Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Do currency exchange rates impact gold prices? New evidence from the ongoing COVID-19 period

Tauhidul Islam Tanin a, Ashutosh Sarker b,* , Robert Brooks c

a Department of Finance, School of Business, Monash University, Australia
b Department of Economics, Faculty of Arts, University of Alberta, Edmonton, Canada
c Department of Econometrics and Business Statistics, Monash University, Melbourne, Victoria, Australia

ARTICLE INFO

JEL codes:
C58
E44
Q02
F33
F37
G23

Keywords:
Exchange rates
Gold prices
COVID-19 pandemic
Uncertainty
Nonlinear ARDL (NARDL)

ABSTRACT

We apply the nonlinear autoregressive distributed lag method to examine the relationships between seven leading currency exchange rates and gold prices using daily data from January 2017 to April 2021. The results reveal that in the short term, while negative United States dollar (USD) to United Kingdom pound, negative USD to Canadian dollar, negative USD to Japanese yen, negative USD to Danish krone, and positive USD to euro exchange rates increase gold prices, a lagged positive USD to euro and lagged positive USD to Danish krone exchange rates decrease gold prices. A test of the pre-pandemic normal period reveals that the uneven and unpredictable impacts of six exchange rates on gold prices are particularly due to COVID-19. We find efficiency in the gold market, in line with the market efficiency hypothesis and random walk theory. Our findings indicate that gold acts as a safe-haven asset for investors during COVID-19.

1. Introduction

The COVID-19 pandemic is likely to continue having substantial economic, social and consequences on financial markets and institutions (Corbet, Larkin, & Lucey, 2020; Goodell, 2020). Gold allows investors to diversify their portfolios to minimize macroeconomic and financial risks (Agyei-Ampomah, Gounopoulos, & Mazouz, 2014; Baur & Lucey, 2010; Baur & McDermott, 2010; Beckmann, Berger, & Czudaj, 2015, 2019; Bilgin, Gozgor, Lau, & Sheng, 2018; Bouoiyour, Selmi, & Wohar, 2018; Gürgün & Ünalmış, 2014; Reboredo, 2013). As such, in both stressed and unstressed economic conditions, gold is seen as a safe asset (Beckmann et al., 2019; Harris & Shen, 2017; Ji, Zhang, & Zhao, 2020; Mensi, Hammoudeh, Al-Jarrah, Sensoy, & Kang, 2017), spurring investors to buy gold as a hedge against exchange rate volatility (Singhal, Choudhary, & Biswal, 2019).

Over the past two decades, literature and research have reflected a significant interest in investment in gold (O’Connor, Lucey, Batten, & Baur, 2015). Investors prefer to invest in gold when the economy underperforms (Jain & Biswal, 2016) and during periods of financial uncertainty (Bouri, Jain, Biswal, & Roubaud, 2017). Following the global financial crisis (GFC), gold has become an immensely popular substitute hedge tool in portfolio diversification (Kirkulak Uludag & Lkhamazhapov, 2014).

A series of studies (Jain & Biswal, 2016; Pukthuanthong & Roll, 2011; Singhal et al., 2019; Sjaastad & Scacciavillani, 1996) have identified the relationship between exchange rates and the volatility of gold prices, suggesting that changes in exchange rates contribute to gold prices’ volatility during normal times. Pukthuanthong and Roll (2011), in particular, have indicated that the United States dollar (USD) exchange rate generally relates negatively with gold prices in USD, meaning that when the USD depreciates in light of appreciations in other currencies, gold prices in USD increase. This suggests a link between appreciations in other currencies and gold prices in USD. Studying the period spanning January 2, 1971 to December 10, 2009, Pukthuanthong and Roll (2011), in particular, have indicated that the United States dollar (USD) exchange rate generally relates negatively with gold prices in USD, meaning that when the USD depreciates in light of appreciations in other currencies, gold prices in USD increase. This suggests a link between appreciations in other currencies and gold prices in USD. Studying the period spanning January 2, 1971 to December 10, 2009, Pukthuanthong and Roll (2011) empirically demonstrate that fluctuations in USD, European Union euro, United Kingdom pound, and Japanese yen exchange rates affect gold prices. The investigation, however, treats the span of time as a single sitting, not differentiating crisis periods from normal...
periods and consequently, does not explain whether—and, if so, how—the relationship of exchange rates and gold prices differs in crisis periods.

