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# Impact of Global Economic Policy Uncertainty on Gold Prices – A Granger Mediation Analysis of Gold Demand

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**Abstract**
This paper investigates the impact global economic policy uncertainty (GEPU) on gold prices employing time-series Granger mediation approach. Existing literature focused solely on examining the direct response of gold prices to changes in uncertainty, which omitted important information about the behavior of market participants in the gold market. We introduce investment gold demand as a mediating variable which provides an added dimension to understand how changes in GEPU get transmitted to the gold price. We use monthly net gold demand data of exchange traded funds (ETF) and physical retail investors to proxy for gold demand. The findings show that investors respond differently to GEPU developments, with ETF demand being the main transmission channel for changes in global uncertainty to the gold price. The result of full mediation effect for ETF demand implies that GEPU has no direct effect on gold prices; rather, its entire effect is indirect via ETF interventions. This is a crucial insight into understanding the price influence of this relatively new demand segment. We interpret its influence as safe haven seeking behavior of investors, highlighting gold's safe haven function. We find no mediating role for retail demand, implying that physical gold investors are not responsive to global uncertainty. These findings suggest that the mediating effect is demand-category specific and reflect the behavior of the

fundamentally different types of gold investors. The findings hold important implications for investors and policymakers.

**Keywords:** Gold, Economic Policy Uncertainty, Hedge, Safe Haven, ETF Demand

## Introduction

Both the disruptions from the COVID-19 pandemic and the unprecedented economic policy measures deployed globally in response to the crisis sent shockwaves across financial markets. This has triggered increased interest from researchers and practitioners, alike, to re-examine gold's hedge and safe-haven properties amid the ever-rising levels of uncertainty. Different measures of risk and uncertainty have been adopted in recent literature concerning the study of gold market's reaction to shocks; most notably the CBOE's VIX (Bilgin et al., 2018; Luu, 2020; Hu et al., 2020; Bouri et al., 2021), SKEW (Bilgin et al., 2018), and the partisan conflict index (PC) (Bilgin et al., 2018), along with the geopolitical risk index (GPR) (Gozgor et al., 2019; Gkillas et al., 2020; Hu et al., 2020; Chiang, 2022; Yilanci et al., 2021); with the economic policy uncertainty (EPU) index being among the most commonly used either as the sole indicator, or in combination with other measures. The updated version of the EPU index is publicly available at https://www.policyuncertainty.com. In terms of coverage, there is a global average EPU index, in addition to country indices for developed and emerging economies. As shown in Figure 1, both the gold price and the global economic policy uncertainty (GEPU) index moved in tandem, with spikes in the gold price occurring simultaneously with the spikes in GEPU since 2004. This positive relationship is reflected in the relatively strong correlation coefficient of 0.75. Interestingly, prior to 2004, the relationship between the two variables was not strong.

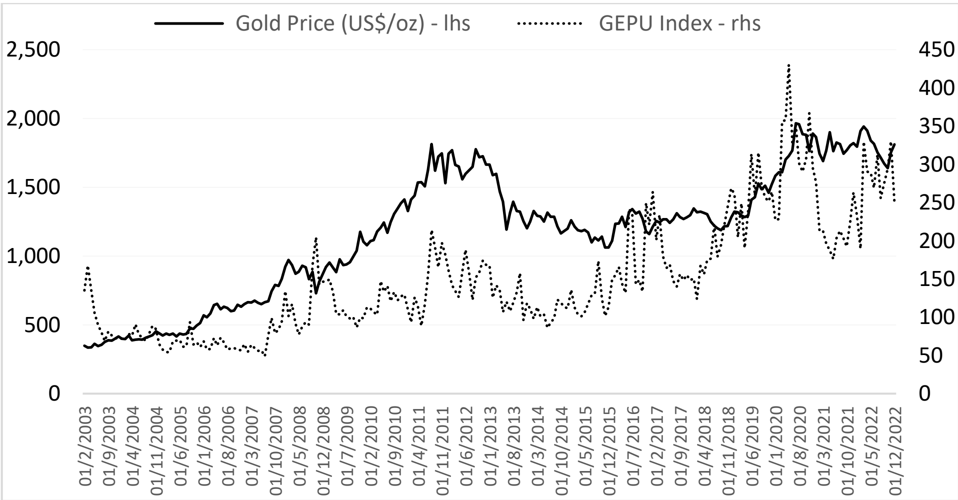


Figure 1. The evolution of global economic policy uncertainty index and gold prices (monthly)
Sources: World Gold Council database, www.policyuncertainty.com

The majority of studies found a positive link between uncertainty, measured by the EPU index and gold returns, which provides support to gold's hedge and safe haven status (Bilgin et al. 2018; Raza et al. 2018; Luu, 2020; Shaikh, 2020; and Chiang, 2022; among others). The disagreement in the literature, however, generally lies in whether such positive reaction is valid across all periods, or only during specific times (Bouoiyour et al. 2018; Chai et al. 2019; Qin et al. 2020; Zhang et al. 2021; and Yilanci et al. 2021; among others). The existing literature focused solely on examining the direct response of gold prices to changes in uncertainty, which omitted important information about the behavior of gold investors in responding to uncertainty.

This study is motivated by the idea that gold investment demand contains important information about the behavior of the fundamentally different types of gold investors (ETF and physical retail investors). We extend literature on the uncertainty-gold price nexus by using gold investment demand as a mediator to establish the transmission mechanism of GEPU to gold prices, which has not been explored in the literature. Mediation analysis allows inferences to be made about the activities of gold market participants. The need to study mediation effect is also prompted by past studies that have questioned and challenged gold's function as a hedge and or safe haven asset (Barro and Misra, 2016; Erb and Harvey, 2013; and Bekiros et al. 2017; among others). The use of gold demand as a mediating variable can be supported by the literature that examines the impact of ambiguity on asset prices and financial markets, indicating that increased ambiguity in the capital markets leads to increased investor activity (Kostopoulos et al., 2022). For examples, ambiguity shocks trigger investors' exit from risky markets (Mele and Sangiorgi, 2015), reduce portfolio holdings of risky assets (Garlappi et al., 2007; Peijnenburg (2018), and lead to increased investors' trading activity due to portfolio adjustments and risk exposure reduction (Kostopoulos et al., 2022). The findings of Kostopoulos et al. (2022) are also robust to alternative measures such as the newspaper-based EPU. These findings lend support to the use of gold demand as a mediating variable in the current study. Furthermore, given that financial media and market commentators frequently associate gold demand to gold prices in making inferences about gold's safe haven and hedge properties while the academia relates uncertainty to gold prices to make the same inferences, no study has investigated the role of gold demand as a mediator in the uncertainty-gold price nexus. Mediation analysis is important to understand the underlying mechanism for explaining how the uncertainty effect is transmitted to gold prices. The current study fills the gap and addresses the following research questions: How does the GEPU affect market participants' behavior? How does the behavior of market participants affect the gold price?

This paper brings three major contributions to the literature. Firstly, it introduces a novel variable, gold investment demand, to draw inferences on gold's hedge and safe haven effects. The existing literature implicitly assumes that market participants in the gold market are homogeneous in their reactions to uncertainty, hence the use of a single variable i.e., price to represent the market and thus overlooked the presence of two distinct subsegments of gold investors (ETF and physical retail segments). In essence, the reaction of gold prices to economic policy uncertainty should reflect the underlying buying and selling activities of gold investors; and yet the dynamics of how these investors behave under uncertainty have not been explored. The proposed use of gold investment demand in this study is substantiated by Baur and Löffler's (2015) argument that actual gold demand is more appropriate than gold prices in examining gold's safe haven and hedge functions since the gold demand variable reflects retail investors' behaviors. According to the authors, existing literature only uses gold prices instead of the actual gold demand probably because retail demand data at quarterly frequency were only available from 2002. We concur with Baur and Löffler (2015) and believe that the gold demand variable is a more direct method than gold prices to understand and explain investors' behaviors under uncertainty. While gold prices are important market signals, gold demand is also equally valuable as it directly signals investors' behaviors in the gold market, which are captured in the gold prices. Hence, the use of gold investment demand (ETF and physical retail demand) may provide insights into the gold's hedge and safe haven functions.

