



NONLINEAR SPILLOVER EFFECTS BETWEEN GOLD AND OIL PRICES IN VIETNAMESE AND GLOBAL MARKETS: A QUANTILE-ON-QUANTILE APPROACH

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ARTICLE INFO	ABSTRACT
DOI: 10.52932/jfmr.v4i3en.1239 <i>Received:</i> February 26, 2026 <i>Accepted:</i> April 28, 2026 <i>Published:</i> July 25, 2026 Keywords: Quantile-on-Quantile Regression, SJC, Vietnam, WTI, XAU Article classification: Research paper JEL codes: C58, G15, Q41	Purpose – This study examines the nonlinear, asymmetric, and state-dependent effects of international gold prices (XAU) and crude oil prices (WTI) on Vietnam's domestic gold market, represented by SJC gold prices, during the COVID-19 crisis and post-pandemic recovery. Design/methodology/approach – Using daily data from January 1, 2020, to December 31, 2023, the study converts the price series into logarithmic returns and applies Quantile-on-Quantile Regression to capture heterogeneous relationships across different market conditions. Findings – The findings indicate that these effects are stronger and more widespread during the COVID-19 period than in the post-pandemic period. International gold prices exert a more persistent influence on SJC prices than crude oil prices, while domestic supply constraints, regulatory controls, and market segmentation weaken the response of domestic gold prices to international price movements. Originality/value – The study provides new evidence on how institutional characteristics shape the response of Vietnam's domestic gold market to external shocks by jointly examining the effects of international gold and crude oil prices across crisis and recovery conditions. Practical implications – The results support state-dependent portfolio allocation and risk management and suggest that policymakers should improve market transparency, supply responsiveness, and the transmission of international gold-price information. Social implications – Greater transparency and more efficient transmission of international price signals can strengthen investor protection, reduce market distortions, and support financial stability in Vietnam.

1. Introduction

The global shock associated with the COVID-19 pandemic and its aftermath has caused unprecedented disruptions in international financial markets, markedly amplifying the volatility of safe-haven assets such as gold and key commodities like crude oil. These shocks, driven by supply chain disruptions, mobility restrictions, and large-scale fiscal and monetary interventions, have intensified uncertainty and significantly altered investor behavior. As a result, fluctuations in gold and oil prices reflect not only fundamental supply-and-demand conditions but also broader macroeconomic risks, market expectations, and the evolving degree of global financial integration.

From a theoretical perspective, the relationship between gold and oil prices can be understood through the concepts of economic interdependence and financial contagion. Economic interdependence suggests that markets are intrinsically linked through global macroeconomic conditions, while financial contagion emphasizes the amplification of cross-market linkages during periods of crisis. As highlighted by Forbes and Rigobon (2002), contagion occurs when the transmission of shocks across markets intensifies beyond normal levels following major disturbances. In such settings, price movements in one market can influence others through information flows, portfolio reallocation, and changes in investor sentiment, leading to dynamic and state-dependent spillover effects.

Empirical studies have provided substantial evidence on the interconnections between gold and oil markets. For example, Mensi et al. (2022) document significant spillover effects between oil and gold prices, particularly during periods of financial stress. Reboredo (2013) shows that gold can act as a hedge against oil price fluctuations under extreme market conditions. Other studies, including Abuzayed et al. (2022), Akbar et al. (2019), and Khalfaoui et al. (2015) highlight the importance of these

commodities in portfolio diversification and risk management. More recent research indicates that the strength of these linkages tends to increase during major economic disruptions such as the COVID-19 pandemic (Aziz et al., 2024; Bani-Khalaf & Taspinar, 2022). Importantly, these relationships are often nonlinear and vary across different market conditions, suggesting that traditional approaches based on average effects may not fully capture the complexity of spillover dynamics.

In the case of Vietnam, the empirical context remains relatively underdeveloped. Existing studies have primarily focused on linear relationships or aggregate measures of market linkage, providing limited insight into how spillover effects evolve across different states of the market. Evidence from Ngo and Vo (2021) indicates that the degree of financial integration and shock transmission increased significantly during the COVID-19 period, reflecting greater systemic vulnerability. However, this line of research does not fully address the heterogeneous and state-dependent nature of spillover effects. Given the distinct institutional characteristics of Vietnam's gold market, including regulatory constraints and market segmentation, further investigation is required to better understand how external shocks are transmitted under different market conditions.

Motivated by these considerations, this study examines the relationships among domestic gold prices, international gold prices, and crude oil prices using the Quantile-on-Quantile Regression approach. This method allows for a detailed assessment of how different parts of the distribution of one market affect corresponding parts of another, thereby capturing nonlinear and state-dependent dependence structures. By doing so, the study provides a more comprehensive understanding of spillover dynamics and identifies the conditions under which markets act as transmitters or receivers of shocks.

