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Do Exchange Rates Fluctuations Influence Gold Price in G7 Countries? New Insights from a Nonparametric Causality-in-Quantiles Test

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Abstract: *In the recent era, gold is considered an essential investment source, a source of hedging inflation, and a medium of monetary exchange. The gold and exchange rate nexus become prominent after events like sovereign debt crisis, subprime mortgage crisis, low-interest rate problem, and global financial market solvency. These events attract the attention of researchers and academician for investigating the dynamics of the relationship between gold and exchange rates, and the majority of the studies discusses the linear dynamics, but the non-linear dynamics are ignored. Therefore, the current research investigates the non-linear dynamics of gold price and exchange rate relationship in G7 countries using the new technique named the nonparametric causality approach. This study uses monthly data from the years 1995(January)-2017 (March). The empirical results show that exchange rate return causes gold prices in four out of G7, especially at the low tails. This study also gives valuable insights for monetary policymakers, gold exporter's international portfolio managers, and hedge fund managers.*

***Keywords*:** Gold Prices; Exchange Rates; Non-Parametric Causality Approach; G7 Countries

JEL Classification: D49, G1, D53, F51, C58, F51

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Introduction

In this contemporary era, until now the gold has been used as a means of reserve for the countries or used as jewelry for the households. Thus, it is an important research area to explore those factors that affect price movements in gold as it has been witnessed as an essential investment tool for the whole world. Several economic factors have been identified that affect gold prices such as, inflation rates, the force of supply and demand, state reserves, and interest rate (Alola, Asongu, & Alola, 2019). Apart from inflation and interest rate, the exchange rate is one of the critical factors for the economic health of a country. The exchange rate and gold prices have gained considerable attention from practitioners and academicians globally (Kumar, 2019), especially after the global financial crisis.

Gold is a commodity that is considered immune to physical deterioration, can be stored and used for exchange purposes (Jones and Sackley, 2016; Raza et al., 2018). Historically, gold was treated as a medium of monetary exchange and a store of value before the collapse of the Bretton Woods system. Shafiee and Topal (2010) stated that in gold mine production, 60% of the produced gold had been used for jewelry, while 40% was used for industrial demand and bank reserves. Currently, gold is considered safe even in political and economic uncertainty, financial crisis (Gao and Zhang, 2016; Beckmann et al., 2015; Arouri et al., 2015). After the post-Bretton Woods world, gold has been used as an investment by the governments and investors (Jain and Ghosh, 2013). Investors considered gold a desirable asset in their portfolio as it acts as a friend on rainy days. Any loss that occurs due to extremely adverse stock market movement is compensated upward trend of gold prices. The decline in purchasing power due to currency depreciation or inflation is also balanced by Gold (Iqbal, 2017). Additionally, it is seen as a source of hedging against inflation, oil prices, stock and bond prices, exchange rates (Beckmann and Czudaj 2013a, b; Beckmann et al., 2015; Balcilar et al., 2016 b, c, d). These two gold properties are also emphasized by the media reports and investors (Balcilar et al., 2016b).

These gold properties also get the attention of researchers and academicians, and various studies have been conducted. Some studies explore the association between inflation and gold prices (Blose 2010, Ghosh et al. 2014, Capie et al. 2005). Other studies discuss the "safe heaven" property of investment related to gold (Baur and Lucey 2010, Baur and McDermott 2010), the relationship between business-cycle fluctuations and gold-prices (Pierdzioch et al. 2014b), and the link between oil prices and gold prices (Reboredo 2013b, Beckmann and Czudaj 2013). Few research studies investigate the dynamics of gold prices and exchange rates (Pukthuanthong and Roll 2011, Sjaastad 2008, Reboredo 2013a, Pal, et al. 2014).

It is a noteworthy point that the exchange rate and the gold price relationship attains a growing concern among industry and academia (Jain and Biswal, 2016). In empirical finance, a long-standing research question is how and whether exchange-rate movements and gold price fluctuations are interconnected (Beckmann et al., 2015; Joy 2011). The first strand of literature argues that such links exist because a low US interest rate makes an investment in a dollar less attractive whereas, at the same time, a zero-yield gold investment becomes more attractive (Beckers and Soenen, 1984). Another strand of literature argues that a causal relationship exists between the variables, i.e., Exchange-rate movements cause gold-price fluctuations, and such volatility may help investors to invest in gold as it considers as a safe-haven or hedge against exchange-rate movements (Baur and Lucey 2010; Beckmann et al. 2015). Another strand of literature has examined this association in a single country or using or panel data (Pierdzioch et al., 2016; Iqbal, 2017). The recent strand of literature has examined this study by using advanced econometric techniques and explore the non-linear dynamics of these two commodities (Blacier et al., 2016; Baur 2013).

Thus, the purpose of this study is to examine the gold price and exchange nexus in the context of G7 countries by using the nonparametric causality approach. The selection of countries and technique have some noticeable features. These countries are ranked among the top advanced economies. Out of seven countries, the five countries (United States, Japan, Germany, United Kingdom, France) are ranked among the top 10 economies with the highest national wealth and gross domestic product (GDP) (Central Intelligence Agency [CIA], CIA World Fact Country Ranking, 2017). In addition to this, out of seven economies, five economies (United States, Germany, Italy, France, and Japan) are ranked among the top 10 economies with the highest the largest gold reserves (World Gold Council). The US ranked one with the significant official gold holding of 8,133.5 tonnes, followed by Germany, which holds 3,371.0 tonnes, followed by Italy, which has 2,451.8 tonnes, followed by France, which holds 2436 tonnes, whereas Japan holds 765.2 tonnes.

Consequently, the nonparametric technique is used because of its novel properties (i). This technique is robust to misspecification errors as it identifies the underlying dependence structure between the time series under consideration. This property could prove to be particularly important, especially when we look at high-frequency data because it is well known that commodity market returns in particular and asset prices generally show non-linear dynamics ((Balcilar et al. 2016; 2017). (ii) This technique not only explore causality-in-mean but also test the causality that may exist in the tails of the joint distribution of the variables, which is predominantly essential to explore when the dependent variable has fat-tails (Jeong et al. 2012; Balcilar et al. 2016). (iii) This test also explores the causality-in-variance and thus, examine the high-order dependency. In other words, when causality-in- conditional mean may not exists, there may exist higher-order interdependencies that only become visible when one study the dynamics of the variance of the time-series (Balcilar et al. 2017).