Secondly, this study employs a new approach to analyze the gold price reaction to GEPU by exploring the mediating role of gold investment demand. While past studies have indicated that the actions of specific investors through their gold demand for speculative or hedging purposes have changed gold's role as hedge and safe haven asset (Baur and Glover, 2016; Baur, 2013; Cheng et al., 2020), no research has explored the potential role of gold as a mediator. The current study fills the gap. Mediation analysis provides an added dimension to understand the pathway of GEPU influences, hence providing inferences on the activities of participants in the gold market. Since GEPU could influence gold prices via direct and indirect pathways, this study examines how much of the total effects of GEPU is transmitted through ETF demand and physical retail demand to gain insights and deeper understanding of the actions of these market participants. Through mediation analysis, the study infers the association for each investment demand subsegment with gold's function that corresponds to investors' respective behaviors.

Thirdly, is the application of mediation analysis using time-series data. While mediation analysis is a common approach employed in a variety of research areas, it cannot be readily applied to time series data which may be autoregressive or temporal dependence in nature (Zhao and Luo, 2019). To our best knowledge, mediation analysis using time-series data has not been explored before in the gold literature. In the current study, we employ Zhao and Luo's (2019) framework, called Granger mediation analysis (GMA) to model multiple stationary autoregressive time series data. Unlike standard mediation models, the Zhao and Luo's (2019) method considers the temporal dependence in error processes by integrating two types of models: causal mediation and vector autoregressive (VAR) models into the analysis. As noted by Zhao and Luo (2019), the term "Granger" refers to the temporal dependence in time series errors, thus the coefficients of the error dependence are not meant to be interpreted as causal. The remainder of this paper is divided as follows: The literature review is covered in Section 2, while section 3 describes the data and explains the methodology. Section 4 discusses the results, then section 5 concludes.

**Literature Review**

Economic and behavioral theories remain largely unexplored in the context of uncertainty and the gold market. This paper touches on the law of demand to help point out the demand characteristics of the two types of gold investors under study namely, gold ETF investors, and physical retail investors. According to Mukherjee et al. (2017), demand for gold bars in India is found to be inelastic or unitary elastic. This finding follows the law of demand, as both types of elasticity represent variations of a normal "downward sloping" demand curve. This view is in line with an earlier study by Sazonov & Nikolayev (2014), which argues that coin and bar demand has a negatively sloping curve. Interestingly, Erb and Harvey (2013) show that gold investment demand, unlike the other demand segments, has an upward sloping curve, and attribute that to gold ETFs potentially being momentum-based investors. Furthermore, Sazonov & Nikolayev (2014) also hint at gold ETF demand having a positively sloping curve during certain periods, and attribute that to the expectations effect. The fundamental difference in the shape of the demand curve of ETF and physical gold investors brings the need to look at the demand volumes of each investment subsegment, and study them separately to gain more insights about their behavior under uncertainty.

Gold's hedge and safe haven properties can be inferred by linking each investment demand subsegment with gold's property that fits investors' objective. The emergence of gold ETFs, according to Baur (2013), leads to a structural shift in demand for the commodity, which has implications for the price, volatility, and traded volume of gold. This view is mirrored by Cheng et al. (2020), who show that gold's role changed after the introduction of gold ETFs. In an earlier study, Baur and Glover (2016) argue that ETFs not only provide exposure to gold in investors' portfolios, but also bring the ease of liquidation which, consequently, increases gold price volatility and its appeal to speculators. Moreover, the fact that gold ETFs have significant tax implications[1] for long-term investors makes them more suitable for short term investors (i.e., less than 1 year). Given that the safe haven seeking behavior is by virtue a short-term activity, we may infer that gold ETF demand subsegment is more closely associated with gold's safe haven property. On the other hand, as retail investors tend to hold into their bullion long term rather than for trading purpose (O'Connor et al. 2015), we may infer that the physical retail demand subsegment (i.e., bar and coin investment) is closely associated with gold's hedge property, which is a long-term function. The rationale behind bullion holders having the hedge intention could be borrowed from the 2019 Central Banks Survey by the World Gold Council (WGC), which placed the "long term store of value" or hedge, at the top of the list of motives for central banks to own gold bullion. Given that both central banks and coin and bar investors acquire gold in its physical form, it is logical to also associate hedging with the latter group. Moreover, the 2019 WGC survey also listed "no default risk" as the second most important motive for emerging and developing countries' central banks to hold gold bullion. This hints at counterparty risk potentially being a deal breaker for hedgers, or physical gold holders. Based on that, one could argue that while it is possible for some investors to have hedging in mind when getting into gold ETFs, they, whether or not knowingly, would be accepting to take some level of counterparty risk; something hedgers, or physical gold investors, may not accept. This goes against the view presented by Cheng et al. (2020) that gold ETFs could replace gold bullion to hedge against risks in financial markets. Based on the above, since the gold investment segment comprises two distinct subsegments with different motives and demand characteristics, this warrants the study of the potential mediating role of their demand between uncertainty and the gold price.

It is important to note that non-investment demand segments are to a large extent not perceived in the literature to have a close association with gold properties under uncertainty, and therefore have been excluded from this paper. Nevertheless, demand from the jewellery segment, while mainly driven by weddings and festival seasons in Asian markets, is noted to carry an investment motive besides personal adornment in developing countries (Starr and Tran, 2008), and therefore may have an association with hedging against uncertainty in regions with less developed or limited access to financial markets. This may be a topic for investigation in future research. Moreover, it is worth noting that while central banks represent a significant source of physical gold demand, they may not fit the criteria of gold investors in the classical sense; as they are regulatory bodies that have different motives

[1] CNBC reported in a 2022 article that gold ETFs are treated as collectibles for tax purposes, subject to 28% tax if held for longer than 1 year.

for holding gold bullion besides using it as a hedge, such as backing up their sovereign currencies, or diversifying their reserves beyond holding foreign currencies. Meanwhile, gold exchanges' demand, which captures gold futures, is purely speculative and has minimal use of physical bullion due to the use of margins.

Extant research that has investigated the impact of EPU on the prices of assets and financial markets, concludes that EPU matters. The majority of the studies that focus mainly on examining the influence of EPU on the gold price find a positive link, which provides support to gold's hedge and safe haven status. The disagreement in literature, however, generally lies in whether such positive reaction is valid across all periods, or only during specific times. Bilgin et al. (2018) examine the determinants of the price of gold using four measures of uncertainty. They find that rising economic and political uncertainties lead to an increase in gold price; adding that the new prices are less likely to drop following an improvement in EPU conditions; suggesting a potentially permanent impact. Interestingly, Raza et al. (2018) which, initially finds no causal relationship between EPU and gold prices when using the standard linear Granger causality test, later confirm that EPU causes gold prices in all the examined countries after employing the nonparametric causality-in-quantiles method. Luu (2020) explores EPU and VIX causal relationship with precious metals' returns, and finds that gold's safe haven ability against uncertainty is still intact. Moreover, Shaikh (2020) confirms that gold market volatility tends to be positive in relation to policy uncertainty. Furthermore, Chiang (2022) confirms gold's hedge property against EPU when testing prices in different exchange rates. Bouri et al. (2021) used EMVD, a similar measure of uncertainty to EPU, which is a daily newspaper-based index of uncertainty related to infectious diseases, find that uncertainty increases gold's realized variance in the in-sample exercise, and significantly improves the forecasting performance in the out-of-sample exercise.