2. Theoretical background

2.1. *Theoretical background: Interdependence, contagion, and behavioral channels*

Santos (1970) defines economic interdependence as a condition in which the performance of one or several economies is influenced by developments in other economies through both positive and negative transmission mechanisms. In financial markets, interdependence refers to the extent to which shocks in one market are transmitted to others, leading to comovements in asset prices and risks. In the context of gold and oil markets, this implies that changes in crude oil prices may affect gold prices through macroeconomic channels such as inflation expectations, exchange rates, and global financial integration.

From a behavioral finance perspective, herd behavior refers to the tendency of investors to imitate the actions and decisions of others, particularly under conditions of uncertainty, even when their own private information may suggest alternative choices (Banerjee, 1992; Bikhchandani et al., 1992). Such collective behavior may lead market outcomes to be driven more by aggregated investor sentiment than by purely rational decision-making. In commodity markets, including gold and oil, herd behavior can strengthen price co-movements during periods of heightened uncertainty, as investors adjust their portfolios simultaneously in response to common information and market signals. This behavioral mechanism is particularly relevant to commodity markets, where common macroeconomic news and geopolitical shocks often trigger synchronized trading, thereby reinforcing the co-movement of gold and oil prices (Kilian & Park, 2009).

Building on these foundations, Brooks and Del Negro (2004), Rigobon (2002), and Pericoli and Sbracia (2003) define financial contagion as a significant increase in cross-market linkages following a shock, beyond what can be explained by economic fundamentals. The literature identifies several transmission channels, including real linkages, financial

linkages, behavioral responses, and liquidity conditions. Real linkages operate through trade and macroeconomic policy transmission, while financial linkages reflect institutional structures and capital market integration. Behavioral channels capture the role of investor expectations and sentiment, whereas liquidity channels emphasize funding constraints and market depth in propagating shocks. In the context of gold and oil markets, these mechanisms suggest that spillover effects may intensify during crisis periods and vary across different market conditions.

Taken together, these theoretical frameworks imply that spillover dynamics between gold and oil markets are unlikely to be constant but instead exhibit nonlinear and state-dependent characteristics. This provides a strong motivation for employing econometric approaches capable of capturing such complexities. Accordingly, this study adopts the Quantile-on-Quantile Regression framework to examine how different market conditions shape the transmission of shocks between gold and oil prices.

2.2. *Empirical evidence on Gold-Oil-Stock market spillovers*

A substantial body of empirical research has documented the existence of spillover effects among gold, crude oil, and financial markets, particularly during periods of global uncertainty. Early evidence indicates that the strength and direction of these interactions are not constant but vary across market conditions. Ha and Nham (2022) show that spillover intensity among gold, crude oil, Bitcoin, and the United States stock market increased markedly during the COVID-19 pandemic, with gold acting both as a receiver and a transmitter of shocks across markets. Extending this analysis, Ha and Nham (2022) reports that spillover effects intensified during both the COVID-19 crisis and the Russia-Ukraine conflict, although the magnitude of transmission differed across these episodes. Using a time frequency perspective, Shaik et al.

(2023) find that the comovement between gold, oil, and stock markets is significantly influenced by geopolitical risk, particularly over medium and long-term horizons.

Evidence from the ASEAN region further supports the importance of global shocks in shaping spillover dynamics. Mensi et al. (2022) show that connectedness among gold, crude oil, and stock markets increases substantially during periods of financial stress, reflecting a higher degree of integration across markets. Taken together, these findings suggest that spillover effects are dynamic in nature and closely linked to broader macroeconomic and geopolitical conditions. Despite this growing body of international evidence, empirical research in the Vietnamese context remains relatively limited. Nguyen Thu Thuy (2018) finds that oil prices and exchange rates exert short-run effects on the Vietnamese stock market, while gold prices play a less prominent role. Hung et al. (2021) document bidirectional spillovers between gold and oil markets before the COVID-19 period and show that gold becomes a net transmitter of risk to the stock market during the pandemic. Tran Thi Kim Oanh and Le Quoc Dinh (2023) provide one of the few studies using daily SJC gold prices and report that the relationship between gold and the stock market changes across different phases of crisis and recovery. However, most existing studies focus on international gold prices and rely on linear or static modeling approaches, which limits their ability to capture more complex patterns of dependence.

Recent contributions have further emphasized the role of nonlinear dynamics and market conditions in shaping spillover effects. Reboredo (2013) shows that gold can serve as an effective hedge and safe haven against oil price movements, although its effectiveness varies across different market conditions. Similarly, Ngo and Vo (2021) demonstrate that spillover effects among oil, gold, and stock markets are both time-varying and frequency-dependent, particularly during the COVID-19 outbreak.

