The (Asymmetric) Effect of El Niño and La Niña on Gold and Silver Prices in a GVAR Model[#]

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Abstract

Recent studies show that El Niño episodes are generally inflationary, due to increases in the prices of agricultural commodities and crude oil. Given this, we examine the inflation-hedging property of gold (along with silver) from a novel perspective by analysing the impact of a negative shock to the negative component of Southern Oscillation Index (SOI) anomalies, i.e., El Niño shock. To this end, we apply a large-scale global vector autoregressive (GVAR) model to 33 countries covering both developed and emerging markets using quarterly data from 1980:Q2 to 2019:Q4. The GVAR methodology provides an appropriate framework as it allows us to capture the transmission of global climate-related shocks while simultaneously accounting for individual country peculiarities. We find that both gold and silver serve as good hedges in periods of inflation and rare disaster risks resulting from an El Niño negative shock. Interestingly, silver is a better hedge than gold, as implied by bigger positive real returns in response to El Niño shock. At the same time, La Niña shocks, captured by a positive effect to the positive component of SOI anomalies, fail to have a statistically significant impact on either gold or silver real returns. Overall, our results confirm the inflation-hedging benefits offered by the two precious metals, suggesting that investors can offset losses resulting from inflation-related risks stemming from El Niño events by investing not only in gold, but more so in silver.

Keywords: El Niño; La Niña; Gold and Silver Prices; Inflation-Hedging Property; Global Vector Autoregressive Model

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1. Introduction

The El Niño-Southern Oscillation (ENSO) is an irregularly periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting the climate of much of the tropics and subtropics (Trenberth et al., 2007). The warming phase of sea temperature is known as El Niño and the cooling phase as La Niña. Each of the two phases can last several months and typically occur every few years with varying intensities per phase. However, it would be a mistake to think of El Niño as a slight warming of ocean temperatures in the Pacific accompanied by storms, heavy precipitation, and unusual weather patterns. A large number of studies have highlighted the potential economic implications of such global climatic fluctuations resulting in a downturn phase of the business cycle to some extent, but primarily leading to an inflationary impact via increases in agricultural commodity and crude oil prices (see for example, Handler and Handler (1983), Changnon (1999), Brunner (2002), Laosuthi and Selover (2007), Ubilava (2012, 2017, 2018), Ubilava and Holt (2013), Iizumi et al. (2014), Cashin et al. (2017), Smith and Ubilava (2017), Peersman (2020), Qin et al. (2020), De Winne and Peersman (2021a), and references cited therein).

Against this backdrop, and in light of the well-established role of gold as a hedge against inflation (see for example, Beckmann and Czudaj (2013), Bampinas and Panagiotidis (2015a), Aye et al. (2016, 2017), and Salisu et al. (2019)), agricultural commodities and oil price increases (Reboredo, 2013; Bampinas and Panagiotidis, 2015b; Balcilar et al., 2019; Tiwari et al., 2020, 2021; Liu and Lee, 2022), as well as economic crises (Boubaker et al., 2020), the objective of our current paper is to determine whether an El Niño shock results in an increase in real gold returns. We check the effect of the shock on real gold returns (instead of nominal gold returns) since an increase in the same due to El Niño events would provide us with an indication of whether gold possesses the ability to over-compensate for the inflation risks. Additionally, we consider real silver returns to compare the inflation-hedging capabilities of gold to those of silver.

At this stage, given our empirical research question, it is worthwhile to motivate the relationship between the ENSO cycles and real gold (precious metals) returns theoretically, based on the following line of reasoning: The ENSO has been held (partially) responsible for some of the world's greatest humanitarian disasters, with Grove and Chappell (2000) and Davis (2001) documenting the global El Niño droughts of 1876-78, 1888-91, and 1896-1902, which contributed to the deaths of between 30 and 60 million people in India, China, and Brazil over the 26 year period. Moreover, these extreme weather conditions can constrain the supply of rain-driven agricultural commodities and induce food-price and generalized inflation, which may trigger social unrest as shown empirically by Paldam (1987), and both theoretically and empirically in Bittencourt et al. (forthcoming). In this regard, Tol (2009), Hsiang et al. (2011), Dell et al. (2014), and De Winne and Peersman (2021b) show that El Niño shocks may have played a role in a substantial number of civil conflicts. In this sense, the ENSO cycle can serve as a proxy for rare disaster risks, which have been shown by Barro and Misra (2015) to result in higher real gold returns, based on the theoretical asset-pricing (two-trees) model of Lucas (1978) which incorporates rare disasters associated with consumption, against which gold acts as a hedge.[1] While this is a direct channel, with rare disaster risks also impacting financial (bonds, currencies, and equities) markets adversely (see for example, Berkman et al. (2011, 2017), Gupta et al. (2019a, b)), an indirect effect can be the increase in the trading of precious metals, and hence their returns due to the safe haven nature of these commodities that allow them to hedge against the turmoil associated with conventional financial markets.