Our study contributes to the existing literature by folds: (i) this paper examines the association between gold prices and exchange rate for G7 countries. (ii) We apply a nonparametric causality approach to explore the dynamics between gold prices and exchange rates. (iii) This study used the most recent data in G7 countries employing quarter frequency data from 1995 to 2017. (iv) Earlier studies focused on the linear relationship between gold prices and exchange rate and limitedly discuss the non-linear dynamics of gold prices and exchange rate. We employ a newly developed methodology, namely, nonparametric quantile causality proposed by Balcilar et al. (2016, 2017). This technique allows us to analyze the causality between gold prices and the exchange rate over their respective conditional distributions. Hence, a better explanation of gold prices and the exchange rate is presented. The results from the nonparametric causality-in-quantiles test concluded that the exchange rate return affects gold prices in China, France, Germany, and the USA. However, the exchange rate return doesn't affect gold prices in Canada, the UK, Japan, and Korea.

(v) We consider the most critical indicators of commodity markets (gold prices and exchange rate), suggesting a useful policy for investors in the markets. The empirical results from the nonparametric causality-in-quantiles test showed that the exchange rate return affects gold prices in four out of G7 countries: China, France, Germany, and the USA. The strength of the causality of the exchange rate return to gold prices is evident from the hump-shaped pattern across quantiles of the examined countries.

The remainder of our study is organized as follows: Section 2 discusses the litertue review, section 3 explains the methodology, section 4 presents the data and section explains the data analysis. Lastly, Section 5 explains the conclusion and policy implications.

Literature review

The literature related to the exchange rate and gold price can be divided into four strands. The first strand explains the hedging or safe heaven property of gold against exchange rates. The second start explains the positive association. The third strand explains the negative association, and the fourth strand explains the no casual association between the gold price and exchange rates.

Gold as a Hedge or Safe Heaven against Exchange Rate

Joy (2011) also used the DCC-GARCH approach and concluded that gold price hedge against the dollar. Iqbal (2017) studied the gold and exchange rate nexus in Pakistan, India, and the US. They reported that gold acts as a safe-haven and hedge currency risk in Pakistan and India. Quershi et al. (2018) examined the nexus between the gold price and exchange rate in the context of Pakistan. The wavelet approach result showed that in the short run, gold acts as a hedge against the exchange rate. Furthermore, the result, as mentioned above, is also confirmed by the continual regression.

The result also suggested that the lead association exists between the gold price and exchange rate; however, the association changes over specific time intervals. Reboredo (2013) examined the gold and US dollar nexus by applying the copula approach. The result shows that gold act as a safe-haven and act as a hedge against the US Dollar rate movements. Ciner et al. (2013) studied the relationship between exchange rate and gold's safe-haven property in the US and the UK. The data of trade-weighted values of the US Dollar and UK Pound have been taken from the year 1990-2010. The result from a dynamic conditional correlation showed that gold could be considered as a safe-haven for exchange rates in both countries.

Positive Association

Dooley et al. (1992) examined the association between the gold price and exchange rate using the monthly data of Japan, USA, France, UK, and Germany currencies comprised of the years 1976-1990. The VAR model result shows that parity between the US dollar and the other currencies explains gold prices changes. Dooley et al. (1995) excluded the data of France and identified that the new results match with the previous study. Sjaastad and Scacciavillani (1996) presented their work on the relationship between US$, euro exchange rate, and gold prices. Their empirical findings report that the euro was under the influence of gold prices in the 1980s, but in the 1990s, the euro gradually replaced by US $ in commodity markets. Tully and Lucy (2007) investigated the macroeconomic shocks of future markets and gold spot using the APGARCH model and found that US$ greatly influence the gold price volatility. Sjaastad (2008) used the data from 1991–2004 and reported that the US dollar-dominated the gold market, followed by the Yen. However, the currencies of gold-producing countries did not create a significant impact on the gold price. Ismail et al. (2009) used multiple linear regression techniques and reported that the USD/Euro exchange rate significantly influences the gold prices. Sari et al. (2010) examined the dollar/euro exchange rate and four precious metals associations. They reported that the exchange rate and commodity returns exhibit a weak long-run equilibrium relationship. They further suggested that investors can attain benefits from the diversification of precious metals in the long-term.

Sujit and Kumar (2011) studied the gold price and the exchange rate relationship using the daily data from 2nd January 1998 to 5th June 2011. The vector autoregressive and cointegration technique shows that the exchange rate is affected by the gold price. Jain and Ghosh (2013) used the cointegration approach and Granger causality test and confirmed the relationship between the gold price and the US dollar- Indian rupee exchange rate. Apergis (2014) also concluded that gold acts as a predictor for the Australian dollar. Yang and Hamori (2014) examined the exchange rate and the gold price nexus by applying the copula approach. Their empirical results were divided into three parts. First, the upper and lower dependence between exchange rate and gold prices was weaker during the financial crisis period. Second, the conditional lower dependencies for the JPY/gold and the GBP/gold are more vulnerable than the conditional upper tail dependences, while the Euro/gold lower tail dependence was unchanged. Last, they report an asymmetric dependence structure between the exchange rate and gold prices. Beckmann (2015) investigated the volatility and causality patterns between exchange rate and gold prices. Their study concluded that gold prices dominate the currency market while increasing after depreciating the local currency (US $). Jain and Biswal (2016) studied the link between the gold price and the Indian exchange rate. The DCC-GARCH approach shows that the gold price has a direct effect on Indian exchange rates. Zhang et al. (2016) studied the causal relationship between the exchange rate and commodity prices. The data comprised the prices of the dominant export commodities, i.e., Gold, WTI crude oil, Copper and Brent crude oil, and four commodity-exporting economies, i.e., Chile, Canada, Norway, and Australia. The result shows that causality from commodity prices to exchange rate is more substantial than vice-versa. Balcilar et al. (2017) studied the gold prices and exchange rate nexus in gold-producing countries. The nonparametric causality-in-quantiles test showed that gold-price fluctuations predict the returns and the volatility of exchange rates in the majority of the examined nations. Bedoui et al. (2018) explored the gold price and US exchange rate nexus in the global financial crisis. They reported that the dependence between the variables is strong during both crisis periods than the normal period. Singh (2018) studied the relationship between the oil, US dollar, gold, and stock market (GODS) in the pre-crisis, crisis, and post-crisis periods. The result shows that the association among the variables is dynamic across the global financial crisis.