Wang et al. (2024) further demonstrate that oil security attention significantly influences oil price volatility, suggesting that information related to oil security provides valuable signals beyond observed price movements in explaining volatility transmission. In addition, AlGhazali et al. (2025) find that policy changes in oil markets can alter both the magnitude and direction of volatility transmission, highlighting the importance of institutional and structural factors. Collectively, these studies suggest that spillover dynamics are nonlinear, time-varying, and highly sensitive to changes in market conditions.

Nevertheless, much of the existing literature continues to rely on models that focus on average effects or a single part of the distribution, which may not adequately capture heterogeneous dependence across different market states. This limitation is particularly relevant in emerging markets such as Vietnam, where the interaction between domestic gold prices, international gold prices, and crude oil has not been fully explored. To address this gap, the present study adopts the Quantile-on-Quantile Regression approach, which allows for a detailed examination of how different parts of the distribution of one market affect corresponding parts of another. This framework provides a more comprehensive understanding of spillover dynamics across varying market conditions and contributes to the literature by offering new evidence from the Vietnamese context.

3. Research methodology and data

3.1. Research data

The study employs univariate time-series data collected from January 1, 2020, to December 31, 2023, covering international gold prices (XAU), domestic gold prices in Vietnam (proxied by SJC gold), and global crude oil prices (WTI). Domestic gold prices in Vietnam (SJC) are treated as the main variable of interest, while international gold prices (XAU) and crude oil prices (WTI) are considered key external drivers. The use of XAU reflects global

gold market dynamics, whereas WTI serves as a widely accepted benchmark for global energy markets and macroeconomic conditions. These variables are selected due to their relevance in capturing both international shocks and domestic market responses.

The study period from January 1, 2020, to December 31, 2023, is chosen to encompass the COVID-19 crisis and the post-pandemic recovery phase, both of which are characterized by heightened volatility and structural shifts in financial and commodity markets. This period allows for a comprehensive examination of spillover dynamics across different economic conditions.

Daily frequency data are employed to capture short-term market fluctuations and high-frequency spillover effects. Compared to lower-frequency data, daily observations provide richer information on time-varying relationships, particularly during periods of market stress when price adjustments occur rapidly. International gold prices (XAU) and crude oil prices (WTI) are denominated in U.S. dollars, while domestic SJC gold prices are quoted in Vietnamese dong. To ensure comparability across markets, all price series are transformed into logarithmic returns, which removes differences in measurement units and reduces scale effects.

The dataset was also preprocessed to ensure consistency across markets. Non-overlapping trading days were aligned using a common calendar, and observations with missing values were excluded to maintain balanced time series. This procedure helps ensure that the estimated spillover effects are based on synchronized market information.

In the empirical estimation, the quantile grid is set from 0.05 to 0.95 with an increment of 0.05, allowing the analysis to capture spillover effects across lower, middle, and upper market states. The QQR model is estimated using local linear regression with a bandwidth parameter selected following standard practice in the QQR literature. The empirical analysis

is implemented using R, depending on the computational procedure adopted in the study.

The data are sampled at a daily frequency in order to capture richer information on market dynamics than would be available from weekly or monthly observations. Based on the price series, return series (measured in percentage terms) are computed using the following formula:

$$r_t = \ln(P_t/P_{t-1}) \times 100$$

Where P_t và P_{t-1} denote the prices at time t and time $t - 1$, respectively.

The data sources for SJC, XAU, and WTI used in this study are summarized in Table 1.

Table 1. Data sources and market indices

Index	Source
SJC	SJC.com.vn
XAU	Investing.com
WTI	Investing.com

3.2. Research methodology

This study employs the quantile-on-quantile regression (QQR) approach to examine the linkages among the energy market (WTI), the international gold market (XAU), and the domestic gold market in Vietnam (SJC) during periods of extreme volatility induced by the COVID-19 pandemic as well as the post-COVID-19 period. By combining the strengths of quantile regression with local linear approximation, the QQR framework enables the identification of asymmetric effects and complex dependence structures across quantiles, which cannot be adequately captured by conventional methods such as ordinary least squares (OLS).

The quantile-on-quantile regression (QQR) method, originally introduced by Sim and Zhou (2015), is designed to analyze nonlinear relationships across the quantiles of both dependent and independent variables. In this study, the QQR approach is applied to investigate the dependence structure between the Vietnamese gold market, represented by

SJC gold returns, and the international gold market (XAU) as well as the crude oil market (WTI) across different quantile levels of both markets. The following equations are specified to describe the relationship between the Vietnamese gold market and the respective financial markets:

$$r_{SJC_t} = \beta_0(\theta, \tau) + \beta_1(\theta, \tau)(r_{WTI_t} - r_{WTI_t^T}) + u_t^\theta \quad (1)$$

$$r_{SJC_t} = \beta_2(\theta, \tau) + \beta_3(\theta, \tau)(r_{XAU_t} - r_{XAU_t^T}) + w_t^\theta \quad (2)$$

Where θ denotes the quantile level or_SJC and τ represents the corresponding quantile level of the international gold and crude oil markets.