In terms of modelling, our current paper approaches the issue under study from a novel, global perspective by analysing the impact of the ENSO cycle, i.e., both El Niño and La Niña effects represented by negative and positive shocks to the Southern Oscillation Index (SOI) respectively, based on a global vector autoregressive (GVAR) model, over the period 1980:Q2 to 2019:Q4. Consequently, it is important to emphasize the significance of the GVAR model in analysing the effect of global climate shocks on the gold market. Recall that the GVAR model, originally proposed by Pesaran et al. (2004) and further developed by Dees et al. (2007), is a global modelling framework for analysing the international macroeconomic transmission of shocks, taking into account drivers of economic activity, interlinkages and spillovers among countries, and the effects of (unobserved or observed) common factors. Hence, the GVAR is an extension of a VAR model which has been used extensively to capture the effects of shocks on various types of variables (Cai et al., 2022). Therefore, we augment the basic GVAR model by including the SOI, over and above the existing country-specific variables and commodity prices. The GVAR approach is the ideal model for analysing the "true impact" of a global shock like that of the SOI on real gold and silver returns, as it simultaneously accommodates country-specific

[1] The same can also hold for investment, besides the wide array of other predictors affecting the same (see for example, Wu et al., 2022).

macroeconomic conditions and their interlinkages, thereby circumventing omitted variable bias and any potential endogeneity bias resulting from the use of a single-equation model which runs the risk of overestimating the impact of the shock. This is more so, because the literature on predicting gold and silver price movements has highlighted the role of a wide-array of economic and financial variables of multiple countries (see for example, Pierdzioch et al. (2014a, b, 2015a, b, 2016), Aye et al. (2015), Gupta et al. (2017), Bonato et al. (2018), Dichtl (2020), Pierdzioch and Risse (2020)), which in turn can be modelled via the GVAR.

To the best of our knowledge, our current paper is the first to examine the inflation-hedging property of gold and silver in the wake of ENSO cycles based on a GVAR model. The only other related paper is that of Ubilava (2018), which, while dealing with 41 other commodities, analyses the effects of the ENSO cycle on gold and silver prices using the time-varying smooth transition autoregressive (STAR) modelling framework. The statistical tests employed by Ubilava (2018), however, indicate that the dynamics of gold returns are best represented by an autoregressive (AR) model, i.e., it is unrelated to the ENSO cycle, while that of silver is optimally captured by an autoregressive distributed lag (ARDL) model, i.e., it is related linearly to the ENSO cycle. Given this, a positive shock to sea surface temperature (SST) anomalies, capturing El Niño events, is shown to increase silver returns. But, as stated above, single-equation approaches, as employed by Ubilava (2018), are likely to suffer from biases due to omitted variables and possible overestimation of the effect.

The remainder of the paper is organized as follows: Section 2 outlines the data and the methodology, while Section 3 present the results, and Section 4 concludes the paper.

2. Data and Methodology

2.1. Data

The GVAR dataset includes quarterly macroeconomic variables for 33 economies (log real GDP, y_{it}, the rate of inflation, dp_{it}, short-term interest rate, r_{it}, long-term interest rate, lr_{it}, the log deflated exchange rate, ep_{it}, and log real equity prices, eq_{it}), as well as quarterly data on commodity prices (oil, $poil_t$, agricultural raw materials, $pmat_t$, and metals, $pmetal_t$). The 33 countries included in the GVAR dataset cover more than 90% of the world GDP and the data is available for download at: http://www.econ.cam.ac.uk/people-files/emeritus/mhp1/GVAR/GVAR.html, with further details regarding the description of its compilation, revision and updates discussed in Mohaddes, and Raissi (2020). As stated, we augment the above set of commodities which already exist in the GVAR database by including the United States (US) dollar-based price series for gold and silver, derived from DataStream. The nominal log-returns of gold and silver are first computed, and then the corresponding real returns are obtained by subtracting the inflation rate of the US, already available in the GVAR database.