Numerous studies find that EPU's influence on gold is time varying, including Bouoiyour et al. (2018), who use the quantile-on-quantile regression model to measure the response of gold prices to uncertainty. The authors construct their own uncertainty measure and find that gold's role as a hedge and safe haven ability does not hold all the time as they find a positive and strong relationship between gold returns and uncertainty at the highest level of uncertainty and in the scenario of a normal market. Chai et al. (2019) find a positive impact of GEPU shock on gold prices over the periods 2006−2008 and 2013−2017, but negative between 2009−2012; indicating that gold's status as a safe haven is not stable and depends on market conditions. Qin et al. (2020), examine gold's ability to hedge global risks, initially finds no causality support under the full sample test, but later finds causality under the sub-sample test. The authors note that GEPU risks can be hedged by gold during the Asian financial crisis, dot-com bubble, and the financial crisis, but, interestingly, not in periods of non-crisis and high uncertainty. Similarly, Yilanci et al. (2021) show that causality from GEPU to gold exists only in some periods. Zhang et al. (2021) confirm the effect of uncertainty shocks on the volatility of gold. Gozgor et al. (2019) finds that both gold returns and volatility increased sharply during the 2007-2008 Financial Crisis and the 2009 European Debt Crisis periods, which reflect the gold's hedge and safe haven properties. However, the study highlights that the spillover from EPU is not the main cause, but rather geopolitical uncertainty and the real effective exchange rate (REER). Gkillas et al. (2020) demonstrate that after controlling for EPU, geopolitical risk (GPR) had a significant positive impact on gold prices. The study concludes that by including gold, investors can improve their portfolios to hedge against mainly long-run risks. Hu et al. (2020) find that gold's realized volatility is more reactive to market sentiment, and that the macro influence is time-varying and is less relevant for gold. On cryptocurrency policy, Hasan et al. (2022) find that uncertainty in cryptocurrency has positive impact on gold, highlighting gold's hedge and safe haven functions.

Nevertheless, although not directly related to the topic of EPU, a few contrasting views are brought by earlier works, such as Barro and Misra (2016), pointing out that gold may not serve as a hedge against risk. Similarly, Erb and Harvey (2013) finds gold to be an unreliable hedge against inflation. A few other studies expressed more critical views towards the role of ETFs. For instance, Cheng et al. (2020) hinted at ETFs being potentially responsible for the loss in gold's hedge and safe haven effectiveness in stock markets, arguing that both properties wear off during the period following the introduction of gold ETFs. However, they also find that gold's hedge and safe haven functions in the currency markets become stronger after the introduction of gold ETFs. O'Connor et al. (2015) touched on the existing skepticism surrounding gold ETFs and the potential loss of gold's functions, but held off making a final verdict on the topic until more data was available. These studies imply that ETF interventions exist and their involvement in the gold market have important implications for gold's hedge and safe haven functions. Baur and Löffler (2015) argue that since gold demand variable reflects the behavior of retail investors, gold demand for bars and coins can be used as a new predictive variable for equity premium, as higher demand is associated with higher risk aversion, reflecting the safe haven property of gold. In this study, we aim to gain more insights and acquire deeper understanding into the role of gold as a hedge and safe haven against global economic uncertainty by using gold ETFs and retail demand as a mediator.

## Data and Methodology

*Data Description*

To shed light on how the global gold market reacts to uncertainty, we obtain data for the global economic policy index (GEPU), gold prices (GOLD), and gold demand stemming from two key market participants, namely gold ETFs (ETF) and retail coin and bar investors (RETAIL). The data sample for the study runs from March 2003 to December 2022. Data for gold prices, GEPU index, and ETF demand is available in monthly frequency, while data for retail demand is only available in quarterly frequency. Since our model requires a consistent time interval for all variables and retail demand is only available on quarterly basis, we convert the quarterly demand into monthly using since Cubic Spline technique. For the data sources, gold retail investment demand data is sourced from the Refinitiv Eikon database – GFMS. Data for gold prices and gold ETF demand is obtained from the World Gold Council database, while the global economic policy uncertainty (GEPU) index is obtained from www.policyuncertainty.com. The GEPU Index is a GDP weighted average of national EPU indices for 21 countries.

## Methodology

Many causal mediation literatures assume the independence of error terms (Imai et al., 2010; Hossain et al., 2022) which are not suitable for time-series data which may be autoregressive or temporal dependence. The temporal dependence needs to be taken into consideration to avoid econometric issues in the estimation of causal mediation model. Causality studies suggested by Granger (1969, 1980) look at the relationship of past values of a variable that caused another variable's value, and this further generalized to Vector Autoregressive Model

(VAR). As suggested by Zhao and Luo (2019), in the estimation of time-series with mediation effect, the Johansen (1991) cointegration of variables in the model needs to be taken into consideration through conditional likelihood estimation. Thus, in this paper, the "Granger" mediation refers to the temporal multivariate autoregressive correlation of the "two" normal forms of equations used in studying the direct and indirect effects of mediation effect, rather than the conventional usage of Granger causality. Figure 2 shows the conceptual diagram for time-series mediation effect as suggested by Zhao and Luo (2019). The test statistics for the indirect effects of mediation is based on Phillips & Park (1988) and Feiveson (1999).

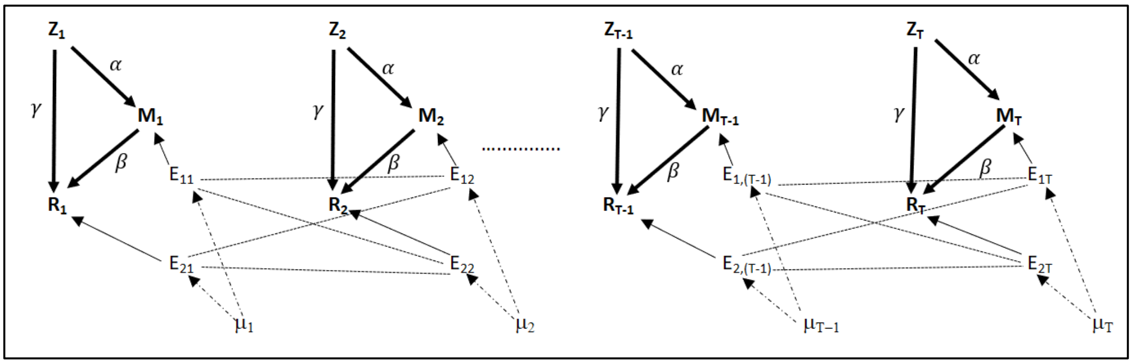


Figure 2. A conceptual diagram for time-series mediation effect (Zhao and Lou, 2019).
$Z_t$ = Independent variable, $R_t$ = Dependent variable, $M_t$ = Mediator, $E_{ij}$ = Random autoregressive error, $\mu_{ij}$ = Random error.

**Model and Methods**

*A Mediation Model for Time Series and Causal Assumptions*

Zhao and Luo (2019) presented the following mediation model where the variables are defined as in Figure 2.

$$M_t = Z_t\alpha + E_{1t} \tag{1}$$
$$R_t = Z_t\gamma + M_t\beta + E_{2t} \tag{2}$$
$$E_{1t} = \sum_{j=1}^{p}\left(\omega_{11j}E_{1,t-j} + \omega_{21j}E_{2,t-j}\right) + \varepsilon_{1t} \tag{3}$$
$$E_{2t} = \sum_{j=1}^{p}\left(\omega_{12j}E_{1,t-j} + \omega_{22j}E_{2,t-j}\right) + \varepsilon_{2t} \tag{4}$$
$$\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix} \sim \mathcal{N}(0,\Sigma), \Sigma = \begin{pmatrix}\sigma_1^2 & \delta\sigma_1\sigma_2\\ \delta\sigma_1\sigma_2 & \sigma_2^2\end{pmatrix} \tag{5}$$

Where $\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix}$ is independent of $\begin{pmatrix}\varepsilon_{1u}\\ \varepsilon_{2u}\end{pmatrix}$ for t ≠ u.