3.3. Research hypotheses

Building on established theoretical frameworks and prior empirical studies on gold, oil, and financial market spillovers in both international and Vietnamese contexts (e.g., Ha & Nham, 2022; Mensi et al., 2022; Ngo Thai Hung et al., 2021; Reboredo, 2013; Shaik et al., 2023; Tran Thi Kim Oanh & Le Quoc Dinh, 2023), this study develops the following research hypotheses to be tested using the quantile-on-quantile regression (QQR) approach:

Hypothesis H1: International gold prices (XAU) and crude oil prices (WTI) exert spillover effects on domestic gold prices in Vietnam (SJC).

Hypothesis H2: The spillover effects from international gold prices (XAU) and crude oil prices (WTI) to domestic gold prices (SJC) are nonlinear and asymmetric across different quantiles of the return distributions.

Hypothesis H3: The magnitude and transmission patterns of spillover effects from XAU and WTI to SJC vary across different market regimes, particularly between the COVID-19 and post-COVID periods.

Hypothesis H4: Spillover effects from international gold prices (XAU) and crude oil prices (WTI) differ in their magnitude and transmission patterns across market conditions.

4. Research results

4.1. Descriptive statistics

Appendix 1 (see Appendix 1 online) presents the results of the descriptive statistics for the returns, including the mean, maximum, minimum, and standard deviation, along with various statistical measures for global gold and SJC gold during the two research periods. Overall, the average return of domestic gold is consistently higher than that of global gold in both research periods, while the volatility is lower. Notably, the average return and standard deviation for both global gold and domestic gold recorded during the COVID-19 period are higher than those in the post-COVID period. Additionally, the table also displays the tests for normal distribution and stationarity of the return series during the two specific research periods. The results indicate that, in both periods, the return series for Vietnamese gold, global gold, and global oil do not follow a normal distribution and are non-stationary at level with statistical significance at the 1% level, as evidenced by the J-B test and the ADF test.