For the metric to represent the ENSO cycle, we use the Southern Oscillation Index (SOI), obtained from the Bureau of Meteorology, Government of Australia, available at: http://www.bom.gov.au/climate/current/soihtm1.shtml. The SOI gives an indication of the development and intensity of El Niño or La Niña events in the Pacific Ocean. The SOI is calculated using the pressure differences between Tahiti and Darwin. Sustained negative (positive) values of the SOI below (above) −7 (+7) often indicate El Niño (La Niña) episodes. Low atmospheric pressure tends to occur over warm water and high pressure occurs over cold water, in part because of deep convection over warm water. El Niño episodes are defined as sustained warming of the central and eastern tropical Pacific Ocean, and La Niña episodes are defined as sustained cooling of the central and eastern tropical Pacific Ocean, resulting in a decrease and increase, respectively, in the strength of the Pacific trade winds.

Following Cashin et al., (2017), we use SOI "anomalies" in our GVAR model, which are defined as the deviation of SOI in any given quarter from its historical average, normalized (divided) by its historical standard deviation, as plotted in Figure A1 in the Appendix (along with real gold and silver returns).[2] Given this, sustained negative SOI anomaly values below -1 (above +1) indicate El Niño (La Niña) episodes. To capture the two phases of the ENSO cycle, we build a dummy variable which takes the value of one when SOI anomalies are negative (positive) and zero otherwise, and then multiply the dummy variable by the SOI anomalies to obtain a metric for the El Niño (La Niña) episode. The two resulting SOI anomalies series, i.e., SOI1 and SOI2, are considered separately in the GVAR, and are negatively and positively shocked by one standard deviation to study the impact of El Niño and La Niña events, respectively, on real gold and silver returns.

[2] Note that the underlying raw SOI data is available monthly, which we convert to quarterly frequency using a three-month average.

Our period of analysis covers 1980:Q2 to 2019:Q4, which is contingent on the availability of gold and silver prices.

2.2. The GVAR model

In this section, we formally specify the link between SOI anomalies and gold and silver real returns via a global VAR (GVAR) model that accommodates the transmission of El Niño (and La Niña) episode induced shocks to the precious metal markets. In this context, the GVAR model is appropriate as it considers the world economy as a network of interdependent countries, which allows the model to capture the transmission of shocks – both global and regional – across these economies, while accounting for country-specific characteristics.[3] Accordingly, the advantage of constructing a large-scale GVAR for the SOI anomalies-precious metals nexus in our application is that it allows us to account for the interconnectedness among various strata of markets and also demonstrate how a shock (favourable or unfavourable) to the SOI anomalies can impact precious metals.

From an economic point of view, one can expect a negative relationship between SOI anomalies and real returns on gold and silver, given that an El Niño (La Niña) shock would reduce (increase) the SOI anomalies and result in inflation (deflation), and hence higher (lower) real gold and silver returns due to their inflation-hedging capabilities. To formally examine this nexus, we consider $N+1$ countries in the global space, indexed by $i = 0,1,2,\dots,N$ such that all N countries are modelled as small open economies with their respective VARs constructed, except the US which is taken as the reference country and labelled 0. It is worth mentioning that, in a typical GVAR model, there are three variables, domestic, foreign and global variables. Therefore, we begin our GVAR set-up by specifying the individual VARs of the countries that combine domestic and foreign variables and describing the VARX$^*(p_i, q_i)$ model for the ith country which relates a $k_i \times 1$ vector of domestic macroeconomic variables (strictly endogenous), x_{it}, to a $k_i^* \times 1$ vector of country-specific foreign variables (weakly exogenous), x_{it}^*:

$$\gamma_i(L, p_i)x_{it} = \beta_{i0} + \beta_{i1} + \varphi_i(L, q_i)x_{it}^* + \varepsilon_{it} \quad (1)$$

$$t = 1,2,3,\dots,T.$$

[3] For the computational suitability and theoretical sophistication of this framework over traditional multivariate models, see Pesaran et al. (2004) and Dees et al. (2007).

where $\gamma_i(L, p_i) = I - \sum_{i=1}^{p_i} \gamma_i L^i$ and $\varphi_i(L, q_i) = \sum_{i=0}^{q_i} \varphi_i L^i$ are the matrix lag polynomials of the coefficients associated with the domestic and foreign variables, respectively; β_{i0} and β_{i1} are $k_i \times 1$ vectors of time invariant intercepts and coefficients of the deterministic time trends, respectively, and ε_{it} is a $k_i \times 1$ vector of country-specific shocks, with the assumption of non-serially correlated with zero mean and a non-singular covariance matrix, Σ_{ii}, that is, $\varepsilon_{it} \sim i.i.d.(0, \Sigma_{ii})$. Notably, lag orders of p_i and q_i are selected on a country-by-country basis thereafter such that $\gamma_i(L, p_i)$ and $\varphi_i(L, q_i)$ are allowed to differ across countries.

