes gold less attractive to investors, causing its demand and price to fall further (Su et al., 2022c). In the second stage, GSCP rose to 0.55 in April 2009, and GP also showed an upward trend, this positive effect from GSCP to GP could be explained similarly: High GSCP is accompanied by rising oil prices, which increases the demand for safe havens (e.g., the gold market) to avert potential uncertainties and costs, driving GP to a relatively high level. Thereby, the positive influence of GSCP to GP from July 2008 to April 2009 could be confirmed.

As the adverse shocks of the global economic crisis, the European debt crisis and the March 11 Japan earthquake wear off, the average of GSCP remains around −0.67 from May 2013 to August 2013, meaning that the global supply chain is relatively stabilised (Benigno et al., 2022). Meanwhile, GP has fallen to 2010 levels, and the positive impact of GSCP on GP could be made clear from two aspects. On the one hand, low GSCP makes investors and enterprises have better expectations of economic development prospects, and their risk aversion has cooled significantly (Su et al., 2020a, 2022b; Triki & Maatoug, 2021). Then, they reduce their holdings of safe haven assets (e.g., gold) that help them avoid potential risks, which inevitably decreases GP. On the other hand, the better economic expectations from low GSCP make the U.S. Federal Reserve inclined to

reduce or even withdraw quantitative easing (Qin et al., 2020c, 2021). After that, investors generally realise that the U.S. dollar would be appreciated, and then they increase their holdings of the U.S. dollar and reduce the demand for gold to gain more returns (Su et al., 2022c), which further causes GP to fall. Hence, GP was positively affected by GSCP from May 2013 to August 2013 can be ascertained.

From December 2016 to February 2017, GSCP rose from −0.2 to 0.19, indicating that the global supply chain is increasingly strained. This phenomenon could be interpreted as follows: On the one hand, in December 2016, Saudi Arabia and Russia reached an agreement to jointly cut oil production, which pushed its price up by more than 20%. High oil price makes production and transportation costs soar, driving GSCP to increase (Brown, 2017). On the other hand, in January 2017, the Trump administration withdrew the U.S. from the Trans-Pacific Partnership Agreement (TPP), which worsens the trade and supply environment (Su et al., 2020b), undoubtedly intensifying GSCP. During this time, there exist positive impacts of GSCP on GP (GP increases from 1145.9 dollars per troy ounce to 1255.6 dollars per troy ounce, which grows by nearly 10%), which can be analysed in four ways. First, high GSCP brings considerable uncertainties or risks to the public and enterprises, making them more willing to hold hedging assets such as gold (Chiang, 2022; Qin et al., 2020a, 2020b), which inevitably raises GP. Second, high GSCP is accompanied by high oil prices, triggering more demand for gold to fight against inflation (Valadkhani et al., 2022). Third, Trump's withdrawal from TPP not only intensifies GSCP but also aggravates pessimism about future development, further increasing the safe-haven demand for gold (Qin et al., 2020c). Fourth, high GSCP reduces gold production and transportation capacity, resulting in a decline in gold supply and an increase in GP. Therefore, GSCP positively affected GP from December 2016 to February 2017 could be proved.

The global supply chain was extremely strained from October 2019 to March 2020; GSCP rose from 0.03 to 2.45, which is the highest value since the beginning of statistics (Benigno et al., 2022). The main reasons for this phenomenon are the occurrences of global trade wars (especially Sino-U.S. trade disputes and the trade war between Japan and South Korea) and the outbreak of COVID-19 (e.g., suspending production and implementing the closed-door policy worldwide). The positive effect of GSCP on GP could be explained from the demand and supply sides. From the perspective of demand, high GSCP may cause the public's demand for several products or services to be unmet, which generates more consumption costs for them, thereupon they tend to store gold to avoid potential losses (Oloko et al., 2021; Valadkhani et al., 2022). Also, enterprises might be short of raw materials to sustain their production and are inclined to hold gold to cover losses or stave off bankruptcy. In addition, an extremely high GSCP leads investors to take a rather pessimistic expectation of the economic prospects, triggering them to invest in safer and more risk-averse assets such as gold (Qin et al., 2020a, 2020b; 2021). From the perspective of supply, high GSCP not only reduces the production capacity of gold but also prevents it from being transported, which decreases its supply. For instance, China, the world's largest gold producer, produced 82.63 tons of gold in the first quarter of 2020, which is down 10.93% compared with the same period of the previous year (92.77 tons)[2]. Then, the increase in gold demand and the decline in its supply make GP show an

upward trend. Consequently, we can conclude that GSCP positively affects GP from October 2019 to March 2020.