4.2. During the COVID-19 period

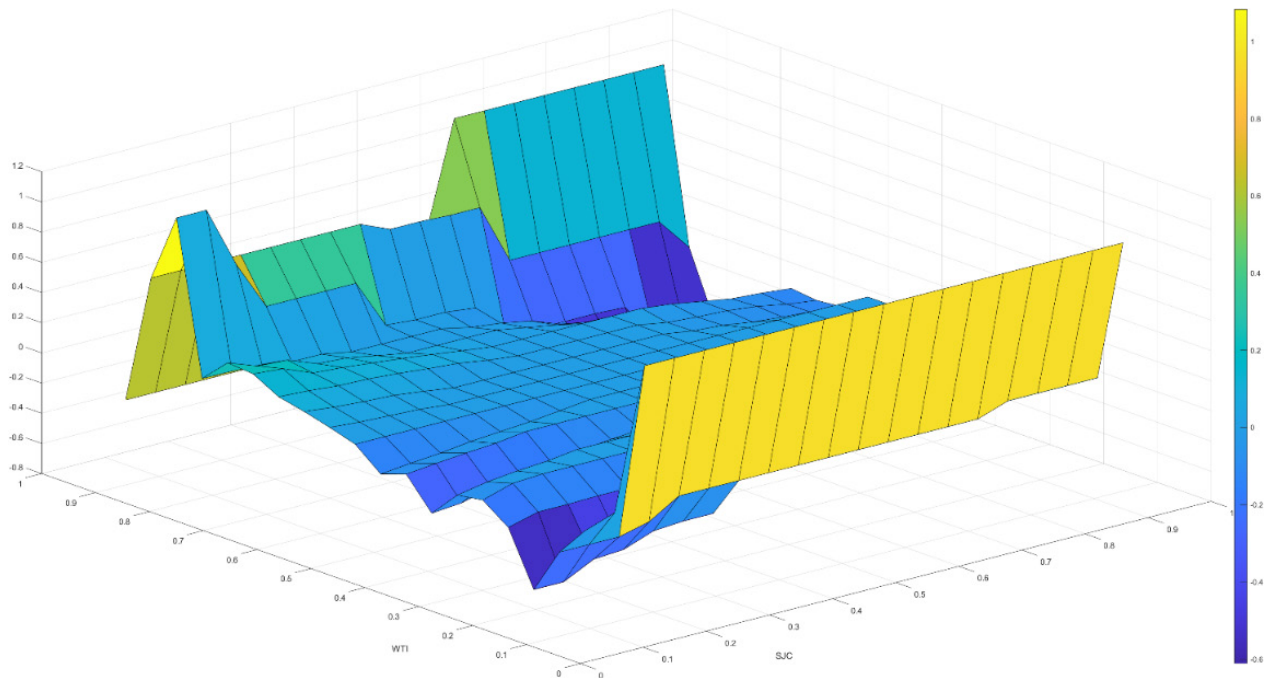


Figure 1. The quantile-on-quantile regression results between SJC and WTI

Figure 1 presents the Quantile-on-Quantile Regression (QQR) results between SJC and WTI during the COVID-19 period, revealing significant and state-dependent spillover effects. At the lower quantiles of WTI (0.05–0.15), the estimated coefficients are predominantly negative for the lower and middle quantiles of SJC, indicating that declining oil prices increased the safe-haven demand for gold during the early stage of the pandemic. This finding is consistent with Reboredo (2013), who highlights the hedging role of gold against oil price fluctuations, and Ha and Nham (2022), who report intensified spillover effects between oil and gold markets during the COVID-19 crisis. In contrast, positive coefficients emerge

at higher quantiles, reflecting stronger co-movement under severe market stress and during the subsequent recovery, which is also in line with the increased market connectedness documented by Mensi et al. (2022). Overall, the QQR surface demonstrates that the impact of WTI on SJC varies substantially across different market states, confirming that spillover effects are nonlinear, asymmetric, and state-dependent. These findings provide empirical support for Hypothesis H1, which proposes the existence of spillover effects from WTI to SJC, and Hypothesis H2, which predicts that these spillover effects differ across quantiles of the return distributions.

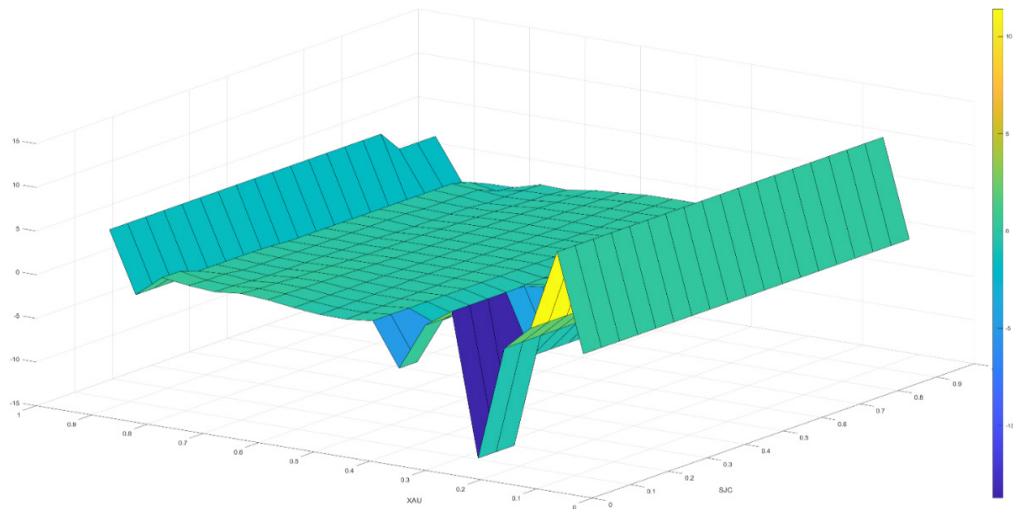


Figure 2. The quantile-on-quantile regression results between SJC and XAU

Figure 2 presents the QQR results between SJC and XAU during the COVID-19 period. The XAU–SJC relationship appears stronger and more stable than the WTI–SJC linkage, consistent with Ha and Nham (2022) and Shaik et al. (2023), who emphasize the central role of the global gold market in spillover networks. At the lower quantiles of SJC, XAU exerts a relatively strong influence, indicating rapid transmission of international gold shocks to the domestic market. However, negative coefficients at the lower-to-middle quantiles reveal phase shifts and weakened

transmission, which may reflect supply constraints and institutional characteristics of Vietnam’s gold market, in line with Tran Thi Kim Oanh and Le Quoc Dinh (2023). At the upper quantiles, strong positive co-movement reappears, showing that SJC responds more closely to XAU during sharp global gold price increases. Overall, the results support H1 and H2 and provide preliminary evidence for H4, as XAU exhibits stronger and more persistent spillover effects on SJC than WTI.