While the domestic variables used in this study include equity prices, inflation, real exchange rate and real GDP the ordering of which relies on a standard monetary policy transmission mechanism, the country-specific foreign variables are constructed as the cross-sectional averages of the domestic variables using data on bilateral trade flows as the weights, w_{ij}. Therefore:

$$x_{it}^{*} = \sum_{j=0}^{N} w_{ij} x_{jt} \tag{2}$$

where $j = 0,1,2, \ldots, N$, $w_{ii} = 0$, and $\sum_{j=0}^{N} w_{ij} = 1$.

Similarly, for empirical application, the trade weights are computed as:

$$w_{ij} = \frac{\sum_{t=1}^{T} Tr_{ij,t}}{\sum_{t=1}^{T} Tr_{i,t}} \tag{3}$$

where $Tr_{ij,t}$, computed as the average of exports and imports of country i with country j, is the measure of bilateral trade flows between country i and country j during a given year t. $Tr_{i,t}$, on the other hand, is the trade volume of country i at a given period t. Moreover, having estimated each country's VARX*(p_i, q_i) model independently, all endogenous variables, collected in the $k \times 1$ vector $x_t = (x_{0t}^{'}, x_{1t}^{'}, x_{2t}^{'}, \ldots, x_{Nt}^{'})$, are solved simultaneously using the link matrix defined in terms of the country-specific weights.[4] The VARX* model in Eq. (1) can be written in a more compact form as:

$$\mu_i(L, p_i, q_i) z_{it} = \eta_{it} \tag{4}$$

where $\mu_i(L, p_i, q_i) = [\gamma_i(L, p_i) - \varphi_i(L, q_i)]$, $z_{it} = (x_{it,}^{'} x^{'*}{}_{it})^{'}$ and $\eta_{it} = \beta_{i0} + \beta_{i1} + \varepsilon_{it}$.

In addition, following Chudik and Pesaran (2013), we extend Eq. (4) to a case in which common/global variables such as the SOI anomalies and gold and silver nominal or real returns

[4] For an early illustration of the solution of the GVAR model, using a VARX*(1, 1) model, see Pesaran et al. (2004), and for a broad survey of the new developments in GVAR modelling, both the theoretical foundations of the approach and its numerous empirical applications, see Chudik and Pesaran (2016).

are included in the model in addition to the existing commodity prices in the GVAR database (as discussed above). This allows us to account for the global variables by extending Eq. (1) as:

$$\gamma_i(L, p_i)x_{it} = \beta_{i0} + \beta_{i1} + \varphi_i(L, q_i)x_{it}^* + \lambda_i(L, m_i)\kappa_t + \varepsilon_{it} \tag{5}$$

where $\lambda_i(L, m_i) = \sum_{i=0}^{m_i} \lambda_i L^i$ is the matrix lag polynomial of the coefficients associated with the common variables - κ_t (SOI anomalies and the two precious metals). Also, κ_t can be recognized as weakly exogenous for ease of estimation. The marginal model for the dominant variables can be estimated with or without feedback effects from x_{it} (Cashin et al., 2017). Thus, to allow for feedback effects from the variables in the GVAR model to the dominant variables via cross-sectional averages, we define the following model for κ_t:

$$\kappa_t = \sum_{l=1}^{p_w} \gamma_{\kappa l}\, \kappa_{i,t-l} + \sum_{l=1}^{p_w} \gamma_{\kappa l}\, x_{i,t-l}^* + \psi_{\kappa t} \tag{6}$$

It should be noted that the contemporaneous values of the foreign variables do not feature in Eq. (6) and the vector of dominant or global variables, κ_t are causal. Thus, conditional and marginal models specified in Eq. (5) and Eq. (6), respectively, can be combined and solved as a complete GVAR model. To cap it all, the analysis of a GVAR model involves two stages. The first is to construct a set of individual VAR models for each of the cross-sectional units of the panel where each VAR model includes domestic endogenous variables augmented with weakly exogenous foreign (weighted domestic) and global variables. The second takes all the individual VAR models linked using weighted matrices to produce the GVAR estimates which are then used for the analysis of impulse responses to SOI anomaly shocks.