Mei-se et al. (2018) examined the continuously time-varying association between the US dollar exchange rate and gold prices. The recursive cointegration test showed significant and strong cointegration among the US dollar exchange rate and gold prices over the period of 1995. Aftab et al. (2019) examined the gold price and exchange rate in three regions across Asia. The result concluded that gold acts as a diversifier against the Asian stock markets except for Thailand, Korea, and Singapore.

Negative Association

Capie et al. (2005) investigated the linkage among gold prices, the JPY, and US$ using the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) method. They concluded that the exchange rate and gold prices are negatively correlated with each other. Pukthuanthong and Roll (2011) used the Vector Autoregressive (VAR) approach and Dynamic Conditional Correlation (DCC) approach to examine the relationship between exchange rate and gold prices. The result concluded a negative relationship exists between the gold price and the exchange rate. Furthermore, the negative relationship between exchange rate and gold prices signifies that the weaker currency in each case was correlated with a higher gold price. Dong et al. (2019) examined the association between the US exchange rate and gold in each sub-period. The result shows that a negative correlation exists between the variables in almost all periods. Moreover, the correlation coefficients have higher values during the global financial crisis period compared to other periods.

No causal Association

Chang et al. (2013) examined the association between the gold prices, oil prices, and exchange rate and reported that all the variables are independent. Seyyedi (2017) studied the gold price, oil price, and exchange rate nexus in India and reported that all the variables are independent. Singhal, Choudary, and Biswal (2019) studied the dynamic relationship between the gold price and exchange rate and reported that gold prices do not impact the exchange rate in the context of Mexico.

Methodology

In this study, the association between gold price return and exchange rate return is analyzed using the newly developed technique nonparametric causality-in-quantiles approach. This approach was given by Balcilar et al. (2016), which combines the framework of Nishiyama et al. (2011) and Jeong et al. (2012). From Nishiyama et al. (2011), it takes the k-th order nonparametric causality framework, and from Jeong et al. (2012), it takes the nonparametric quantile causality framework. This methodology helps find the non-linear causality and has more advantages over the standard causality test (Blacilaer et al., 2017). Moreover, this technique captures the general non-linear dynamic dependencies and is also robust to the extreme values in the data.

In this study, y_t represents the dependent variable, which is gold prices return, whereas X_t represents the independent variable of the model, which is the exchange rate return. We follow the Jeong et al. (2012), which define the quantile-based causality as X_t does not cause y_t in the θ-quantile concerning the lag-vector of $\{y_{t-1},....,y_{t-p}, X_{t-1},....,X_{t-p}\}$ if:

$$Q\theta = y_t \mid y_{t-1},....,y_{t-p}, X_{t-1},....,X_{t-p}) = Q\theta(y_t y_{t-1},...., y_{t-p}) \tag{1}$$

X_t probably cause y_t in the θ-quantile with respect to $\{y_{t-1},....,y_{t-p}, X_{t-1},....,X_{t-p}\}$ if:

$$Q\theta = y_t \mid y_{t-1},....,y_{t-p}, X_{t-1},....,X_{t-p}) \neq Q\theta(y_t y_{t-1},...., y_{t-p}) \tag{2}$$

In Eq (2) $Q\theta = (y_t.)$ represents the θ*–th* quantile of y_t which is dependent on *t*, and the quantiles are limited between 0 or 1, i.e., $0 < \theta < 1$.

To present the causality-in-quantiles test in a compressed manner, the following vectors $y_{t-1} \equiv (y_{t-1},\ldots, y_{t-p}), X_{t-1} \equiv X_{t-1},\ldots, X_{t-p}), Z_t = (X_t, y_t)$ are defined. The conditional distribution is also described, which is $Fy_t \mid Z_{t-1}(y_t \mid Z_{t-1})$, and $Fy_t \mid y_{t-1}(y_t \mid y_{t-1})$, these distributions signify the distribution functions y_t conditioned on vectors Z_{t-1} and y_{t-1}, respectively. The conditional distribution vector $Fy_t \mid Z_{t-1}(y_t \mid Z_{t-1})$ is supposed to be completely continuous in y_t for nearly all Z_{t-1}.

By denoting $Q\theta(Z_{t-1}) \equiv Q\theta(y_t \mid Z_{t-1})$, and $Q\theta(y_{t-1}) \equiv Q\theta(y_t \mid y_{t-1})$, we found $Fy_t \mid Z_{t-1}\{Q\theta(Z_{t-1}) \mid Z_{t-1}\} = \theta$ which holds the probability equal to 1. Thus, based on the equation (1) and (2), the following hypothesis are developed for the causality-in-quantiles test:

$$H_0 : P\{Fy_t \mid Z_{t-1}\{Q\theta(y_{t-1}) \mid Z_{t-1}\} = \theta\} = 1 \tag{3}$$

$$H_1 : P\{Fy_t \mid Z_{t-1}\{Q\theta(y_{t-1}) \mid Z_{t-1}\} = \theta\} < 1 \tag{4}$$

Jeong et al. (2012), in order to better explain the practical implementation of the causality-in-quantiles tests, we used the distance measure represented by, $J = \{\varepsilon_t E(\varepsilon_t \mid Z_{t-1}) F_Z(Z_{t-1})\}$. In this measure, the error term is defined by ε_t, whereas, $F_Z(Z_{t-1})$ shows the marginal density function of Z_{t-1}. The ε_t drive is based on the null hypothesis developed in equation 3, which would be only true if $E[1\{y_t \le Q\theta(y_{t-1}) Z_{t-1}\}] = \theta$ or it can be equal to $1\{y_t \le Q(y_{t-1})\}] = \theta + \varepsilon_t$ where $1\{\cdot\}$ shows the indicator function. Based on the error term, the distance measure given by Jeong et al. (2012) can be defined as:

$$J = E[\{Fy_{t|}z_{t-1}\{Q\theta(y_{t-1}) \mid Z_{t-1}\} - \theta\}^2 F_Z(Z_{t-1})] \tag{5}$$