4.3. After COVID-19 period

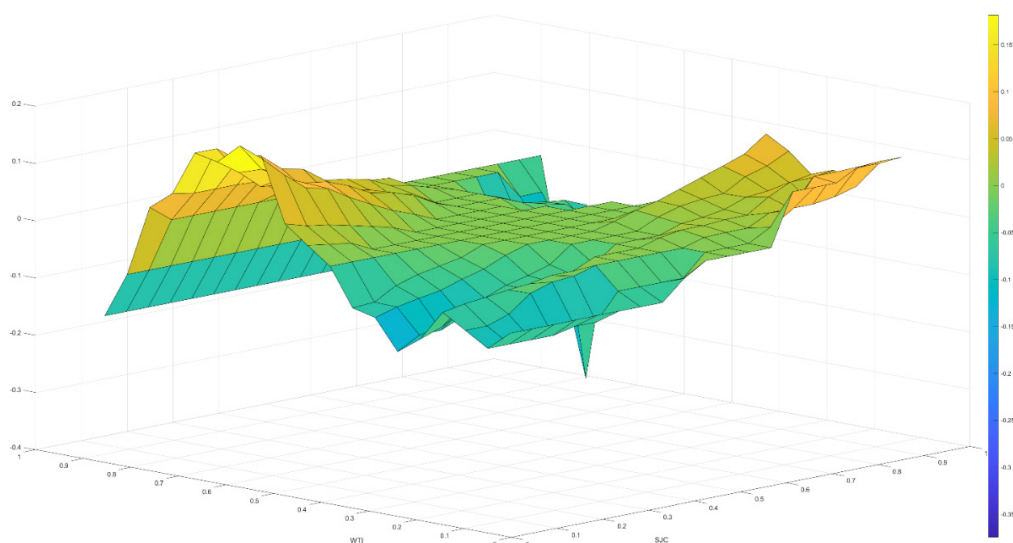


Figure 3. The quantile-on-quantile regression results between SJC and WTI

Figure 3 presents the quantile-on-quantile regression results between SJC and WTI. The QQR estimates indicate that the intensity of WTI's impact on SJC declines markedly relative to the pandemic period, with coefficients fluctuating within a narrow range. This pattern is consistent with the view that spillover effects from the oil market subside as the global economy enters a recovery phase (Ha & Nham, 2022; Mensi et al., 2022). At the lower quantiles of WTI (0.05–0.20), the mild negative coefficients reflect cautious investor sentiment amid declining energy prices and persistent

economic uncertainty. In contrast, positive coefficients at the medium-to-high quantiles suggest that rising oil prices continue to transmit inflationary signals, thereby supporting demand for gold. Overall, the QQR results confirm that the spillover effects from WTI to SJC remain nonlinear, asymmetric, and state-dependent, providing further support for Hypotheses H1 and H2. Compared with the COVID-19 period, the weaker transmission intensity also supports Hypothesis H3, indicating that spillover effects vary across different market regimes.

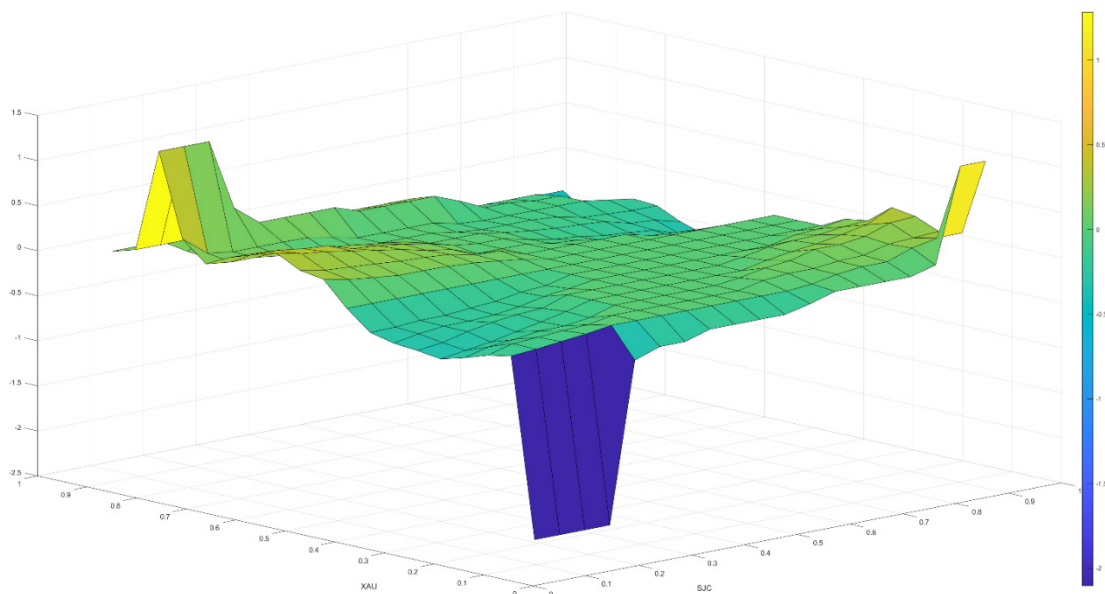


Figure 4. The quantile-on-quantile regression results between SJC and XAU

Figure 4 presents the quantile-on-quantile regression results between SJC and XAU. The QQR estimates indicate that the XAU-SJC relationship is nonlinear, asymmetric, and unstable, reflecting structural distortions in Vietnam's gold market. At the lower quantile (0.05), the large negative coefficient suggests a pronounced phase mismatch, whereby declines in international gold prices are not mirrored by corresponding decreases in SJC prices due to hoarding behavior and supply constraints, consistent with prior evidence for Vietnam (Tran Thi Kim Oanh & Le Quoc Dinh, 2023). Across the central quantiles, coefficients close