Studies (Baur & McDermott, 2010; Nguyen, Bedoui, Majdoub, Guesmi, & Chevallier, 2020; Yang & Hamori, 2014) have also pointed out that historical financial crises impacted the relationship in terms of gold’s role as a safe-haven asset to protect against the risk of exchange rate depreciation. Morales-Zumaquero and Sosvilla-Rivero (2014) have investigated exchange rate volatility in 80 countries ranging from 1970 to 2011 and revealed that GFCs cause structural breaks in exchange rate volatility. Furthermore, these crises required central banks to take macroeconomic measures through unconventional monetary policy, such as pushing the interest rate to zero bound and using quantitative easing to stabilize the exchange rates–gold prices relationship (Baur & McDermott, 2010; Nguyen et al., 2020; Yang & Hamori, 2014).

The COVID-19-induced financial crisis is more global and perilous in scale than other historical financial crises, and the COVID-19 crisis has substantially affected the exchange market (Shehzad, Xiaoxing, & Kazouz, 2020). An overview of the ongoing COVID-19 crisis highlights that this outbreak has brought intense and widespread uncertainty to the financial markets, unprecedented even by the GFC (Baker, Bloom, Davis, & Terry, 2020; Goodell, 2020). Recent studies (Izetzki, Reinhart, & Rogoff, 2020; Yilmazkuday, 2021) have indicated that many advanced and emerging economies have adopted unconventional macroeconomic measures in response to the COVID-19’s impact on the exchange rate, promoting zero-bound interest rates to prevent disruption in the long-term downward trend in exchange rate volatility.

All the above considerations have motivated us to perform this study that examines the relationship between exchange rates and gold prices. The study question is: Have exchange rates impacted gold prices during the ongoing COVID-19 crisis, and if so, how? In analyzing the nexus between exchange rates and gold prices during and prior to the crisis, this study addresses a topic of immense interest to scholars, policymakers, and investors.

As a research method, this study uses the nonlinear autoregressive distributed lag (NARDL) approach to reveal whether gold prices are susceptible to fluctuating exchange rates during the ongoing COVID-19 pandemic and whether changes in exchange rates can predict future gold prices. The results suggest that the exchange rates–gold prices nexus is dynamic and nonlinear but not necessarily asymmetric. Exchange rates have had weak predictive power over gold prices during the ongoing COVID-19 period, a trend that is likely to continue at least until the end of the pandemic. Our study follows a suggestion by Harris and Shen (2017) that a price index free of global exchange rates would safeguard gold from changes in such rates. He, O’Connor, and Thijssen (2018) have further argued that the relationship between gold prices and other assets is constant and that gold is invariably a hedge rather than a safe haven. In examining the relationship between exchange rates and gold prices, however, our study contrasts this view, as we contend that gold will continue to serve as a safe haven. This research is expected to provide new insights into gold as an investment instrument and shed light on how the period following COVID-19 may also contribute to finance literature.

This study brings six-fold contributions to the literature. First, it demonstrates the asymmetric, dynamic, and nonlinear impacts of exchange rates on gold prices in the short term with no impact in the long term. The novelty of this study is the first to explore the effects of prevailing exchange rates on gold prices during the ongoing COVID-19 pandemic. Third, to some extent, this study suggests that leading exchange rates have unpredictably impacted gold prices on occasion during COVID-19. Fourth, the results reveal that exchange rates do not contribute evenly to gold prices. Fifth, to some degree, this study endorses the findings of Bredin, Conlon, and Poti (2015), who suggest that gold can serve as a hedging tool for 1 year. Sixth, we confirm that the recent uneven effects of exchange rates on gold prices are due to the COVID-19 crisis.

2. Data and research methods

2.1. Data

This study uses daily time-series data from multiple sources, outlined in Table 1. The data cover a period from January 1, 2020 to April 19, 2021. Furthermore, we have analyzed the data for a normal period preceding the COVID-19 crisis, from January 1, 2017 to December 31, 2019, during which no crisis or structural break occurred. To control seasonality effects and gain a better understanding of the dynamics, we group the obtained data into 5-day-week clusters and estimate accordingly. We take seven exchange rates as independent variables. These are one United States dollar (USD) to one United Kingdom pound (USD → GBP), one USD to one euro (USD → EUR), one USD to one Canadian dollar (USD → CAD), one USD to one hundred Japanese yen (USD → JPY),1 one USD to one Swiss franc (USD → CHF), one USD to one Norwegian krone (USD → NOK), and one USD to one Danish kroner (USD → DKK).