It is essential to understand that in equation-3) $J \ge 0$ and the equality $J = 0$ holds if and only if the H_0 in equation-5 is true, while $J > 0$ holds under the H_1 in equation-4. In equation-5, the feasible kernel-based sample analog of J has been explained by Jeong et al. (2012) as:

$$\hat{J}_T = \frac{1}{T(T-1)h^{2p}} \sum_{t=p+1}^{T} \sum_{s \ne P+1}^{T} {}_{s \ne t} K\left(\frac{Z_{t-1} - Z_{s-1}}{h}\right) \hat{\varepsilon}_t \hat{\varepsilon}_s \tag{6}$$

In equation-5 $K(\cdot)$ represents the kernel function, h mean the bandwidth, t represents sample size, the lag-order is shown by p and $\hat{\varepsilon}_t$ represent the unknown regression error and can be analyzed by the mentioned below equation:

$$\hat{\varepsilon}_t = 1\{y_t \le Q\hat{\theta}(y_{t-1})\} - \theta \tag{7}$$

Inequation-7, $\hat{Q}\theta(y_{t-1})$ represents the estimate of the θ–*th* conditional quantile of y_t given y_{t-1} Whereas, $\hat{Q}\theta(y_{t-1})$ can be estimated by using the nonparametric kernel method shown in the below equation:

$$\hat{Q}\theta(y_{t-1}) = \hat{F}^{-1}_{yt|yt-1}(\theta y_{t-1}) \tag{8}$$

Where $\hat{F}_{yt|yt-1}(y_t y_{t-1})$ describe the Nadarya-Watson kernel estimator and can be calculated by:

$$\hat{F}_{yt|yt-1}(y_t y_{t-1}) = \frac{\sum_{s=p+1,s\neq t}^{T} L\left(\frac{y_{t-1} - y_{s-1}}{h}\right) 1(y_s \leq y_t)}{\sum_{s=p+1,s\neq t}^{T} L\left(\frac{y_{t-1} - y_{s-1}}{h}\right)} \tag{9}$$

In the above equation, L (·) represents the kernel function, and h shows the bandwidth.

In this study, we want to analyze the causality running from exchange rate return to gold prices return. The causality-in-variance implies volatility transmission, which may exist even there is no causality in the mean (1st moment). By extending the work of Jeong et al. (2012), we establish the causality test for the 2nd moment. To analyze the presence of causality in the highest or second moments involves complications. The procedure for the test needs to be carefully defined because the causality rejection in the m-th moment doesn't mean the non-causality in the k-th moment for $m < k$. So, the Nishiyama et al. (2011) nonparametric Granger quantile causality technique is employed to check the presence of causality in higher-order moments. We begin the procedure by doing it for *yt* by using the following equation:

$$y_t = g(y_{t-1}) + \sigma(X_{t-1})\varepsilon_t \tag{10}$$

Where ε_t represents the white noise process; σ (·), g (·) represents the unknown functions and fulfill the stationary properties of y_t. Although this illustration doesn't allow the linear or non-linear causalities from X_{t-1} to y_t, but can only represent the predictive power of X_{t-1} to y_t^2 when σ (·) is a general non-linear function. Thus, equation-10 displays that the squares X_{t-1} do not necessarily enter into the σ (·) non-linear function. So we formulate equation-10 into equation-3 and equation-4, i.e., in the null and the alternate hypothesis equation, for causality invariance as shown below

$$\mathrm{H}_0 : \mathrm{P}\{\mathrm{F}y_t^2 \mid \mathrm{Z}_{t\text{-}1}\{\mathrm{Q}\theta(y_{t\text{-}1})|Z_{t\text{-}1}\} = \theta\} = 1 \tag{11}$$

$$\mathrm{H}_1 : \mathrm{P}\{\mathrm{F}y_t^2 \mid \mathrm{Z}_{t\text{-}1}\{\mathrm{Q}\theta(y_{t\text{-}1})|Z_{t\text{-}1}\} = \theta\} < 1 \tag{12}$$

To get the feasible test statistic by using equation-10, the y_t in equation-6 to equation-9 are replaced by y_t^2. By incorporating the Joeng et al. (2012) approach, the problem relating causality in the conditional 1st moment (mean) implies causality in the 2nd moment (variance) is overcome, and the causality in the higher moments is interpreted by using the following model:

$$y_t = g(X_{t-1}, y_{t-1}) + \varepsilon_t \tag{13}$$

Thus, the causality-in higher-order quantiles can be defined as:

$$H_0 : P\{Fy_t^{\,k} \mid Z_{t-1}\{Q\theta(y_{t-1}) \mid Z_{t-1}\} = \theta\} = 1 \text{ for } k = 1,2,....,K \tag{14}$$

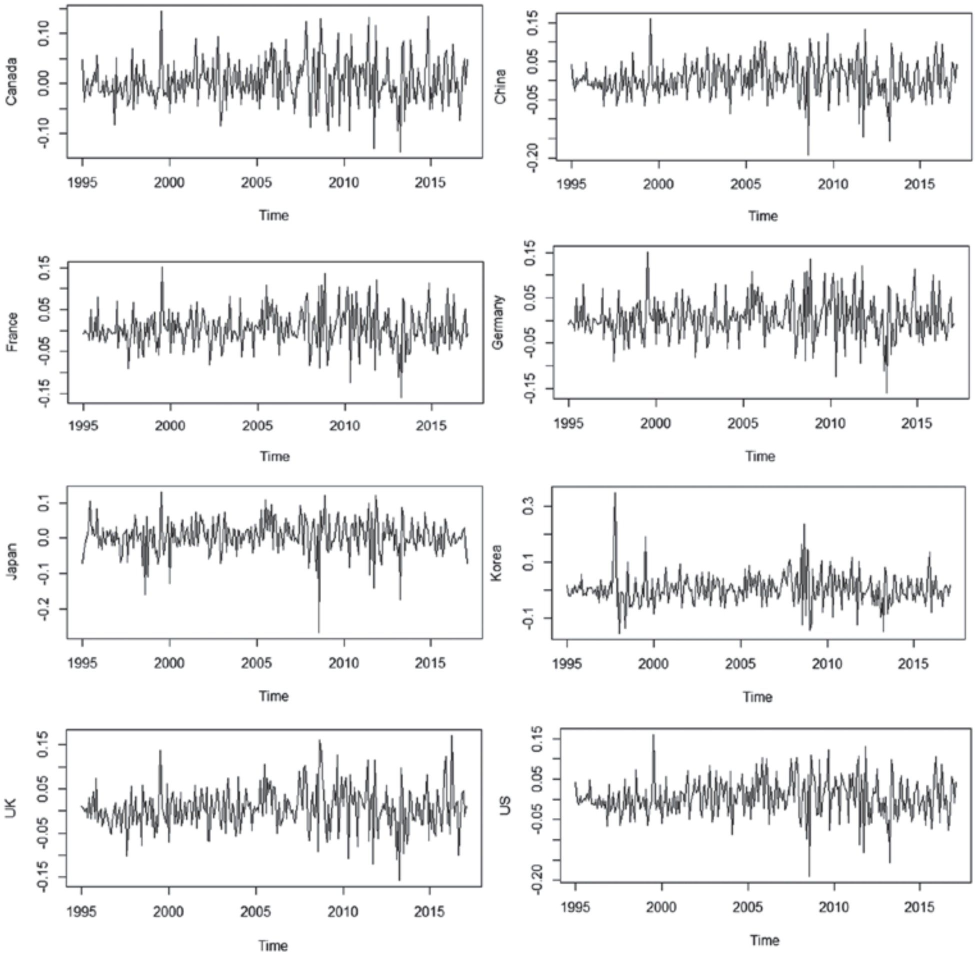
$$H_1 : P\{Fy_t^{\,k} \mid Z_{t-1}\{Q\theta(y_{t-1}) \mid Z_{t-1}\} = \theta\} < 1 \text{ for } k = 1,2,....,K \tag{15}$$