3. Empirical Findings

In this section, we first analyse the effect on real gold returns due to a one standard deviation negative shock to SOI1, and a same-sized positive shock to SOI2, with the former capturing El Niño episodes and the latter La Niña phases of the ENSO cycle. In Figure 1, the median response is represented by solid lines, while the (5%-95%) lower and upper bootstrapped error bands are shown as dotted lines. We see from Figure 1(a), that a one standard deviation negative shock to SOI1, i.e., an El Niño shock, results in an increase in the real returns of gold, with the strongest effect of 1.20% points felt two-quarters after the shock. Interestingly, the response on impact and one quarter after, though positive is not statistically significant. The effect declines at the 3rd quarter after the shock to 1.08% points, and then increases the following quarter to 1.11% points, and thereafter exhibits a stable, slightly increasing, statistically significant tendency in the positive region till the end of the forecast horizon, i.e., 10 years. The average increase in real gold returns over the 41 quarters is 1.14% points. In Figure 1(b) we see the impact of a positive one standard deviation shock to SOI2, i.e., we aim to capture La Niña effects on real gold returns. While real gold returns decline in this instance due to La Niña having a deflationary impact, the effect is not statistically significant at any forecast horizon associated with impulse responses. The asymmetric, but weaker, impact of La Niña compared to El Niño is in line with the observation of Cashin et al. (2017), and is likely due to the latter being more frequent and stronger in intensity than the former phase of the ENSO cycle.

Figure 1(a). Impulse Response Functions of Real Gold Returns to a One Standard Deviation Negative Shock to Negative Components of SOI Anomalies (SOI1; El Niño Effect)

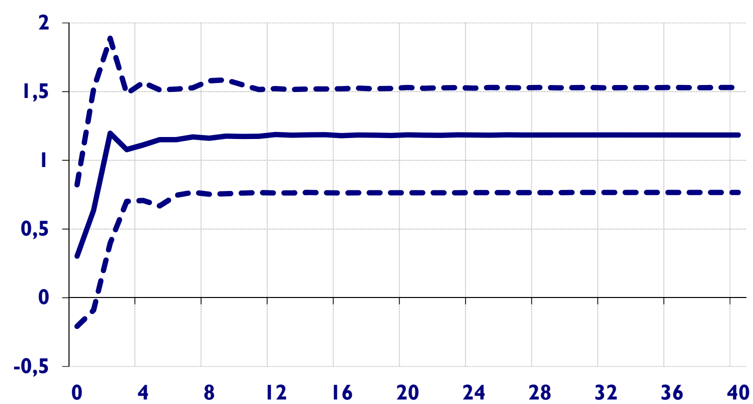
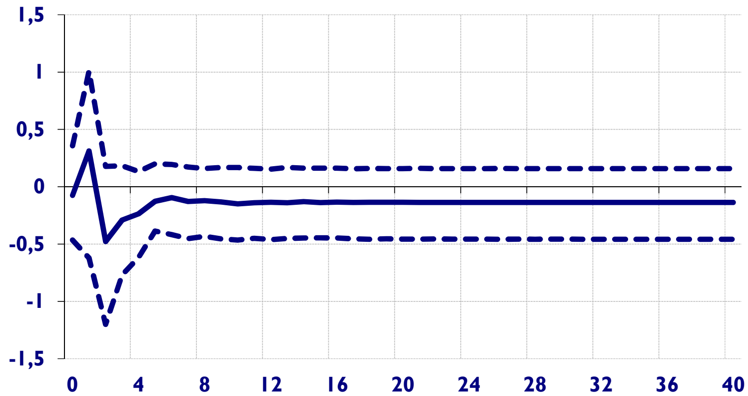


Figure 1(b). Impulse Response Functions of Real Gold Returns to a One Standard Deviation Positive Shock to Positive Components of SOI Anomalies (SOI2; La Niña Effect)



In Figure 2 we compare the effect of a negative one standard deviation shock to SOI1 and a positive one standard deviation shock to SOI2. As in the case of gold, while the effect on real silver returns is asymmetric across El Niño and La Niña shocks, the impact is insignificant under a shock to the latter as captured by SOI2 and shown in Figure 2(b). A negative shock to SOI1, as shown in Figure 2(a), increases real returns on silver, though the effect on impact is insignificant, it is significant at the 5% level from one quarter after the shock until 10 years ahead. The strongest effect is observed at the 3rd quarter after the shock, and stands at 2.77% points. The effect decreases slightly thereafter, but remains stable, producing an average increase of 2.51% points over the 41 quarters considered from the point of shock till the end of 10 years. Our results tend to provide support for El Niño shocks causing an increase in silver prices, as derived by Ubilava (2018) based on an ARDL model.