The rationale in selecting these leading exchange rates is that they are commonly used and thus can provide a rich understanding of the relationships between the exchange rates and gold prices. For example, Goldman (2000) uses USD → GBP; Pukhtuhampong and Roll (2011), USD → EUR, USD → GBP, and USD → JPY; Bedoui, Braeik, Goutte, and

| Table 1 Variables. |
|---------------------|
| Variables | Definitions | Notations | Primary source | Data source |
| Gold Prices | Prices of Gold Bullion, London Bullion Market in United States Dollar (USD), Per Metric Ton Ounce | GLDP | ICE Benchmark Administration | Refinitiv Eikon |
| Independent variable(s): | | | | |
| United States Dollar to British Pound Exchange Rate | USD to GBP - Exchange Rate | GBP | Bank of England (BOE) Spot Rates |
| United States Dollar to Euro Exchange Rate | USD to EUR - Exchange Rate | EUR | European Central Bank (ECB) |
| United States Dollar to Canadian Dollar Exchange Rate | USD to Canadian $ - Exchange Rate | CAD | Refinitiv (GTIS - FTID/TR) |
| United States Dollar to 100 Japanese Yen Exchange Rate | USD to 100 Japanese Yen - Exchange Rate | JPY | Refinitiv (GTIS - FTID/TR) |
| United States Dollar to Swiss Franc Exchange Rate | USD to Swiss Franc - Exchange Rate | CHF | Refinitiv (GTIS - FTID/TR) |
| United States Dollar to Norwegian Krone Exchange Rate | USD to Norwegian Krone - Exchange Rate | NOK | Refinitiv (GTIS - FTID/TR) |
| United States Dollar to Danish Krone Exchange Rate | USD to Danish Krone - Exchange Rate | DKK | Refinitiv (GTIS - FTID/TR) |

1 For the exchange rate conversion, we use one USD to one hundred JPY. The conversions for the six other currencies use one USD to one unit of currency. The difference in conversion has not affected the outcome of the analysis.
Both gold prices ($y$) and exchange rates ($x$) are transformed into their natural logarithmic forms. Fig. 1 presents gold prices and the aforementioned seven exchange rates during the ongoing COVID-19 period. During the pandemic, gold prices (Fig. 1) have jumped from USD 1500 to over USD 2000, and from August 2020, the prices came down to float between USD 1950 and 1800 until the beginning of the third week of April 2021. A sharp decline also occurred between March 1 and April 1, 2020, when tension because of COVID-19 reached a high point. Fluctuations in all seven exchange rates, however, were intense. Similarly to gold prices, we indirectly impose long-term symmetry restrictions $\theta^+=\theta$, which can be simplified as:

$$\Delta y_t = \rho \Delta y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{q-1} \gamma_j' \Delta x_{t-j-1} + \epsilon_t. \quad (5)$$

Short-term symmetry constraints can take two forms: (i) $\gamma_j^+=\gamma_j^-$ for all $i=0,\ldots,q-1$, or (ii) $\sum_{i=0}^{q-1} \gamma_j = \sum_{i=0}^{q-1} \gamma_j^-$. When allowing for such restrictions in the existence of a long-term asymmetric relationship, we obtain:

$$\Delta y_t = \rho \Delta y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{q-1} \gamma_j \Delta x_{t-j-1} + \epsilon_t. \quad (6)$$

We should restrict the insignificant lags of the first-differenced terms in order to formulate the final/restricted NARDL model according to the principles of the NARDL method. Finally, the most constrained model is attained when assuming nonlinearity in the long-term relationship, as well as short-term asymmetric adjustments (Shin et al., 2014):

$$\Delta y_t = \rho \Delta y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{q-1} \gamma_j \Delta x_{t-j-1} + \epsilon_t. \quad (7)$$

We then visually represent the asymmetric, cumulative, and dynamic multiplier effects of a change in $x_{t-1}^+$ and $x_{t-1}^-$ graphically reveal the relationship between asymmetric gold price ($y_t$) and exchange rates ($x_t$). The cumulative dynamic multiplier effects of $x_{t-1}^+$ and $x_{t-1}^-$ on $y_t$ is as follows:

$$m_{i}^+ \equiv \sum_{j=0}^{\lambda} \frac{\partial y_t}{\partial x_{t-j}^+} = \sum_{j=0}^{\lambda} \lambda_{i+}, \quad m_{i}^- \equiv \sum_{j=0}^{\lambda} \frac{\partial y_t}{\partial x_{t-j}^-} = \sum_{j=0}^{\lambda} \lambda_{i-}, \quad h = 0,1,2,\ldots \quad (8)$$

$h \to \infty$, $m_{i}^+ \to \beta^+$ and $m_{i}^- \to \beta^-$,

where $\beta^+ = -\theta^+/\rho$ and $\beta^- = -\theta^-/\rho$ are the asymmetric long-term coefficients, $p$, $q$ is the lag order, and $h$ denotes the horizon. One of the advantages of the NARDL method is that it automatically chooses the appropriate lag order for estimation. Because of its built-in programming mechanism, the method automatically selected a lag order of three.