To sum the entire concept, we stated that x_t granger cause y_t in the θ quantile up to k-th moment by employing equation-14 to construct the test statistic of equation-6 for each *k*. However, it is a difficult task to combine the different statistics for each *k* = 1, 2,…, *K* into one since the statistics are jointly correlated (Nishiyama et al., 2011). To overcome this problem, we add the sequential testing technique given by Nishiyama et al. (2011) with a few alterations. At first, we check the nonparametric Granger causality in the 1st moment by taking K=1, and here the rejection of the null hypothesis of non-causality does not mean no-causality in the 2nd moment. In contrast, the rejection in the 1st moment acts as a strong indication of Granger quantile causality-in-variance. So, we run a test by taking K=2 because this allows testing the existence of causality-invariance and the causality-in-variance and mean successively. Thus, the empirical application of testing causality using quantiles involves three essential selections, (i) *p* (lag order), (ii) the *h* (bandwidth), (iii) the choice of kernel type for *K* (·) and *L* (·) in equation-6 to equation-9. We based our *p* to 1 established on the Schwarz Information Criterion (SIC) under as VAR encompassing gold return and the exchange rate return. The SIC considered parsimonious while choosing lags in comparison to other alternative lag-length selections. Moreover, it also overcomes the over-parameterization issues usually linked with different nonparametric methodologies. We used the least-squares cross-validation method to choose *h* (bandwidth), and the Gaussian-type kernels are employed for *K* (·) and *L* (·).

The Data

This study explores the ability of exchange rate return to predict gold prices return, so to empirically analyze the association, the monthly data is collected. The data covers 1995 (January) to 2017 (March), and the time frame is decided based on data availability. The exchange rate data is taken from International Financial Statistics (IFS) managed by International Monetary Funds (IMF), whereas gold prices data are taken from the data stream. The data is converted into natural logarithmic values for both variables, and the first differences of the natural logarithmic values are used. The prime reason for doing this is, stationary data are required for the application of the nonparametric causality-in-quantile test. Figure-1 shows the plots of gold price return and exchange rate returns.

Figure 1: Time series plots of gold prices.



Note: Figure plots the natural logarithm returns of the series.

The country-wise descriptive statistics of gold prices return, and exchange rate return is reported in Table-1. Table-1 reports the mean, standard deviation, minimum value, maximum value, skewness, Kurtosis, and Jarque–Bera test. The lowest mean value of gold prices return was observed in Canada and China, which is 0.006, and the highest mean value is observed in Korea, which is 0.058. The minimum value of gold prices returns observed in Canada, which is -0.136, and the maximum value is observed in Korea, which is 0.058. The lowest mean value of exchange rate return is observed in China, which is -0.018, and the highest mean value is observed in Korea, which is 0.369. The skewness values show that the data is highly skewed, and the kurtosis statistic shows the fat-tailed distribution for all the series. Both skewness and Kurtosis provide evidence that the data is not normally distributed, which is also confirmed from the Jarque-Bera statistic. The result of JB statistics shows the strong rejection of the null hypothesis of normality at 1 % and 5% significance. It thus provides the basis to use the causality-in-quantile test instead of the standard linear Granger causality test.

Table 1: Descriptive Statistics for returns series

Country	***n***	**Mean**	**S.D.**	**Min**	**Max**	**Skewness**	**Kurtosis**	**JB.**
Panel A: Exchange rate returns								
Canada	266	0.000	0.018	-0.060	0.113	0.645	8.487	352.145***
China	266	-0.001	0.004	-0.018	0.021	0.807	9.179	452.024***
France	266	0.001	0.023	-0.062	0.078	-0.035	3.168	30.368***
Germany	266	0.001	0.024	-0.065	0.078	-0.088	3.227	93.915***
Japan	266	0.000	0.027	-0.105	0.081	-0.367	4.196	21.826***
Korea	266	0.001	0.035	-0.089	0.369	4.910	50.686	26272.31***
United Kingdom	266	0.001	0.021	-0.059	0.097	0.582	5.394	78.559***
United States	266	-0.001	0.021	-0.095	0.060	-0.574	5.322	74.369***
Panel B: Gold price returns								
Canada	266	0.004	0.145	-0.136	0.045	0.251	3.720	8.536**
China	266	0.004	0.160	-0.192	0.048	-0.141	4.373	21.776***
France	266	0.005	0.152	-0.160	0.046	0.174	3.797	8.386**
Germany	266	0.005	0.152	-0.160	0.046	0.174	3.797	8.386**
Japan	266	0.005	0.131	-0.267	0.049	-0.922	6.962	211.642***
Korea	266	0.006	0.349	-0.153	0.058	1.077	8.420	376.939***
United Kingdom	266	0.005	0.171	-0.157	0.048	0.216	3.987	12.864***
United States	266	0.005	0.160	-0.191	0.048	-0.117	4.259	18.177***

Note: The asterisks ***, ** and * represent significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' Estimations

Empirical Results and their Discussion

As discussed earlier, the prime objective of the study is to examine the ability of exchange rate return to predict gold prices, so for the sake of comparison and completeness, at first, we apply the standard linear Granger causality test based on a linear VAR (vector autoregression) model with a lag value of 1. The result is reported in Table-2 and shows that all the countries show the F-statistic value insignificant, which implies accepting the null hypothesis, i.e., exchange rate return does not Granger cause gold prices return. Hence, we can conclude that in a linear VAR framework, even at the significance level greater than 10%, no evidence is found which predict causality from exchange rate to gold prices.