However, the above view could not be supported by the negative effect of GSCP on GP. From August 2018 to October 2018, the values of GSCP are above 0, and the average is close to 0.5, indicating that the global supply chain is under strain. The primary causes of high GSCP are global trade wars (mainly the Sino-U.S. trade disputes) and rising oil prices (the Brent oil price increased by more than 10%). High GSCP should have increased the hedging demand for gold (Chiang, 2022; Qin et al., 2020a, 2020b; Valadkhani et al., 2022), but instead, GP is at a lower level in this period. The underlying causes behind this phenomenon could be expressed as follows: The U.S. Federal Reserve has raised interest rates several times in 2018 (in March, June, September and December, respectively), which keeps USDI above 95 basically. On the one hand, the appreciation of U.S. dollars makes gold less attractive to investors; they are more inclined to reserve U.S. dollar assets (e.g., treasury securities), causing gold demand and its price to fall. On the other hand, since gold is priced in U.S. dollars, its appreciation of it is a headwind for the gold market, inevitably leading to a decrease in GP. As a result, we could provide evidence that affected by the rising value of U.S. dollars, GSCP exerted an adverse effect on GP from August 2018 to October 2018.

The *p*-values and coefficients of GP on GSCP are depicted in Figures 4 and 5. GP significantly Granger causes GSCP at a 10% level from August 2009 to January 2010. Additionally, only an adverse effect exists from GP to GSCP during this period.

From August 2009 to January 2010, GP rose from 955.5 dollars per troy ounce to 1078.5 dollars per troy ounce, which grew by more than 10%; the leading cause is that the gold market has been stimulated by quantitative easing in the U.S. On the one hand, the U.S. dollar depreciation makes gold cheaper to purchase and a more valuable asset, leading to a gold bull market (Su et al., 2020a, 2022c). On the other hand, the depreciation of U.S. dollars leads to an oil bull market (Qin et al., 2020c), causing the demand for gold to fight against inflation to rise, which further raises GP (Oloko et al., 2021; Valadkhani et al., 2022). But the values of GSCP are lower than 0, and the average is around −0.8; the primary reasons for this negative effect from

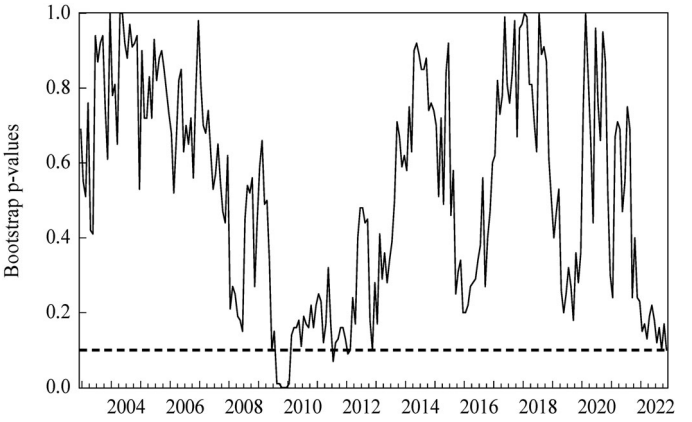

Figure 4. Examining the null hypothesis that GP does not Granger cause GSCP.
Source: Authors' calculation.

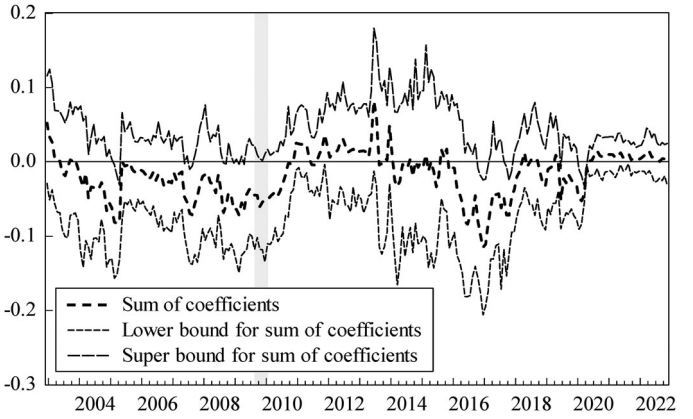

Figure 5. The coefficients of the influence from GP to GSCP.
Source: Authors' calculation.

GP to GSCP could be interpreted as follows: In terms of the public, accompanied by the rise in GP, losses and costs to them are reduced by the storage of gold, which is beneficial to decrease social panic, and then promote the economic recovery and relieve the stress of global supply chain. In terms of enterprises, they could obtain profits through investing in gold, which enables them to recover and enhance the production and supply capacity, further mitigating GSCP. Accordingly, we could certify that GP adversely impacts GSCP from August 2009 to January 2010.