*Method*

This section shows the likelihood estimation of equations (1) to (5) above as proposed by Zhao and Luo (2019).

$$M_t = Z_t\alpha + \sum_{j=1}^{p}\left(\phi_{1_j}Z_{t-j} + \psi_{11_j}M_{t-j} + \psi_{12_j}R_{t-j}\right) + \varepsilon_{1t} \tag{6}$$
$$R_t = Z_t\gamma + M_t\beta + \sum_{j=1}^{p}\left(\phi_{2_j}Z_{t-j} + \psi_{21_j}M_{t-j} + \psi_{22_j}R_{t-j}\right) + \varepsilon_{2t} \tag{7}$$

Where $\left\{\phi_{1j}, \phi_{2j}, \psi_{11_j}, \psi_{21_j}, \psi_{12_j}, \psi_{22_j}\right\}$ are the new parameters introduced to facilitate our likelihood formulation, and we do not intend to interpret them individually.

To simplify the notation in our derivation, we introduce the following representation: let $\boldsymbol{\theta}_1 = (\alpha, \boldsymbol{\phi}_1^T, \boldsymbol{\psi}_{11}^T, \boldsymbol{\psi}_{21}^T)^T$ , $\boldsymbol{\theta}_2 = (\alpha, \boldsymbol{\phi}_2^T, \boldsymbol{\psi}_{12}^T, \boldsymbol{\psi}_{22}^T)^T$ , where $\boldsymbol{\phi}_j = (\phi_{j_1}, \ldots, \phi_{j_p})^T$ , $\boldsymbol{\psi}_{jk} =$

$(\psi_{jk_1},\ldots,\psi_{jk_p})^T$, for j, k =1, 2; $\boldsymbol{X}_t = (Z_t, \boldsymbol{Z}_{t-1}^{(p)\,T}, \boldsymbol{M}_{t-1}^{(p)\,T}, \boldsymbol{R}_{t-1}^{(p)\,T})^T$, where $\boldsymbol{Z}_{t-1}^{(p)} = (Z_{t-1},\ldots\ldots,Z_{t-p})^T$, and $\boldsymbol{M}_{t-1}^{(p)}$ and $\boldsymbol{R}_{t-1}^{(p)}$ are defined analogously. Let $\Theta = (\boldsymbol{\theta}_1, \boldsymbol{\theta}_2, \beta, \sigma_1, \sigma_2)$ be all parameters except $\delta$. Given the initial p time periods, the conditional log-likelihood (ignoring constants) is

$$\ell(\boldsymbol{\theta},\ \delta|\boldsymbol{Z},\ \mathcal{J}_p) = \sum_{t=p+1}^{T} log\, f((M_t\,, R_t)|\boldsymbol{X}_t)\ 1$$
$$= -\frac{T-p}{2} log\sigma_1^2\sigma_2^2(1-\delta^2) - \frac{1}{2\sigma_1^2}\|\boldsymbol{M} - \boldsymbol{X}\boldsymbol{\theta}_1\|_2^2$$
$$-\frac{1}{2\sigma_1^2(1-\delta^2)}\|\boldsymbol{R} - \boldsymbol{M}\beta - \boldsymbol{X}\boldsymbol{\theta}_2) - \mathcal{k}(\boldsymbol{M} - \boldsymbol{X}\boldsymbol{\theta}_1\|_2^2$$

(8)

The analysis is performed using dependent variable gold prices (GOLD), independent variable GEPU, and mediator variable represented separately by gold demand from the ETF and physical retail segments. The first equation estimated is as follows:

$$\Delta GOLD_t = \Delta GEPU_t\gamma_0 + (\phi_0 GEPU_{t-1} + \psi_0 GOLD_{t-1}) + \varepsilon_{0t}$$
(9)

Where $\Delta GOLD_t$ and $\Delta GOLD_{t-1}$ are the first difference in gold prices for each quarter t and t-1 respectively; $\Delta GEPU_t$ and $\Delta GEPU_{t-1}$ represent the first difference in GEPU for each quarter t and t-1 respectively; $\varepsilon_{0t}$ is the error term.
Following equations (6) and (7), we use equations (10) and (11) to estimate the "Granger" mediation.

$$MEDIATOR_t = \Delta GEPU_t\alpha + (\phi_1 GEPU_{t-1} + \psi_{11} MEDIATOR_{t-1} + \psi_{12} GOLD_{t-1}) + \varepsilon_{1t}$$
(10)

$$\Delta GOLD_t = \Delta GEPU_t\gamma + MEDIATOR_t\beta + (\phi_2 GEPU_{t-1} + \psi_{12} MEDIATOR_{t-1} + \psi_{22} GOLD_{t-1}) + \varepsilon_{2t}$$
(11)

Where $MEDIATOR_t$ and $MEDIATOR_{t-1}$ are investment gold demand for quarter t and t-1 respectively; $\Delta GEPU_t$ and $\Delta GEPU_{t-1}$ represent the first difference in GEPU for quarter t and t-1; $\Delta GOLD_t$ and $\Delta GOLD_{t-1}$ are the first difference in gold prices for each quarter t and t-1; $\varepsilon_{1t}$ and $\varepsilon_{2t}$ are the error terms.

**Discussion of the Results**

Table 1 presents descriptive statistics of the variables. In terms of size, ETF demand is relatively small compared to the physical gold retail segment. On average, the ETF demand is about five times smaller than retail demand. However, ETF demand has a high relative variation at 397.07% whereas the relative variability in retail demand is only 45.11%. This may indicate that ETF demand is far more responsive to changes in economic and financial factors than retail demand. Among the variables, gold prices have the lowest degree of relative variability and the standard deviation of GEPU is almost half as large as its mean value.

Table 1
*Descriptive statistics*

| | GEPU | GOLD | ETF | RETAIL |
|---|---|---|---|---|
| Mean | 149.8062 | 1165.3 | 14.52912 | 249.8813 |
| Median | 132.7182 | 1244 | 10.45046 | 262.8107 |
| Maximum | 430.2744 | 1964.9 | 223.6436 | 652 |
| Minimum | 48.87514 | 334.85 | -179.341 | 68.34301 |
| Std. Dev. | 76.58254 | 458.3388 | 57.6912 | 112.7181 |
| Coeff. of variation | 51.12% | 39.33% | 397.07% | 45.11% |
| Observations | 238 | 238 | 238 | 238 |

Before running the mediation model, we test the variables for stationarity. As mentioned earlier, cointegration of variables are needed for the conditional likelihood estimation. The ETF and RETAIL are stationary, I(0), while GOLD and GEPU are I(1). Next, we run the Johansen's (1991) cointegration tests for (GOLD and GEPU), (GOLD, GEPU and ETF) and (GOLD, GEPU and RETAIL) and found one cointegration for both as reported in Table 2.

Table 2
*Johansen's cointegration tests*

| ***Series: GOLD GEPU ETF*** | | | | |
|---|---|---|---|---|
| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
| None * | 0.205 | 65.473 | 29.797 | 0.000 |
| At most 1 | 0.045 | 11.682 | 15.495 | 0.173 |
| At most 2 | 0.004 | 0.958 | 3.841 | 0.328 |
| ***Series: GEPU GOLD*** | | | | |
| None * | 0.0790 | 22.2691 | 18.3977 | 0.0137 |
| At most 1 | 0.0128 | 3.0119 | 3.8415 | 0.0827 |
| ***Series: GOLD GEPU RETAIL*** | | | | |
| None * | 0.1424 | 35.7920 | 21.1316 | 0.0002 |
| At most 1 | 0.0400 | 9.5109 | 14.2646 | 0.2461 |
| At most 2 | 0.0050 | 1.1715 | 3.8415 | 0.2791 |
| Trace test indicates 1 cointegrating equation(s) at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) p-values | | | | |

Trace test indicates 1 cointegrating equation(s) at the 0.05 level. *denotes rejection of the hypothesis at the 0.05 level. **MacKinnon-Haug-Michelis (1999) p-values.