Table 2: Linear Granger causality test

Country	**F-stats: Exchange Rate does nor Granger cause Gold Prices**	**Lag Order**
Canada	2.858	1
China	0.008	1
France	1.879	1
Germany	1.706	1
Japan	2.670	1
Korea	1.169	1
United Kingdom	1.452	1
United States	0.313	1

Note: The table reports the F-statistic for the no Granger causality restrictions imposed on a linear model under the null hypotheses H0. All hypotheses indicate acceptance of the null hypothesis of no Granger causality at 5% level of confidence interval.

Source: Authors' Estimations

Before applying the nonparametric quantile-in-causality approach, we examine the nonlinearity in the association of gold prices return, and exchange rate returns. To statistically investigate this, we used the BDS test, given by Brock et al. (1996), and applied it on the residuals of gold prices equation of the VAR(1) model comprised of the exchange rate and gold prices. The result is reported in Table-3, and it can be seen from the result that the null hypothesis of *iid* residuals is rejected at the 1 % significance level on various dimensions. It provides strong evidence that the non-linear association exists between the examined variables.

Table 3: BDS test for nonlinearity

Country	***m*=2**	***m*=3**	***m*=4**	***m*=5**	***m*=6**
Exchange rate equation residuals					
Canada	29.550	30.912	32.645	35.425	39.340
China	63.670	68.311	73.413	80.513	90.069
France	58.223	62.081	66.837	73.880	83.569
Germany	59.195	63.221	68.228	75.589	85.684
Japan	54.081	57.727	62.062	68.590	77.630
Korea	75.047	81.601	89.516	100.704	115.662
United Kingdom	77.716	83.896	91.576	102.376	116.984
United States	77.941	84.201	91.897	102.738	117.356

Country	*m*=2	*m*=3	*m*=4	*m*=5	*m*=6
Gold prices equation residuals					
Canada	40.047	41.897	44.307	48.031	53.234
China	52.601	56.205	60.085	65.557	72.943
France	46.966	49.582	52.922	57.902	64.757
Germany	48.125	50.907	54.591	59.934	67.260
Japan	46.466	48.876	51.750	56.040	62.096
Korea	43.955	46.638	49.933	54.594	60.834
United Kingdom	34.171	35.637	37.592	40.782	45.176
United States	32.088	33.544	35.446	38.519	42.778

Note: The entries indicate the z-statistics BDS test based on the residuals of exchange rate series and gold price series. *m* denotes the embedding dimension of the BDS test. All hypothesis are rejected at 1% of significance level.

Source: Authors' Estimations

We also applied the parameter (in) stability test proposed by Andrews (1993) and Andrews and Ploberger (1994). We used the VAR(1) model comprised of exchange rate return and gold prices return, and the result related to the test are reported in Table-4. The result shows that the null hypothesis of stability is rejected at the 1 % significance level by all three tests, i.e., Max-F, Exp-F, and Ave-F. The result is also verified by the test of multiple structural breaks given by Bai and Perron (2003), which deducted the multiple breaks in the VAR (1) model.

Table 4: Parameter stability testing

Country	Maximum LR *F* Statistics		Exp LR *F* Statistics		Ave LR *F* Statistics	
	Stats.	Prob.	Stats.	Prob.	Stats.	Prob.
Canada	772.948	0.000	382.485	0.000	275.114	0.000
China	134.949	0.000	63.645	0.000	77.471	0.000
France	835.707	0.000	414.133	0.000	513.490	0.000
Germany	844.407	0.000	418.543	0.000	524.554	0.000
Japan	726.020	0.000	359.091	0.000	503.508	0.000
Korea	995.207	0.000	493.832	0.000	793.580	0.000
United Kingdom	1568.921	0.000	780.499	0.000	1126.746	0.000
United States	1527.770	0.000	759.979	0.000	1107.663	0.000

Note: Parameter stability test by Andrews (1993) and Andrews and Ploberger (1994) with the null hypothesis of parameter stability.

Source: Authors' Estimations

Thus, the results of BDS and parameter (in) stability confirm structural breaks and the non-linear association between the variables, which implies that the framework based on a linear Granger causality test are likely to suffer from misspecification. To overcome this issue, we employed the causality-in-quantiles test, which is considered robust against outliers, jumps, non-linear dependence, and structural breaks.

To test the non-linear Granger causality between gold prices and the exchange rate returns, we employed the non-linear Granger causality test given by Diks and Panchenko (2006). Table-5 presents the result related to the non-linear Granger causality test. To be robust against the lag order used in the test, the non-linear Granger causality test is performed for embedding dimension m =2, 3, 4. From the result reported in Table-5, it is concluded that no null hypothesis of non-linear Granger causality running from exchange rate returns to gold prices return rejected for any of the under-examined countries. On the complete sample, no evidence of the nonexistence of non-linear Granger causality is found, so we applied the nonparametric causality-in-quantiles tests. This approach not only considers the center of the distribution but also consider distribution at all quantiles.

Table 5: Diks and Panchenko (2006) Nonlinear Granger causality test

Country	***m*=2**		***m*=3**		***m*=4**	
	Stats.	**p-value**	**Stats.**	**p-value**	**Stats.**	**p-value**
Canada	0.675	0.250	0.719	0.236	0.774	0.219
China	1.504	0.066	1.431	0.076	1.422	0.078
France	1.430	0.076	1.347	0.089	1.494	0.067
Germany	1.272	0.102	1.242	0.107	1.306	0.096
Japan	0.944	0.173	0.248	0.402	0.427	0.335
Korea	1.224	0.110	1.208	0.114	0.588	0.278
United Kingdom	1.126	0.130	1.065	0.144	1.341	0.090
United States	1.484	0.069	1.322	0.093	1.247	0.106

Note: *m* denotes the embedding dimension.