Figure 2(a). Impulse Response Functions of Real Silver Returns to a One Standard Deviation Negative Shock to Components of Negative SOI Anomalies (SOI1; El Niño Effect)

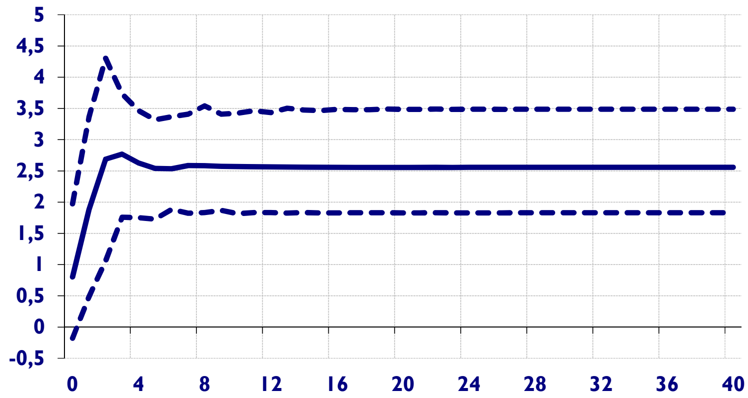
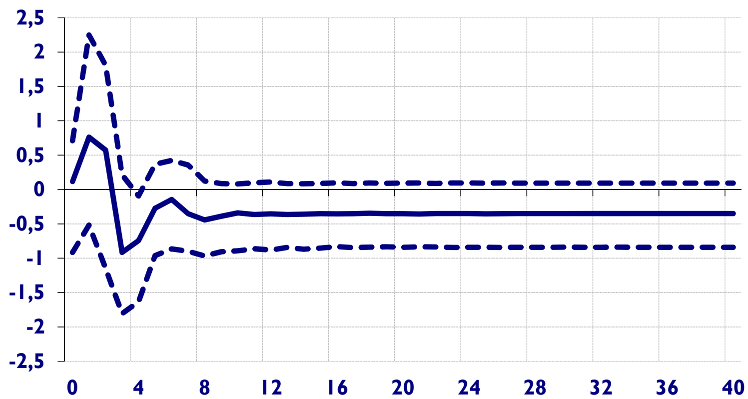


Figure 2(b). Impulse Response Functions of Real Silver Returns to a One Standard Deviation Positive Shock to Positive Components of SOI Anomalies (SOI2; La Niña Effect)



In summary, our results confirm the inflation-hedging ability of gold and silver for both short and long runs in the wake of inflationary El Niño events, with real silver returns increasing more than double those of gold, and hence providing a greater safeguard to investors in terms of inflation risks.[5]

[5] In Figures A2(a) and A2(b) in the Appendix of the paper, we present the impact of a one standard deviation negative shock to overall SOI anomalies, i.e., by not distinguishing between El Niño and La Niña episodes, on real gold and silver returns, respectively. While our basic conclusions remain the same in terms of both gold and silver serving as inflation hedges, with the real returns increasing in both cases, the average increase in real gold returns and that of real silver returns are 0.71% points and 1.48% points, respectively, which are lower than when we disentangle El Niño episodes from La Niña episodes. This result highlights the importance of disaggregation of the two phases of the ENSO cycle, especially in terms of providing more accurate inflation-hedging estimates for market agents.

4. Conclusion

The role of gold as a hedge against commodity prices and general inflation as well as economic crises is well-documented in the academic literature. Accordingly, investors are often attracted to this precious metal because of its ability to offer portfolio diversification during periods of inflationary pressures. In this paper, we revisit the inflation-hedging property of gold (along with silver) from a novel perspective by analysing the impact of the El Niño–Southern Oscillation (ENSO) cycle, whereby the associated El Niño episodes are shown to be inflationary, and a proxy for rare disaster risks. Our econometric analyses rely on a large-scale global vector autoregressive (GVAR) model, which in turn allows us to capture the transmission of global shocks, i.e., El Niño and La Niña events, as captured by negative and positive shocks, respectively, to the negative and positive components of the Southern Oscillation Index (SOI) anomalies, while simultaneously accounting for individual country peculiarities.