Table 3 presents the result of equation (9) for the effect of GEPU on gold price, indicating that there is a relationship to be mediated between GEPU and gold price. GEPU significantly and positively influences gold price, implying that gold price increases on safe haven purchases as a reaction to uncertainty in global economic policy. As illustrated previously in Figure 1, both the gold price and GEPU index move in tandem, and the movements are consistent with gold's safe haven function. The results with ETF as a mediator in equations (10) and (11) are reported in Tables 4, and 5 respectively.

Table 3
*The effect of GEPU on gold price*

| Eq. (9) | Coefficient | Robust Std. error | z | P>z | [95% conf. interval] | |
|---|---|---|---|---|---|---|
| $\Delta GEPU_t$ | 0.2555* | 0.1300 | 1.97 | 0.0510 | -0.0006 | 0.5116 |
| $GOLD_{t-1}$ | -0.0357*** | 0.0130 | -2.76 | 0.0060 | -0.0613 | -0.0102 |
| $GEPU_{t-1}$ | 0.1929** | 0.0786 | 2.45 | 0.0150 | 0.0380 | 0.3478 |
| constant | 18.9935* | 10.8037 | 1.76 | 0.0800 | -2.2920 | 40.2789 |

***, **, * denote significance at 1%, 5%, and 10% levels

Table 4 reports the results of equation (10) for the effect of GEPU on ETF demand. As shown, GEPU exerts a highly significant positive impact on ETF demand, indicating that independent variable relates to the mediator variable, which is important in establishing mediated effect. The positive coefficient means ETF holdings increased as investors rushed into gold-backed ETF in response to higher GEPU, implying that safe haven phenomena may be at play during this time. In other words, the sharp increase in ETF demand during periods of high uncertainty, and the preceding sharp liquidation as uncertainty subsides could be taken as a manifestation of the safe haven seeking behavior in action. ETFs, short term gold investors, or speculators see more utility in acquiring gold when the prevalent level of uncertainty rises, and the consequent increase in gold price they cause themselves would only drive their demand higher, as they chase higher returns. This reasoning is consistent with Erb and Harvey's (2013) contention that gold investment demand exhibits momentum investing perhaps due to the actions of a relatively small momentum gold buyers that drive the gold price higher. Since gold ETFs are short term oriented (especially due to tax implications), they wouldn't possibly be buying gold for its hedge function, but rather for the safe haven function, which basically serves as a shelter during a storm. Once the uncertainty level subsides, there will be a sharp selloff as they run to reap the return from the gold price appreciation.

Table 4
*The effect of GEPU on ETF demand.*

| Eq. (10) | Coefficient | Robust Std. error | z | P>z | [95% conf. interval] | |
|---|---|---|---|---|---|---|
| $\Delta GEPU_t$ | 0.4789*** | 0.1015 | 4.72 | 0.0000 | 0.2799 | 0.6779 |
| $GOLD_{t-1}$ | -0.0283*** | 0.0105 | -2.70 | 0.0070 | -0.0488 | -0.0078 |
| $ETF_{t-1}$ | 0.4905*** | 0.0546 | 8.99 | 0.0000 | 0.3835 | 0.5975 |
| $GEPU_{t-1}$ | 0.1602** | 0.0639 | 2.51 | 0.0120 | 0.0350 | 0.2854 |
| constant | 16.3652* | 8.5233 | 1.92 | 0.0550 | -0.3401 | 33.0704 |

***, **, * denote significance at 1%, 5%, and 10% levels.

Table 5 presents the results of equation (11) for the effects of GEPU and ETF demand on gold price. The finding indicates that the relationship between GEPU and gold prices disappears when the mediated effect of ETF is taken into consideration. That is, the significant positive coefficient of ETF demand and the insignificant GEPU coefficient are evidence showing the full mediation effect of ETF demand. The ETF mediation effect is an indirect effect with a coefficient of 0.3463, calculated by multiplying the coefficient for the impact of GEPU on ETF (0.4789 in Table IV), with the coefficient for the impact of ETF on gold prices (0.7231 in Table V). The test statistics for the mediation effects was computed based on Phillips & Park (1988) and Feiveson (1999).

Table 5
*The effects of GEPU and ETF on gold price*

| Eq. (11) | Coefficient | Robust Std. error | z | P>z | [95% conf. interval] | |
|---|---|---|---|---|---|---|
| $ETF_t$ | 0.7231*** | 0.0682 | 10.60 | 0.0000 | 0.5894 | 0.8567 |
| $\Delta GEPU_t$ | -0.1001 | 0.1105 | -0.91 | 0.3650 | -0.3166 | 0.1164 |
| $GOLD_{t-1}$ | -0.0122 | 0.0111 | -1.10 | 0.2720 | -0.0340 | 0.0096 |
| $ETF_{t-1}$ | -0.2377*** | 0.0715 | -3.33 | 0.0010 | -0.3777 | -0.0976 |
| $GEPU_{t-1}$ | 0.0581 | 0.0677 | 0.86 | 0.3910 | -0.0747 | 0.1908 |
| constant | -0.2426*** | 0.0606 | -4.00 | 0.0000 | -0.3613 | -0.1238 |
| The test statistics for ETF full mediation | | | | | | |
| Coefficient | | Std. error | z | P> z | [95% conf. interval] | |
| 0.3463*** | | 0.0804 | 4.3100 | 0.0000 | 0.1888 | 0.5038 |

***, **, * denote significance at 1%, 5%, and 10% levels.

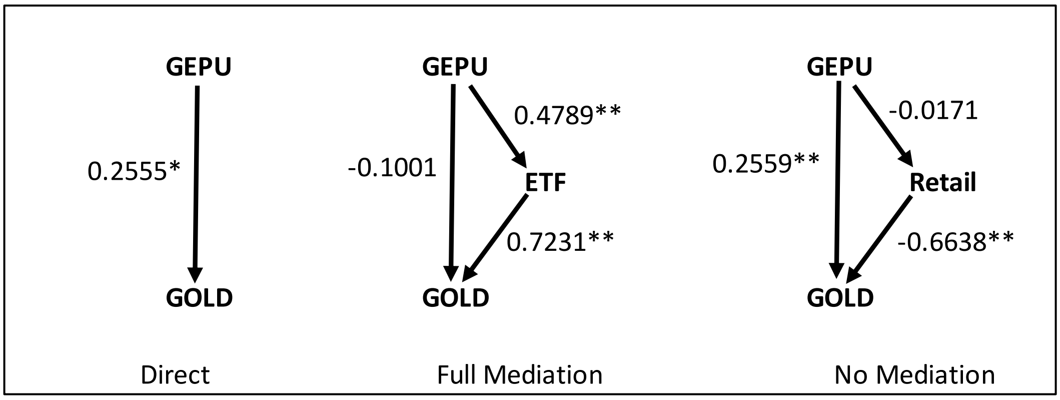


Figure 3. Path diagram for mediation analysis.