For estimation purposes, we applied four steps. First, we conducted a unit root test to confirm our variables are I(1). Second, although the regular OLS was the first point of estimation, we followed a general-to-specific procedure (Sukmana & Ibrahim, 2017) to limit insignificant lags from our model and get a final specification (Table 4). Third, cointegration and asymmetry tests were conducted to determine whether a long-term equilibrium and asymmetric relationship exist between gold and exchange rates. This is done by analyzing $w_{j}\text{LOO}$ (Shin et al., 2014) and $t_{\text{RDM}}$ (Banerjee, Dolado, & Mestre, 1998) statistics. Finally, we visualized the cumulative and dynamic multiplier effects of a 1% change in $\Delta x_{t-1}^+$ and $\Delta x_{t-1}^-$ graphically determine the asymmetric relationship between $x$ and $y$ (Shin et al., 2014).

3. Results and discussion

3.1. Unit root test

Both the augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests (Table 2) suggest that all variables are stationary in their first differenced forms, indicating that we can empirically examine exchange rate and gold price dynamics.

3.2. Asymmetry and cointegration relationships

The bound tests for cointegration and asymmetry are presented in Table 3. The $t_{\text{RDM}}$ confirms that exchange rates and gold prices are not cointegrated at the 5% level, denoting the unlikeliness of long-term equilibrium between them, yet the empirical evidence may suggest otherwise. Nevertheless, we expect at least a short-term nonlinear...
Fig. 1. Exchange rates and gold prices during the ongoing COVID-19 period. (i) GLDP. (ii) USD → GBP, (iii) USD → EUR, (iv) USD → CAD, (v) USD → JPY, (vi) USD → CHF, (vii) USD → NOK, (viii) USD → DKK. Notes: GLDP is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.
USD to one Norwegian krone, and euro, this result. An additional explanation is that financial markets generally have a notable bond with gold prices. However, lagged (1- and 2-week-throughout the 1980s (Sjaastad, 1996). Can we assume that COVID-19 has hit almost all financial markets, and the Canadian, Japanese, and Danish markets are no exception. The latter result, however, could be explained by the adjusting nature of the financial markets, as mentioned. Our later tests of the normal period preceding COVID-19 may support these explanations. We find no evidence that lagged gold prices impact gold prices either positively or negatively. This result calls attention to the efficiency of the gold market, in line with the market efficiency hypothesis and random walk theory (Fama, 1970). Our finding is in agreement with Goldman (2000), who confirmed the efficiency of the gold market, investigating the USD → GBP exchange rate under the gold standard between 1890 and 1906. Our finding, however, contrasts the results that Kirkulak Uluadag and Likhazhavap (2014) report in the Turkish gold markets and Narayan, Narayan, and Zheng (2010) in the gold-oil futures markets’ nexus.

### 3.4. Additional test: pre-COVID-19 normal period

We validate our findings by examining the normal period preceding COVID-19, from January 1, 2017 to December 31, 2019, to determine whether the effects of seven exchange rates on gold prices during the ongoing COVID-19 crisis are identical to those observed before the crisis. As shown in Table 5, the seven exchange rates studied have no impact on gold prices in the long term, as in the COVID-19 period (Table 4). In the short term, positive and lagged positive (1 week prior) USD → JPY, positive USD → CHF, positive USD → NOK, and positive USD → DKK exchange rates have been shown to increase gold prices, although we see no impact from such positive exchange rates with the