In summary, the outcome of the bootstrap full-sample technique indicates that GSCP does not significantly affect GP and vice versa. But this result is not reliable if the coefficients are not unchangeable. In order to provide proof of this variability, we employ four parameter stability techniques, giving evidence that GSCP, GP and the VAR (j) system have sudden structural changes. Hence, this investigation applies the more advanced sub-sample technique to identify this dynamic correlation between two series. The conclusions suggest that positive and negative effects from GSCP to GP exist. The positive influences reveal that high GSCP may increase the safe-haven demand for gold, indicating that global supply chain pressure could motivate the gold market. At the same time, low GSCP might reduce the incentive for the gold market. However, the negative effect of GSCP on GP is not consistent with the above opinion, mainly because the rising value of U.S. dollars causes GP to decline even during the period with high GSCP. Conversely, GP exerts a negative influence on GSCP, highlighting that the rise in GP during economic crises may benefit the economy's recovery and the alleviation of GSCP.

5. Conclusions

5.1. Theoretical contributions

This investigation mainly addresses three research questions, which are also article advantages to the extant literature. Firstly, existing efforts ignore the changeable interaction between GSCP and GP. To answer if the conduction mechanism between the global supply chain and the gold market is dynamic, we apply the *Sup-F*, *Ave-F*, *Exp-F*, and L_c statistics techniques to examine the time-varying characteristics. Based on these four

techniques, we confirm that structural mutations exist in GSCP, GP and the VAR (j) process, indicating that GSCP has a time-varying relation with GP and that the more advanced sub-sample technique should be implemented. Secondly, studies have yet to explore the safe-haven properties of gold from the global supply chain, and this investigation answers whether global supply chain pressure could motivate the gold market. We discover that GSCP has positive and negative effects on GP. The positive effects reveal that the rise in GSCP might raise the gold demand to hedge potential risks and uncertainties, highlighting that global supply chain pressure could motivate the gold market. But the negative influence can not support this view, mainly due to the appreciation of U.S. dollars weakening gold's ability to hedge against high GSCP. Thirdly, the previous efforts neglect the role of the gold market in the global supply chain, and we answer this question by exploring the effect of GP on GSCP. We find that GSCP can be negatively affected by rising GP, indicating that the gold market might be considered an instrument to stabilise the global supply chain during economic crises.

5.2. Managerial implications

Based on these results, significative implications could be brought for the public, enterprises and countries in the context of a deepening global supply chain crisis. For the public, since GSCP exerts positive effects on GP during several periods, consumers could judge the trend of the gold price according to the global supply chain. Then, they can reserve gold in advance to reduce high costs caused by possible uncertainties, such as inflation and demand outstripping supply. Also, investors can invest in gold or consider adding gold to their portfolio at high GSCP levels in order to earn more returns and avoid potential losses, but they should reduce their gold exposure at low GSCP levels. For enterprises, they could also forecast the gold price based on the global supply chain. When the global supply chain is strained, they should invest in gold as a strategic arrangement to prevent huge losses or even bankruptcy caused by the disruption of production and supply. In turn, by earning returns from investing in the gold market, enterprises can restore and improve their production and supply capacity, pushing them back into normal operations. More importantly, the gold bear market may accompany the high pressure of supply chains. Thereupon, the public and enterprises ought to focus on the values of other assets (such as U.S. treasury securities) when they purchase or invest in gold, which is beneficial to avert the gold bear market caused by the appreciation of U.S. dollars. The countries can reserve gold to withstand economic risks and crises caused by global supply chain pressure. At the same time, governments should guide investment correctly to prevent a flood of investors into the gold market from creating bubbles. In addition, countries or regions need to improve connectivity to jointly build a stable and secure global supply chain, which is indispensable to recovering and developing the world economy.

5.3. Limitations and future Research directions

The limitations of this investigation are reflected in two aspects. On the one hand, the global supply chain pressure data is only updated to 2022, which is not enough to

analyse the medium- and long-run impacts of the global supply chain crisis on the gold market. On the other hand, this paper primarily focuses on the gold market, but there is no comparison between gold's response to global supply chain pressure and other assets. In future research, we would study which asset (e.g., bitcoin, gold, currencies) or portfolio is the most powerful hedge during periods with high global supply chain pressure. Moreover, we would do a similar study with an interval of one year and compare the results obtained, and the medium- and long-term effects should also be further probed.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. To identify the stability, we also employ widths of 20-, 28-, 32-months to analyze, finding that their conclusions are coincident with 24-months.
2. The data is taken from the China Gold Association (CGA).

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