Figure 3 shows the mediation analyses path diagram based on equations (9), (10) and (11). The diagram illustrates the paths from GEPU to ETF and from ETF to gold prices with their respective coefficients. The result of full mediation suggests that the entire effect of GEPU on gold prices is transmitted fully through ETF demand, which means GEPU has no direct effect on the gold price, rather its entire effect is indirect. In other words, the response of gold price to GEPU was fully intercepted by ETF demand. The significant positive ETF coefficient is consistent with strong safe haven effect (Baur and McDermott, 2010). The presence of mediation effect reflects the interventions of ETF investors in the gold market. The mediation result implies that ETF investors appear in the "pathway" between GEPU and gold prices. Such finding is consistent and supportive of past studies that ETF interventions exist and their involvements in the gold market have implications for gold's hedge and safe haven functions, gold price, trading volume, and volatility (Baur and Glover, 2016; Baur, 2013; Cheng et al., 2020). This is unsurprising because ETFs provide investors with lower transaction costs and higher liquidity than physical gold (Baur, 2013; Cheng et al., 2020), hence due their market accessibility and transaction size, ETFs have strong market influence on gold price movements.


Figure 4. Evolution of ETF holdings and gold prices (monthly, holdings in tons, prices in USD/oz.)
Source: World Gold Council database

As illustrated in Figure 4, both the gold price and ETFs holdings tend to move in tandem.
The ETF mediation result may also shed light on some prior studies that have questioned or challenged gold's function as a hedge or safe haven asset. That is, past findings indicating that gold appeared to have lost its safe haven status in response to uncertainty may not be entirely true and perhaps could be explained by the actions of specific market participant in the gold market. As argued by Baur and McDermott (2016), if investors react to large negative shock by purchasing gold as a safe haven asset, they tend to sell it once they have fully understood the implications of the shock. That said, the downward pressure on gold prices in response to uncertainty in past studies could have resulted from ETF investors cashing-in on higher gold prices due to heavy profit taking or investors' portfolio re-balancing activities. The sharp selloffs push gold prices down, thereby giving the impression that gold has lost its safe haven functions against uncertainty.

Tables 6 and 7 present the results of equations (10) and (11) with physical retail gold demand as the mediator. The result in Table 6 for equation (10) on the effect of GEPU on physical retail demand indicates that there is no significant relationship between GEPU and physical gold demand, suggesting no mediated effect for retail gold demand. GEPU doesn't affect retail demand perhaps because investors just could not deal with policy fluctuations since physical gold is less liquid and more difficult to sell. Moreover, bars and coins are normally stored long-term rather than traded, which explains why retail demand is not responsive to GEPU. Baur (2013) argues that physical gold coins and bars investors find it relatively costly and cumbersome to buy and sell compared to ETF investors, which hinder their reactions to gold related news. Our finding that retail demand is not responsive to GEPU is supportive of Cheng et al.'s (2020) contention that investors could replace physical gold with gold ETF to hedge against financial market risks.

Table 6
*The effect of GEPU on physical retail demand*

| Eq. (10) | Coefficient | Robust Std. error | z | P>z | [95% conf. interval] | |
|---|---|---|---|---|---|---|
| $\Delta GEPU_t$ | -0.0171 | 0.0507 | -0.34 | 0.7360 | -0.1165 | 0.0823 |
| $GOLD_{t-1}$ | 0.0248*** | 0.0074 | 3.37 | 0.0010 | 0.0104 | 0.0392 |
| $RETAIL_{t-1}$ | 0.9183*** | 0.0211 | 43.57 | 0.0000 | 0.8770 | 0.9596 |
| $GEPU_{t-1}$ | -0.0714** | 0.0332 | -2.15 | 0.0310 | -0.1364 | -0.0064 |
| constant | 3.2136 | 4.3276 | 0.74 | 0.4580 | -5.2684 | 11.6955 |

***, **, * denote significance at 1%, 5%, and 10% levels.

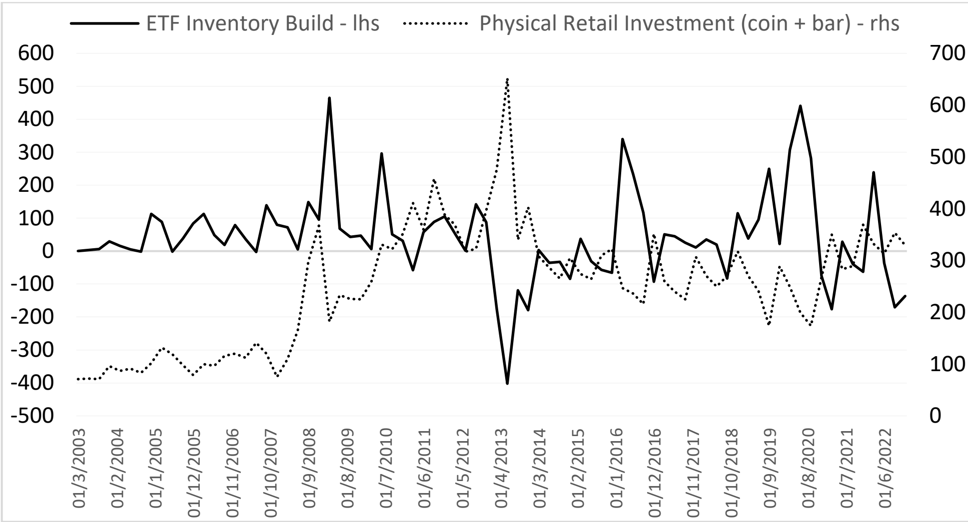


Figure 5. Net gold investment demand by subsegment (quarterly, in tons)
Source: Refinitiv Eikon database - GFMS

As shown in Figure 5, a key difference observed in the behavior of the two demand segments is that throughout the period of analysis net retail investment demand has always been positive, whereas net ETF demand often turns negative (i.e., net supplier). This may imply that physical retail investors are long term oriented, and do not become net sellers (during the period under review), as they buy gold to preserve their wealth long term, thereby they are considered hedgers. The observed net negative ETF demand suggests that gold ETFs are short-term investors, and they liquidate their gold investment for profit taking or when they see diminishing prospect for price appreciation. This is not surprising, given how ETFs benefit from the liquidity advantage, they can react to market developments quicker, and often in a sharp manner.

Table 7
*The effects of GEPU and physical retail demand on gold price*

| Eq. (11) | Coefficient | Robust Std. error | z | P>z | [95% conf. interval] | |
|---|---|---|---|---|---|---|
| $RETAIL_t$ | -0.6638*** | 0.1656 | -4.01 | 0.0000 | -0.9883 | -0.3393 |
| $\Delta GEPU_t$ | 0.2559** | 0.1243 | 2.06 | 0.0390 | 0.0124 | 0.4994 |
| $GOLD_{t-1}$ | -0.0314* | 0.0189 | -1.67 | 0.0960 | -0.0684 | 0.0055 |
| $RETAIL_{t-1}$ | 0.6536*** | 0.1582 | 4.13 | 0.0000 | 0.3435 | 0.9637 |
| $GEPU_{t-1}$ | 0.1835** | 0.0823 | 2.23 | 0.0260 | 0.0222 | 0.3448 |
| constant | 19.8212* | 10.6259 | 1.87 | 0.0620 | -1.0052 | 40.6476 |