Overall, our results indicate that gold serves as good hedge (i.e., real gold returns increase) against sudden negative shocks induced by the SOI, which not only captures the inflationary effects of El Niño depicted in the literature, but also provides a metric for possible rare disaster risks that accompany El Niño episodes. At the same time, the negative impact on real gold returns due to La Niña episodes is statistically insignificant, highlighting the asymmetric effects of the two phases of the ENSO cycle on the gold market. The behaviour of real silver returns to the El Niño and La Niña shocks mimics that of gold, but silver is found to exhibit relatively a higher (more than double) average increase in real returns (compared to gold) over the 10-year horizon considered for the impulse response functions (IRFs), following a negative shock to SOI anomalies. Our results thus imply that, in the wake of El Niño events, investors could always find succour by allocating a certain portion of their investment portfolios to not only gold, but more so to silver. In addition, given that gold and silver returns serve as a leading indicator for the macroeconomy (Stock and Watson, 2003), with their returns increases (decreases) associated with possible recessions (expansions), monitoring their behaviour following El Niño and La Niña shocks would allow policymakers to design appropriate monetary and fiscal policy responses. Also, now that the ENSO cycle can impact gold and silver returns, from the academic perspective, one would need to incorporate it as a predictor, besides the various behavioural, financial and macroeconomic variables used to study their movements in the literature cited in the introduction.

Given that Apergis and Gupta (2017) suggest that unusual weather conditions (i.e., deviations from average values, as associated with El Niño and La Niña phases) can be a proxy for uncertainty, it would be interesting as part of future research, to extend our analysis to the second moment effects of the ENSO cycle on the two precious metals, which have been shown to exist for the oil market (see for example, Bouri et al. (2021), and Demirer et al. (2022)),[6] using nonlinear and time-varying models in particular (Liu and Lee, 2021; Ding et al., 2022), and accounting for also possible co-movements of volatilities (Marfatia et al., 2022). Furthermore, since in-sample predictability does not guarantee the same over an out-of-sample (Campbell, 2008), one can even perform forecasting analyses involving both returns and volatilities of gold and silver, and also additional precious metals.

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APPENDIX:

Figure A1. Data Plot

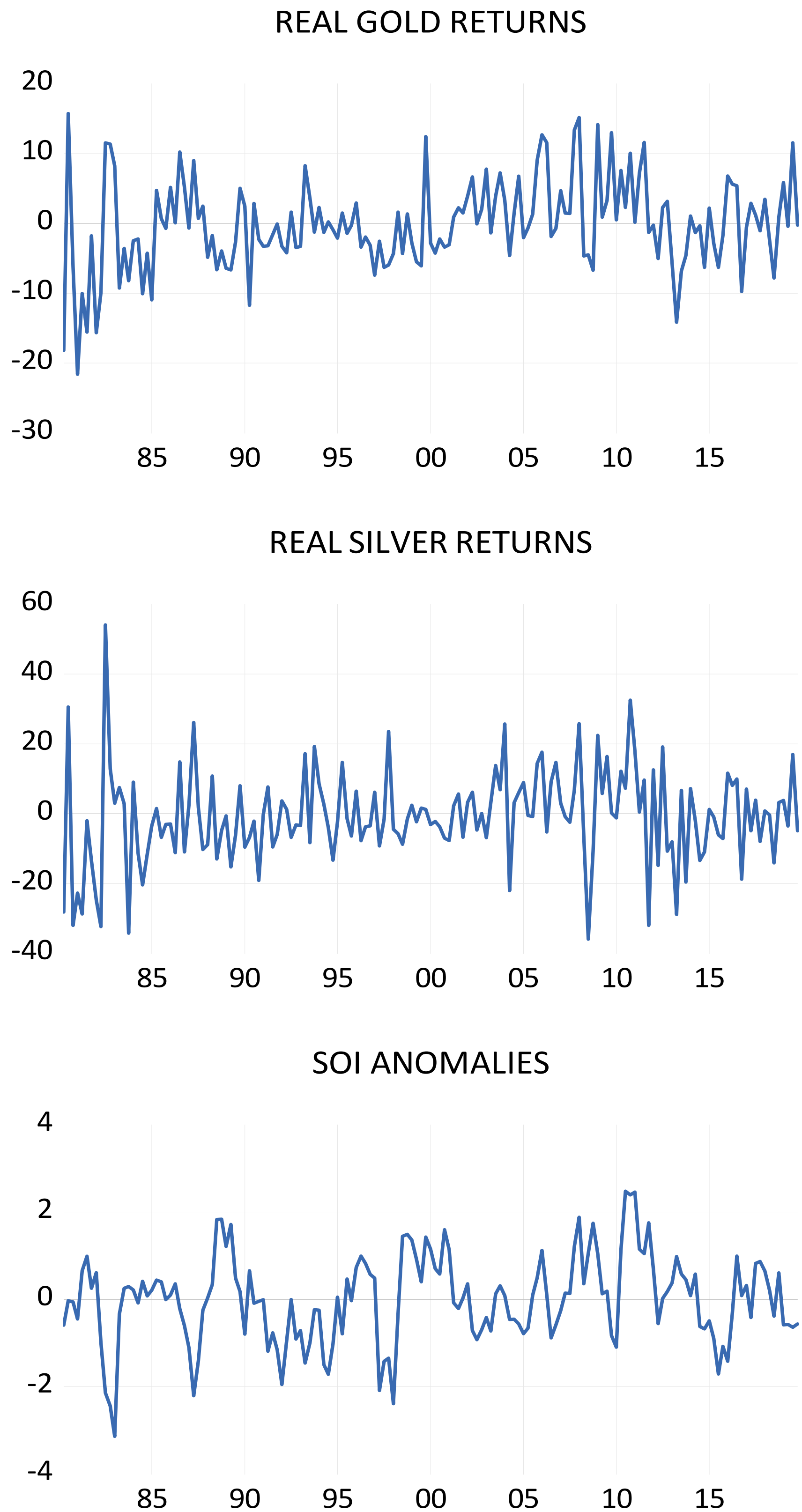

Figure A2(a). Impulse Response Functions of Real Gold Returns to a One Standard Deviation Negative Shock to Overall SOI Anomalies

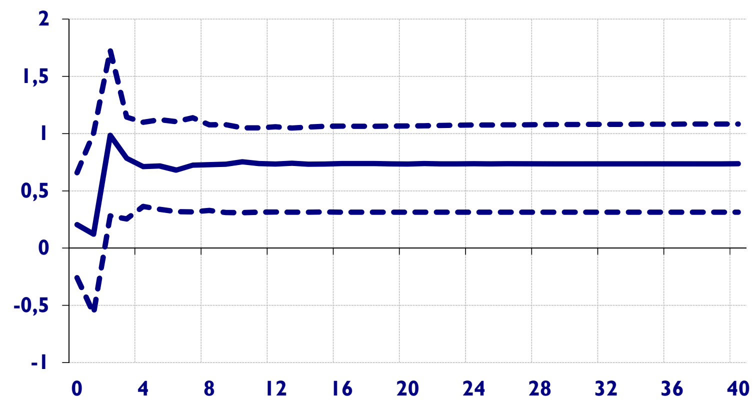

Figure A2(a). Impulse Response Functions of Real Silver Returns to a One Standard Deviation Negative Shock to Overall SOI Anomalies

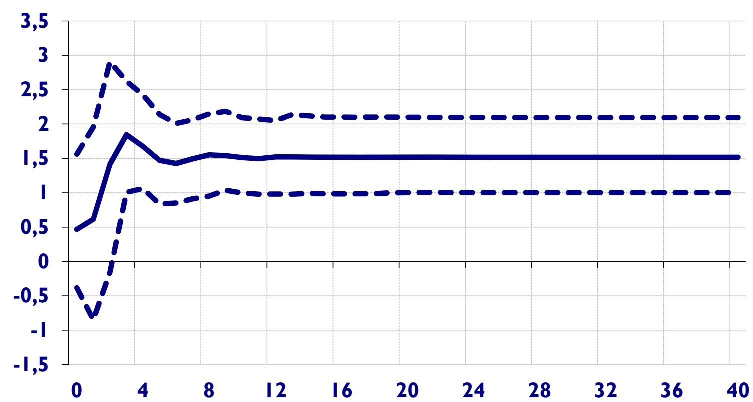

Table A1. Results of the *k*th Order Nonparametric Causality-in-Quantiles Test of Balcilar et al. (2018)

Quantile	*RGOLDR*	*RGOLDV*	*RSILVERR*	*RSILVERV*
0.10	2.865#	14.8726#	2.8601#	11.5775#
0.20	3.1508#	6.1195#	4.1892#	5.1312#
0.30	3.8599#	7.5362#	4.6803#	7.7327#
0.40	4.3012#	8.8517#	4.6194#	10.6068#
0.50	13.0875#	10.5346#	12.4101#	11.3426#
0.60	13.081#	10.8864#	9.6777#	10.8636#
0.70	6.3216#	8.762#	5.0314#	8.1326#
0.80	3.045#	5.8987#	3.4192#	5.3142#
0.90	2.1161*	3.9079#	2.1707*	2.6927#

Note: * and # indicate rejection of the null hypothesis of no Granger causality at 5% (critical value of 1.96) and 1% (critical value of 2.575) levels of significance, respectively, from Southern Oscillation Index (*SOI*) to real gold returns (*RGOLDR*) and squared real gold, i.e., returns volatility (*RGOLDV*), as well as to real silver returns (*RSILVERR*) and squared real silver returns, i.e., volatility (*RSILVERV*), for a particular quantile.