Source: Authors' Estimations

Figure-2 represents the result of the quantile causality in mean and variance from the exchange rate to the gold prices. In Figure-2, the quantiles are represented on the horizontal axis, whereas the nonparametric causality test statistics are shown on the vertical axis. The 5% has a critical value of 1.96, and 10% has a critical value of 1.65. The thin horizontal lines represent the 5% critical value; the thin two-dashed lines represent the 10% critical value. From the results depicted in Figure-2, it is seen that a clear difference exists between the quantile causality in mean and variance analysis. Furthermore, the result significantly varies from one country to another.

In Canada, when the result of the quantile causality test in the mean is analyzed, the null hypothesis that exchange rate returns do not Granger cause gold prices are accepted at a critical value of 1.65 (10%) and 1.96 (5%). The quantile causality test invariance also shows the acceptance of the null hypothesis that exchange rate return does not Granger cause gold prices in all the quantiles at both critical values. The result inline with the study of Balcilar et al. (2017), who also reported that exchange rate return does not cause gold returns in the context of Canada. The plausible reason behind this association is Canadian dollar is associated with the oil commodity instead of gold. Canada is among the countries that are significant exporters of oil, and any change in oil prices badly affects the currency.

In China, when the result of the quantile causality test in the mean is analyzed, the null hypothesis that exchange rate does not Granger cause gold prices are accepted at a critical value of 1.65 (10%) at the majority of the quantiles except for the quantiles ranges from 0.25-0.5. At the critical value of 1.96 (5%), most of the quantile shows the rejection of the null hypothesis except the quantile within the range of 0.1-0.3; 0.75-0.9, which shows the null hypothesis's acceptance. The quantile causality test invariance shows the null hypothesis that the exchange rate does not Granger cause gold prices are rejected at a critical value of 1.65 (10%) at the majority of the quantiles except for the quantiles ranges from 0.1-0.25; 0.7-0.9. At the critical value of 1.96 (5%), most of the quantile shows the rejection of the null hypothesis except for the quantile within the range of 0.1-0.3; 0.75-0.9, which shows the acceptance of the null hypothesis. The result inline with the study of Raza et al. (2016), who also reported that the exchange rate does affect gold prices.

In the case of France, the quantile causality test in mean at critical value 1.65 (10%) shows the acceptance of the null hypothesis except for the quantiles 0.45-0.65, which shows the rejection of the null hypothesis. The critical value of 1.96 (5%) also shows the null hypothesis's acceptance at the majority of the quantiles except for the quantiles from the range of 0.35-0.65, which shows the rejection. The quantile causality test invariance rejects the null hypothesis at the (10%) critical level. At 1.96 (5%) critical, it shows the rejection of the null hypothesis at the majority of the quantile except for quantiles from 0.85-0.9. The result is in line with the study of Dooley et al. (1992). The study suggested that the exchange rate causes changes in gold prices.

Germany shows that at the critical value of 1.65 (10%), the quantile causality test in mean shows the null hypothesis's acceptance except for the quantiles over 0.4-0.65. Whereas at the critical value of 1.96 (5%), the null hypothesis is accepted at most of the quantiles except for the quantiles from the range of 0.35-0.65, which shows the rejection. The quantile causality test invariance shows the null hypothesis's acceptance over all the quantiles at 1.65 (10%)critical level. At 1.96 (5%) critical, it shows the null hypothesis's acceptance at the majority of the quantile except for the quantile 0.4 -0.45. The result is in line with the study of Dooley et al. (1992). The study suggested that the exchange rate causes a change in gold prices.

The reasons behind why the exchange rate affects the gold prices in China, France, and Germany is explained by the level of gold import or export by these countries.

China, Germany, and the Euro countries are among gold exporters countries, and the currency of these countries is tied up with its exports and imports. When a country's exports are less than its import, the value of its currency will decline. Whereas, when a country is a net exporter, the value of its currency will increase. Therefore, these countries experience strength in their currency when gold prices increase, increasing the value of their total exports.

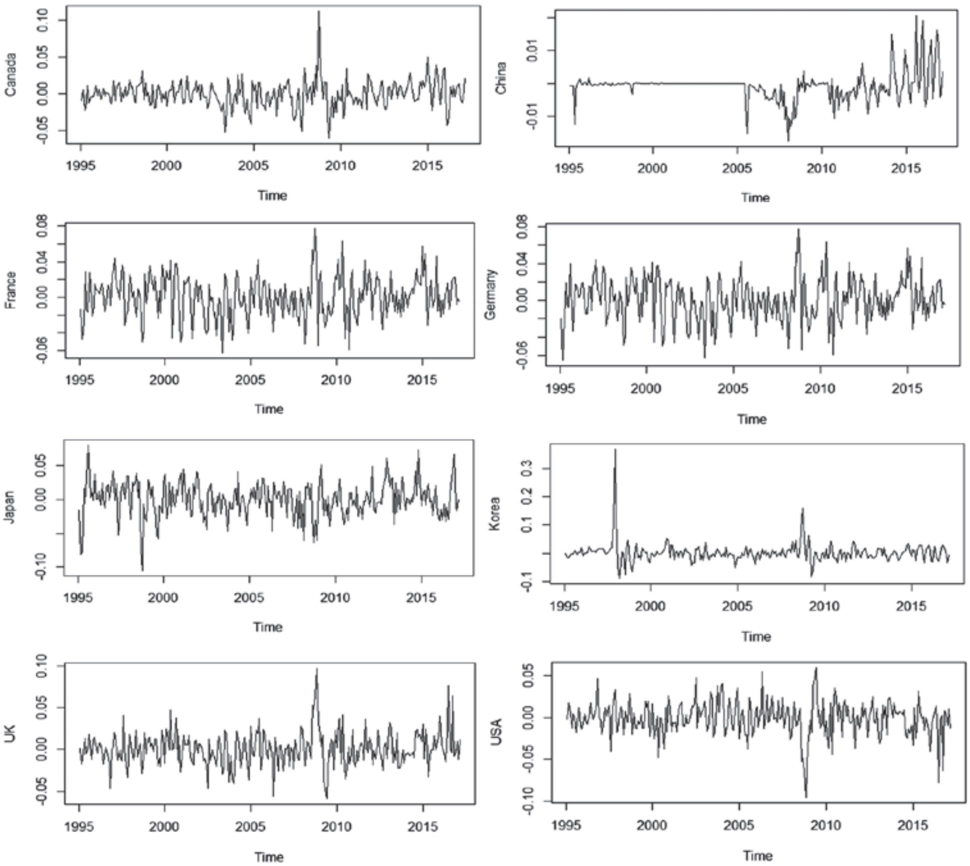
Japan, Korea, and the UK show the same results. The quantile causality test in mean and causality test invariance shows the null hypothesis's acceptance over the quantiles at the critical value of 1.65 (10%) and 1.96 (5%). The result is in line with the study of Wang and Lee (2010) for Japan, Ang and Weber (2017), and Aftab et al. (2019) for Korea, and Sari et al. (2010) for the UK. The plausible reason behind this association is these currencies are considered as flat money and are the most important alternatives to the US dollar. That is why these currencies and gold are considered safe-haven. The current monetary system of these countries is based on fiat currencies; therefore, the currencies like the Yen and the dollar both gain or lose ground against gold.