***, **, * denote significance at 1%, 5%, and 10% levels.

Table 7 reports the result for equation (11) on the effects of GEPU and physical retail demand on gold price. The findings show that both GEPU and retail demand have direct effects on gold prices. The significant positive coefficient of GEPU suggests that heightened global economic policy uncertainty leads to increases in gold prices, which is supportive of gold's hedge and safe haven functions (Bilgin et al. 2018; Raza et al. 2018; Luu, 2020; Shaikh, 2020; and Chiang, 2022; among others). The negative relation between retail demand and gold prices may be more complex than what is suggested by the negative coefficient. Interestingly, we observe in Figure 5 that retail investors' net demand is always positive, suggesting hedging, and tends to increase during periods of ETF selloffs, such as the case in Q2-2013, Q4-2016, and Q1-2021, during which gold prices decreased sharply. This may not be interpreted as higher demand from retail investors causes lower prices; but rather, this suggests they prefer to acquire gold at lower prices during ETF selloffs. The reasoning is in line with demand theory, based on the downward sloping demand curve for physical retail investors. As Sazonov and Nikolaev (2014) noted, demand for gold coins and bar, jewelry gold demand and technological demand all have negatively sloped demand curves. Unlike ETF investors, physical retail investors see higher prices as deterrent, and because hedgers or long-term investors are "rational" in the classical sense, and they see less utility in acquiring gold at a higher premium despite the rise in uncertainty when they can postpone their purchases and get it at a discount instead. This is the exact opposite for ETFs investors who see price increase as a motive and get more utility in acquiring gold as uncertainty clouds the global economy. Hence, there is a possibility that ETFs could be seen in the short term as "price makers" by the physical retail demand subsegment, which are consequently price takers. This is in line with the argument raised by Baur (2013), Ivanov (2011), and O'Connor et al. (2015), that ETFs lead the price discovery for the gold market. Additionally, Mozes and Cooks (2013) also argue that the gold price influence of speculative demand dominates that of physical consumer and investment demand. In contrast to the ETF results, the finding that physical gold demand plays no role in transmitting the effects of GEPU highlights the contradictory nature of the different types of gold investors. This implies that mediating effect is driven by the behavioral differences between ETF and physical retail investors and its presence is demand-category specific. The evidence of behavioral difference in gold demand between ETF and physical retail investors is broadly consistent with the "self-balancing nature" of the gold market that characterizes gold's robust qualities as an investment asset (World Gold Council, 2022). On that note, Sazonov and Nikolaev (2014) also find that speculative gold demand and long-term physical gold demand react oppositely to gold prices, thus they function as an "automatic stabilizer" for the gold market.

The findings of this study provide implications for both investors and policymakers. The substantial price influence of gold ETFs shown in the results is relevant to financial markets' regulators, as it implies that gold ETFs are the main force driving price volatility despite their relatively small size. To help stabilize the gold market, regulators may consider stimulating or incentivizing gold ETFs adoption among portfolio managers and institutional investors by revising the tax treatment of this investment vehicle. Currently, if held for a year or longer, gains from gold ETF investments are subject to a higher tax rate compared to stocks in the U.S., as they are treated similarly to collectibles. Additionally, by providing a better understanding of the behavior of each particular group of investors, the findings may allow individual investors, professional portfolio managers, and institutional investors make better informed decisions when determining the most suitable mode of gold investment based on their intention (i.e., hedging, or safe haven seeking). Moreover, the findings also show that while gold ETFs effectively track the developments in uncertainty, making them an efficient safe haven, they may not be considered suitable for hedging, as they carry counter party risk. This is an important aspect often overlooked in the investment community.

**Conclusions**

In this paper, we explain how GEPU impacts gold prices through a mediating variable to deepen the understanding of uncertainty-gold price nexus. Applying the Granger mediation approach of Zhao and Luo (2019) and using monthly net demand data for ETFs and physical retail investors, we find that the reactions to GEPU differ with respect to market participants. ETF net demand is found to be the main transmission channel of the impact of uncertainty on gold prices. The finding of full ETF mediating effect means the impacts of GEPU on gold prices is fully transmitted through ETF demand. ETF investors adjust their gold holdings in response to changes in global economic policy risk, and their net demand adjustment fully explains the GEPU-gold price relation. This can be interpreted as safe haven seeking behavior in action as gold price increases on safe haven demand in response to global uncertainty. Meanwhile the result show that physical retail investment demand does not have a mediating role between uncertainty and gold price, indicating that retail demand is not responsive to GEPU developments. These results show that gold investors behave differently under uncertainty depending on their motives, and are supportive of gold's hedge and safe haven properties against uncertainty with respect to physical retail and ETF investors, respectively. Making such distinction was not previously possible as the existing literature focused solely on examining the direct response of gold prices to changes in uncertainty, which omitted important information about the behavior of the fundamentally different types of gold investors. In sum, differences in the results between ETF and physical gold retail investors are closely linked to behavioral differences between the two demand segments, and may possibly point to ETFs being the price makers while gold coins and bar investors the price takers. The findings of this study hold important implications for gold investors and regulators.

**Theoretical and Contextual Contribution**

The existing literature focuses on studying the direct response of gold prices to changes in economic policy uncertainty, omitting the behavioural aspect of investors in responding to uncertainty. This study contributes to the literature by finding evidence that gold investment demand (ETF demand and physical retail demand) contains behavioural information, allowing inferences to be made about the activities of gold market participants. A novel time-series Granger mediation approach is employed to examine how changes in the global economic policy uncertainty (GEPU) affect gold prices. The findings show that the impacts of GEPU on gold prices are indirect occurring through ETF demand, which is a relatively new demand segment. The ETF influence is interpreted as investors' safe-haven seeking behaviours. The absence of mediating effect for retail demand indicates that physical gold investors are not responsive to GEPU. The findings benefits investors and policymakers. The significant ETFs gold price impacts suggest that ETFs are the main driving force of gold price volatility despite their small size. Hence, to help stabilize the gold market, regulators may consider promoting greater use of gold ETFs among portfolio managers and institutional investors. The findings enhance understanding of the behaviours of different groups of gold investors, allowing investors to make better investment decisions regarding the mode of their gold investment based on their intention (i.e., hedging, or safe haven seeking).

## References

Barro, R. J., & Misra, S. (2016). Gold returns. *The Economic Journal, 126*(594), 1293-1317. doi:10.1111/ecoj.12274

Baur, D. G. (2013). Exchange-traded funds on Gold - A free lunch? *SSRN Electronic Journal*. doi:10.2139/ssrn.2297756

Baur, D. G., & McDermott, T. K. (2010). Is gold a safe haven? international evidence. *Journal of Banking & Finance, 34*(8), 1886-1898. doi:10.1016/j.jbankfin.2009.12.008

Baur, D. G., & Löffler, G. (2015). Predicting the equity premium with the demand for gold coins and bars. *Finance Research Letters, 13*, 172-178. doi:10.1016/j.frl.2015.01.007

Baur, D. G., & Glover, K. J. (2016). The Destruction of a Safe Haven Asset?. *Applied Finance Letters*, 1(1), 8-15. https://doi.org/10.24135/afl.v1i1.5

Baur, D. G., & McDermott, T. K. (2016). Why is gold a safe haven? *Journal of Behavioral and Experimental Finance, 10*, 63-71. doi:10.1016/j.jbef.2016.03.002

Bekiros, S., Boubaker, S., Nguyen, D. K., & Uddin, G. S. (2017). Black Swan events and safe havens: The role of gold in globally integrated emerging markets. *Journal of International Money and Finance, 73*, 317-334. doi:10.1016/j.jimonfin.2017.02.010

Bilgin, M., Gozgor, G., Lau, C., & Sheng, X. (2018). The effects of uncertainty measures on the price of gold. *International Review of Financial Analysis*, *58*, 1-7. https://doi.org/10.1016/j.irfa.2018.03.009

Bouoiyour, J., Selmi, R., & Wohar, M. (2018). Measuring the response of gold prices to uncertainty: An analysis beyond the mean. *Economic Modelling*, *75*, 105-116. https://doi.org/10.1016/j.econmod.2018.06.010

Bouri, E., Gkillas, K., Gupta, R., & Pierdzioch, C. (2021). Forecasting power of infectious diseases-related uncertainty for gold realized variance. *Finance Research Letters*, *42*, 101936. https://doi.org/10.1016/j.frl.2021.101936

Chai, G., You, D., & Chen, J. (2019). Dynamic response pattern of gold prices to economic policy uncertainty. *Transactions Of Nonferrous Metals Society of China*, *29*(12), 2667-2676. https://doi.org/10.1016/s1003-6326(19)65173-3