to zero indicate weakened transmission, implying that SJC responds only to sufficiently large shocks originating from the international gold market. At the upper quantile (0.95), the negative coefficient shows that SJC adjusts in the opposite direction or remains stagnant even as XAU increases, suggesting a less stable leading role of international gold prices under extreme market conditions (Shaik et al., 2023). Overall, the results provide further support for Hypotheses H1 and H2 and, together with the evidence from Figures 2 and 3, offer additional support for Hypothesis H4, indicating that international gold prices exert stronger and

more persistent spillover effects on SJC than crude oil prices.

4.4. Economic interpretation of the Quantile-on-Quantile Regression results

The empirical results suggest that spillover effects between international commodity markets and Vietnam's domestic gold market are nonlinear, asymmetric, and strongly dependent on market conditions across different quantiles.

At the lower quantiles, the estimated coefficients for both the relationship between SJC and crude oil prices and the relationship between SJC and international gold prices indicate stronger transmission under adverse market conditions. During the COVID-19 period, sharp declines in crude oil prices are associated with negative spillover effects on domestic gold prices at low and medium quantiles. This pattern reflects heightened risk aversion, liquidity pressures, and synchronized portfolio adjustments in global financial markets. At the same time, the relationship between international gold prices and SJC at lower quantiles exhibits negative or unstable coefficients, indicating that declines in global gold prices are not fully transmitted to the domestic market. This outcome is consistent with the institutional characteristics of Vietnam's gold market, including supply constraints, regulatory interventions, and the tendency of investors to hold gold during periods of uncertainty.

At the upper quantiles, positive comovement becomes more evident, particularly during periods of economic recovery and rising commodity prices. When both crude oil prices and international gold prices reach high quantile levels, domestic gold prices tend to move in the same direction. This behavior reflects increasing inflation expectations and stronger demand for gold as a store of value. In this context, gold continues to play an important role in portfolio protection, especially when expansionary monetary conditions and global uncertainty drive commodity price increases.

A comparison between the COVID-19 and post COVID periods reveals a clear change in spillover dynamics. During the COVID-19 period, spillover effects are stronger and more widespread across quantiles, indicating a higher degree of market integration under crisis conditions. The transmission of shocks occurs more rapidly and affects a broader range of market states. In contrast, the post COVID period is characterized by weaker and more fragmented spillover effects. The influence of crude oil prices on domestic gold prices becomes limited and primarily reflects broader macroeconomic conditions such as inflation and global liquidity. Meanwhile, the relationship between international gold prices and SJC becomes less stable and is concentrated mainly at extreme quantiles. This suggests that domestic gold prices respond more strongly to large external shocks, while moderate fluctuations in international markets are not fully reflected.

Overall, the empirical results indicate that spillover mechanisms in Vietnam's gold market operate under a nonlinear and state-dependent framework. The magnitude, direction, and persistence of spillover effects vary considerably across quantiles and economic periods, confirming that market responses differ under normal and extreme conditions. These findings are consistent with the theories of financial contagion and market interdependence, which suggest that cross-market transmission intensifies during periods of heightened uncertainty (Forbes & Rigobon, 2002; Pericoli & Sbracia, 2003). They also support previous empirical evidence on nonlinear and state-dependent spillovers reported by Reboredo (2013), Ha and Nham (2022), Mensi et al. (2022), and Shaik et al. (2023). Collectively, the results demonstrate that the Quantile-on-Quantile Regression framework provides a more comprehensive understanding of spillover dynamics than conventional linear models by capturing heterogeneous dependence across different market states.

Taken together, these findings provide overall support for Hypotheses H1-H4, indicating that spillover effects exist, vary across quantiles and market regimes, and are more persistent for international gold prices than for crude oil prices.

5. Conclusion and policy recommendations

5.1. Conclusion

Based on the Quantile-on-Quantile Regression (QQR) analysis, this study provides evidence that international gold prices and crude oil prices exert significant spillover effects on Vietnam's domestic gold market. The results reveal that these spillover effects are nonlinear, asymmetric, and highly dependent on market conditions. Compared with the post-COVID period, spillover effects are stronger and more widespread during the COVID-19 crisis, reflecting heightened market uncertainty and stronger cross-market transmission. Moreover, international gold prices exert a more persistent influence on SJC prices than crude oil prices, confirming the dominant role of the global gold market in shaping domestic gold price movements. The heterogeneous responses observed across quantiles demonstrate that the magnitude and direction of spillover effects vary substantially under different market states, indicating that average-based approaches may overlook important features of cross-market dependence. These findings are consistent with the theoretical perspectives of financial contagion and market interdependence (Forbes & Rigobon, 2002; Pericoli & Sbracia, 2003) and support previous empirical evidence on nonlinear and state-dependent spillovers reported by Reboredo (2013), Ha and Nham (2022), Mensi et al. (2022), and Shaik et al. (2023).