In the US's case, at the critical values of 1.65 (10%), the quantile causality test in mean shows the acceptance of the null hypothesis at all the quantiles. The quantile causality test invariance shows the rejection of the null hypothesis at most quantiles except for the quantiles 0.3-0.55, which shows rejection. Whereas, at the critical values of 1.96 (5%), the quantile causality test in mean and variance shows the rejection of the null hypothesis at all the quantiles. The result is in line with the study of Dooley et al. (1992) and Joy (2011). They concluded that the US dollar causes a change in gold prices. The plausible reasons behind this association are explained by Sujit and Rajesh (2011). They stated that that the prices of gold are usually dominated in US dollars, implying that the fluctuations influence the experience gained from the selling or buying of gold in the US dollars exchange rate.

Thus, it is concluded that the exchange rate return causes gold prices to return in four countries and can act as a strong predictor of the gold prices. However, no such granger relationship is identified by the linear model, and the linear model gave the misleading result due to the presence of nonlinearity between the variables. The results from the nonparametric causality-in-quantiles test concluded that the exchange rate return affects gold prices in the countries, i.e., China, France, Germany, and the USA.

The strength of the causality from exchange rate return to gold prices is evident from the hump-shaped pattern across quantiles depicted in Figure-2. This causality pattern is a new finding, and it also explains the benefit of using the nonparametric causality-in quantiles tests. As this technique gives results at different quantiles so the researchers who only examines the median of the conditional distribution of gold prices will find the strong evidence predictive power of exchange rate returns to gold prices, but will not be able to find that this relationship gets weak when the quantiles far away from the median are measured. Figure-2 also shows that the hump-shaped curves are asymmetric, and the non-causality is weaker at the right tails.

Figure 2: Time series plots of exchange rate.



Note: Figure plots the natural logarithm returns of the series

The reason behind the causal association between the two variables is due to numerous reasons. Gold prices and exchange rates are mainly concerned by the investors due to their portfolio diversification and investment patterns. It is generally accepted that these commodities (gold and exchange rate) work closely, and their vulnerability is linked with risk and return opportunities. Thus, the mutual role and influence between gold and forex markets may predict future investment in commodity markets. On the other side, the price volatility of the currency market and the gold market is influenced by some external factors, such as war, unrest situation, and political instability. These events have a more significant impact on forex rates and gold prices. Theoretically, gold prices are dominated by exchange rate markets, which implies that the exchange rate fluctuations have a significant impact on gold prices. The exchange rate leads to gold prices in several ways. First, the fluctuations in the exchange rate represent market confidence in currency assets. It highlights that investors with currency-dominated assets will earn a profit. Simultaneously, a decline in the exchange rate reports a loss of confidence in currency assets in favor of gold purchase to increase and preserve the profit. Second, the channel through which the exchange rate affects gold prices is when the dollar price decreases in exchange rate markets. The exchange rate of other currencies like the Yen, euro rose, and gold prices in the domestic gold market are relatively low. Hence, the investors are attracted due to cheap gold prices in yen and euro-dominated markets.

Conclusion and Policy Implications

This study examined the relationship between exchange rate return and gold price return association in G7 countries. To accomplish this, the monthly data comprised of the years 1995 (January) -2017 (March) has been used. In doing so, the standard linear Granger causality test is applied, which shows that no causal association exists between exchange rate returns and gold prices. Then, the nonlinearity tests are also applied, which shows that the association between the examined variables is non-linear, and the application of linear test may give an unreliable result. To overcome this issue, the nonparametric causality-in-quantiles test given by Balcilar et al. (2016) is applied. This approach allows examining the quantile causality-in-mean and variance. The result of the nonparametric causality-in-quantiles shows the rejection of the null hypothesis, which implies the exchange rate return causes gold prices in four out of six countries, especially at the low tails.

The empirical findings give useful implications for monetary policymakers, gold exporter's international portfolio managers, and hedge fund managers. For instance, our results will help investors in risk management, portfolio diversification, and global asset allocation. Our findings are beneficial against inflation, particularly in super inflation time. Lastly, our findings also extend support to export and import-intensive countries in their policy-making because gold prices directly affect them.

The portfolio managers should also take a closer look regarding exchange rate policies as it affects the commodities market of all the leading economies. In addition to this, they should include apart from gold other commodities into their investment portfolios as they will act as a hedge at the time of financial crisis periods. Apart from hedging, the diversified portfolio will help the portfolio managers protect their losses from equities, especially during financial turbulence.

From the investor point of view, the investors should be more cautious about exchange rates as any fluctuations in it will affect the gold prices and vice versa. The investors should also deeply analyze the gold price and exchange rate linkages and invest in diversified portfolios. They should make efficient portfolios by also investing in other commodities like silver, Platinum because it will diversify risk and help in earning risk-adjusted returns. Furthermore, the stock market regulators and central banks should also control the exchange rate movements and take effective measures during the exchange rate crisis periods.

This study has some limitations pertaining to the sample period and size. Future studies can extend this research by analyzing this association in a single economy or doing comparative studies. The said association can also be explored by using other econometrics techniques such as PSTR. In addition to this, this study can be extended by analyzing inflation uncertainty and gold price linkages.

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