Cheng, W., Chen, C., & Lai, H. (2020). Revisiting the roles of gold: Does gold ETF matter? *The North American Journal of Economics and Finance, 54*, 100891. doi:10.1016/j.najef.2018.12.003

Chiang, T. (2022). The effects of economic uncertainty, geopolitical risk and pandemic upheaval on gold prices. *Resources Policy*, *76*, 102546. https://doi.org/10.1016/j.resourpol.2021.102546

Erb, C. B., & Harvey, C. R. (2013). The golden dilemma. *Financial Analysts Journal, 69*(4), 10-42. doi:10.2469/faj.v69.n4.1

Feiveson, A. H. 1999. FAQ: What is the delta method and how is it used to estimate the standard error of a transformed parameter? https://www.stata.com/support/faqs/stat/deltam.html

Garlappi, L., Uppal, R., Wang, T. (2007). Portfolio Selection with Parameter and Model Uncertainty: A Multi-Prior Approach. *Review of Financial Studies*, 20(1), 41-81. doi:10.1093/rfs/hhl003

Gkillas, K., Gupta, R., & Pierdzioch, C. (2020). Forecasting realized gold volatility: Is there a role of geopolitical risks?. *Finance Research Letters*, *35*, 101280. https://doi.org/10.1016/j.frl.2019.08.028

Gold demand by country: Gold demand and Supply Statistics: Goldhub. (2022, November 01). Retrieved January 2, 2023, from https://www.gold.org/goldhub/data/gold-demand-by-country

Gozgor, G., Lau, C., Sheng, X., & Yarovaya, L. (2019). The role of uncertainty measures on the returns of gold. *Economics Letters*, *185*, 108680. https://doi.org/10.1016/j.econlet.2019.108680

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica*, *37*(3), 424. https://doi.org/10.2307/1912791

Granger, C. W. J. (1980). Testing for causality: A personal viewpoint. *Journal of Economic Dynamics and Control*, *2*(C), 329–352. https://doi.org/10.1016/0165-1889(80)90069-X

Hasan, M. B., Hassan, M. K., Karim, Z. A., & Rashid, M. M. (2022). Exploring the hedge and safe haven properties of cryptocurrency in policy uncertainty. *Finance Research Letters, 46*, 102272. doi:10.1016/j.frl.2021.102272

Hossain, K., Che Abdullah, A. S., Mohd Balwi, M. A. W. F., Lubis, A., Azizan, N. A., Alam, M. N., & Taha, A. Z. (2022). Linking entrepreneurial orientation with export performance: mediation effects of multiple differentiation strategies. *Journal of Business and Industrial Marketing*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/JBIM-07-2021-0326/FULL/XML

Hu, M., Zhang, D., Ji, Q., & Wei, L. (2020). Macro factors and the realized volatility of commodities: A dynamic network analysis. *Resources Policy*, *68*, 101813. https://doi.org/10.1016/j.resourpol.2020.101813

Iacurci, G. (2022, March 14). Gold, silver ETF owners face 28% top tax rate on profits. that's higher than levies on stocks. Retrieved December 11, 2022, from https://www.cnbc.com/2022/03/14/gold-silver-etf-owners-face-28-percent-top-tax-rate-on-capital-gains.html

Imai, K., Keele, L., & Yamamoto, T. (2010). Identification, inference and sensitivity analysis for causal mediation effects. *Statistical Science, 25*(1). doi:10.1214/10-sts321

Ivanov, S. (2011). The influence of ETFs on the price discovery of gold, silver and oil. *Journal of Economics and Finance, 37*(3), 453-462. doi:10.1007/s12197-011-9205-8

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregressive models. *Econometrica, 59*(6), 1551. doi:10.2307/2938278

Kostopoulos, D., Meyer, S., & Uhr, C. (2022). Ambiguity about volatility and investor behavior. *Journal of Financial Economics, 145*(1), 277-296. doi:10.1016/j.jfineco.2021.07.004

Luu Duc Huynh, T. (2020). The effect of uncertainty on the precious metals market: New insights from Transfer Entropy and Neural Network VAR. *Resources Policy*, *66*, 101623. https://doi.org/10.1016/j.resourpol.2020.101623

MacKinnon, D. P., Coxe, S., & Baraldi, A. N. (2011). Guidelines for the investigation of mediating variables in business research. *Journal of Business and Psychology, 27*(1), 1-14. doi:10.1007/s10869-011-9248-z

Mele, A., & Sangiorgi, F. (2015). Uncertainty, information acquisition, and price swings in asset markets. *The Review of Economic Studies, 82*(4), 1533-1567. doi:10.1093/restud/rdv017

Mozes, H. A., & Cooks, S. (2013). The disconnect between physical gold demand and gold prices. *The Journal of Wealth Management,* 131018051544009. doi:10.3905/jwm.2013.2013.1.028

Mukherjee, P., Mukherjee, V., & Das, D. (2017). Estimating elasticity of import demand for gold in India. *Resources Policy, 51*, 183-193. doi:10.1016/j.resourpol.2016.12.007

O'Connor, F. A., Lucey, B. M., Batten, J. A., & Baur, D. G. (2015). The Financial Economics of Gold — A Survey. *International Review of Financial Analysis, 41*, 186-205. doi:10.1016/j.irfa.2015.07.005

Peijnenburg, K. (2018). Life-cycle asset allocation with ambiguity aversion and learning. *Journal of Financial and Quantitative Analysis, 53*(5), 1963-1994. doi:10.1017/s0022109017001144

Phillips, P. C. B., & Park, J. Y. (1988). On the Formulation of Wald Tests of Nonlinear Restrictions. *Econometrica*, *56*(5), 1065. https://doi.org/10.2307/1911359

Qin, M., Su, C., Xiao, Y., & Zhang, S. (2020). Should Gold Be Held under Global Economic Policy Uncertainty?. *Journal of Business Economics and Management*, *21*(3), 725-742. https://doi.org/10.3846/jbem.2020.12040

Raza, S., Shah, N., & Shahbaz, M. (2018). Does economic policy uncertainty influence gold prices? Evidence from a nonparametric causality-in-quantiles approach. *Resources Policy*, *57*, 61-68. https://doi.org/10.1016/j.resourpol.2018.01.007

Sazonov, V., & Nikolaev, D. (2014). Demand for gold: Goods and investment markets interdependence as a factor of gold market stabilization. *Investment Management and Financial Innovations*. 11. 60-65.

Shaikh, I. (2020). Does Policy Uncertainty Affect Equity, Commodity, Interest Rates, and Currency Markets? Evidence From CBOE's Volatility Index. *Journal of Business Economics and Management*, *21*(5), 1350-1374. https://doi.org/10.3846/jbem.2020.13164

Starr, M., & Tran, K. (2008). Determinants of the physical demand for gold: Evidence from panel data. *The World Economy, 31*(3), 416-436. doi:10.1111/j.1467-9701.2007.01091.x

World Gold Council. (2019, July 18). 2019 Central Bank Gold Reserve Survey. Retrieved January 1, 2023, from https://www.gold.org/goldhub/data/2019-central-bank-gold-reserve-survey

Yilanci, V., & Kilci, E. (2021). The role of economic policy uncertainty and geopolitical risk in predicting prices of precious metals: Evidence from a time-varying bootstrap causality test. *Resources Policy*, *72*, 102039. https://doi.org/10.1016/j.resourpol.2021.102039

Zhang, H., Demirer, R., Huang, J., Huang, W., & Tahir Suleman, M. (2021). Economic policy uncertainty and gold return dynamics: Evidence from high-frequency data. *Resources Policy*, *72*, 102078. https://doi.org/10.1016/j.resourpol.2021.102078

Zhao, Y., & Luo, X. (2019). Granger mediation analysis of multiple time series with an application to functional magnetic resonance imaging. *Biometrics, 75*(3), 788-798. doi:10.1111/biom.13056