These findings highlight that Vietnam's gold market is influenced by both global shocks and domestic institutional characteristics, including supply constraints and market regulations, which limit the transmission of international price movements. From a methodological perspective, the results confirm the suitability of the Quantile-on-Quantile Regression

framework for capturing heterogeneous spillover effects across different quantiles, which cannot be fully identified by conventional linear models. From an academic perspective, this study extends the literature by providing new evidence on the nonlinear and state-dependent transmission of shocks between international commodity markets and Vietnam's domestic gold market, thereby enriching the evidence from emerging economies.

5.2. Policy implications

Based on the empirical evidence obtained from the quantile-on-quantile regression (QQR) framework, this study derives several practical implications for investors and policymakers in Vietnam's gold market, particularly in light of current market conditions:

First, during the COVID-19 period, the relationship between SJC gold prices and international markets is strongly nonlinear and highly state-dependent. In practice, this reflects the structural characteristics of Vietnam's gold market, where supply constraints, regulatory controls, and persistent price differentials between SJC gold and international gold prices remain evident. These issues have become more pronounced in recent periods, as domestic gold prices have surged significantly and deviated from global benchmarks. Such developments suggest that domestic prices do not fully adjust to international signals. Therefore, during periods of market stress, policymakers should not rely solely on global price movements but should instead prioritize improving supply conditions, enhancing market transparency, and reducing speculative and hoarding behavior that amplify domestic volatility.

Second, the results indicate that crude oil prices primarily reflect broader macroeconomic conditions such as inflation expectations, global liquidity, and geopolitical risk. This is particularly relevant in the current context, where global oil prices have experienced sharp increases due to geopolitical tensions and supply disruptions, contributing to inflationary pressures and exchange rate volatility in many

emerging economies, including Vietnam. In this setting, oil price movements serve as an important early warning signal of macro-financial risks rather than a direct transmission channel to domestic gold prices. Integrating energy market indicators into financial monitoring frameworks may help policymakers better anticipate external shocks and respond more effectively to changing global conditions.

Third, in the post-COVID-19 period, the linkage between domestic and international gold prices has become weaker and more segmented. This is consistent with recent developments in Vietnam, where the gap between SJC gold prices and international gold prices has remained large and persistent, even as global gold prices have reached historically high levels. Domestic prices tend to react strongly only to extreme global shocks, while moderate fluctuations are not fully transmitted. This suggests that existing regulatory mechanisms and market constraints continue to limit price convergence. In the current context of elevated global uncertainty and rising commodity prices, policy design should adopt a more flexible and state-dependent approach. Greater emphasis should be placed on improving supply responsiveness, addressing structural distortions, and strengthening market efficiency, rather than relying solely on price stabilization measures.

Overall, the findings suggest that Vietnam's gold market is influenced by both global shocks and domestic institutional characteristics. Therefore, policy measures should adopt a state-dependent approach that improves market efficiency while considering the structural features of the domestic gold market.

5.3. Limitations and future research

Despite providing new evidence on the spillover dynamics between international gold, crude oil, and Vietnam's domestic gold market, this study has several limitations. First, the analysis is limited to the period from 2020 to 2023, covering the COVID-19 crisis and the post-pandemic recovery. Although this period captures substantial market fluctuations, the relatively short sample may not fully reflect

spillover dynamics under different economic conditions. Second, the empirical analysis focuses on three variables, namely SJC, XAU, and WTI, while other macro-financial factors, such as exchange rates, interest rates, inflation, and stock market movements, are not included. These factors may also influence the transmission of shocks across markets. Third, although the Quantile-on-Quantile Regression (QQR) model effectively captures nonlinear and state-dependent relationships, it does not explicitly model structural changes associated with policy interventions or unexpected global events.

Future studies may extend the sample period to include additional economic cycles and examine whether the spillover relationships remain stable over time. Incorporating macroeconomic and financial variables would also provide a broader understanding of the channels through which external shocks affect Vietnam's gold market. In addition, combining the QQR framework with alternative approaches, such as regime-switching or time-varying models, may provide further evidence on changes in spillover dynamics under different market conditions. Finally, comparative studies across emerging markets may help identify the role of institutional characteristics in shaping spillover mechanisms and improve the generalizability of the findings.

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Data Availability

The data used in this study are publicly available from SJC.com.vn and Investing.com. The processed dataset is available from the corresponding author upon reasonable request.

AI Usage Statement

During the preparation of this manuscript, the authors partially used ChatGPT to assist with language editing. The authors carefully reviewed and revised the content and take full responsibility for the final version of the article.

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