---

2 The ECU was the European monetary unit before it was replaced by the euro in 1999.

### Table 2

| Variable | ADF | PP |
|----------|-----|----|
|          | Z(τ) t-stat. | 5% C. V. | p-value | Result | Z(τ) t-stat. | 5% C. V. | Result |
| Level form | GLDP | -1.594 | | -2.879 | | 0.4668 | | 0.0468 | NS | -4.292 | | 14.000 | NS |
|            | USD → GBP | -0.964 | | 0.7663 | | 0.9800 | | 0.0360 | | 0.232 | | NS |
|            | USD → EUR | | 0.9800 | | NS | | -0.913 | | 0.7835 | | NS | | 1.787 | NS |
|            | USD → JPY | | -2.916 | | 0.2794 | | 0.0865 | | 0.7992 | | NS | | 0.031 | NS |
|            | USD → CHF | | 0.8239 | | | | -0.793 | | 0.7306 | | | 1.076 | NS |
|            | USD → NOK | | 0.221 | | 0.9360 | | NS | | -0.913 | | 0.778 | | NS |
| 1st difference form | dGLDP | -15.070 | | -2.883 | | 0.0000 | | S | | -217.485 | | 13.904 | S |
|            | dUSD→GBP | | 0.13015 | | | | 0.0000 | | S | | 176.794 | | S |
|            | dUSD→EUR | | 0.13466 | | | | 0.0000 | | S | | 179.290 | | S |
|            | dUSD→CAD | | 0.14515 | | | | 0.0000 | | S | | 185.183 | | S |
|            | dUSD→JPY | | 0.13349 | | | | 0.0000 | | S | | 191.494 | | S |
|            | dUSD→CHF | | 0.13235 | | | | 0.0000 | | S | | 165.782 | | S |
|            | dUSD→NOK | | 0.12933 | | | | 0.0000 | | S | | 171.213 | | S |
|            | dUSD→DKK | | 0.12736 | | | | 0.0000 | | S | | 160.789 | | S |

Notes: (1) “NS” and “S” denote “non-stationary” and “stationary,” respectively. (2) “d” represents first differenced variables. (3) We use the MacKinnon approximate p-value for Z(τ). (4) “ ” denotes “critical value.” (5) GLDP is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.

### Table 3

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | 5% critical value |
|----------|-----|-----|-----|-----|-----|-----|-----|------------------|
|          | USD → GBP | USD → EUR | USD → CAD | USD → JPY | USD → CHF | USD → NOK | USD → DKK | Lower | Upper |
| r_f-stat | 0.2066 | 0.4216 | 0.2679 | -0.0300 | 0.1842 | 0.2815 | 0.4778 | -2.86 | 3.22 |
| f_PSS   | 0.0298 | 0.0897 | 0.0718 | -0.0300 | 0.0339 | 0.0792 | 0.2283 | 4.94 | 5.73 |

Notes: (1) Critical values are from Pesaran, Shin, and Smith (2001). (2) GLDP is a dependent variable (y), whereas the rest (USD → GBP, USD → EUR, …, USD → DKK) are independent variables (x). (3) GLDP is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.
exception of USD → DKK, during the ongoing pandemic. This casts doubt on the role of exchange rates during the pandemic. However, 1-week-prior and positive USD → EUR and USD → DKK decrease gold prices, a finding which matches the trends observed during the COVID-19 period. This could again be explained by the adjusting nature of the financial markets.

While we find that short-term negative USD → GBP, USD → EUR, USD → CAD, and USD → JPY, 2-week-prior negative USD → GBP, and 1-week-prior negative USD → DKK increased gold prices in the normal period preceding COVID-19, our findings from the ongoing COVID-19 period present mixed results, with exchange rates having both positive and no impacts on gold prices. In the COVID-19 period, short-term negative USD → GBP, USD → CAD, USD → JPY, and USD → DKK have increased gold prices, but negative USD → EUR, USD → CHF, and USD → NOK have had no impacts on gold prices (Table 4). We thus propose that the uneven and unpredictable effects of exchange rates on gold prices have been due to the stressful situation of the ongoing COVID-19 period.

In sum, we argue that the COVID-19 crisis has contributed to the disharmony in the nexus between exchange rates and gold prices. To some extent, our findings from the normal period preceding COVID-19 contradict our findings from the ongoing COVID-19 period. Thus, we contend that the pandemic is the exclusive cause of those contradictions.

Our finding is in agreement with reports in the literature. Bedoui et al. (2018) show that the co-movement between exchange rates and gold prices differs in normal period than that seen in crisis periods–(1) the Asian crisis of 1997–1998 and the crisis following the Russian debt default in 1998 and (2) the GFC of 2007–2009. In particular, their results suggest that the dependence between USD → GBP, USD → EUR, USD → CAD, USD → JPY exchange rates and gold prices during two crisis periods (i.e., 1 and 2) was stronger than that during normal times. They further find the unusual movement of USD during the GFC of 2007–2009 spurred on the co-movement between those exchange rates and gold prices. Dong et al. (2019) also similarly reveal results for the nexus between exchange rates and gold prices during the GFC differ from those in other periods they investigate. Furthermore, Dong et al. (2019) document that the correlation coefficients between USD → GBP and USD → EUR exchange rates and gold prices have higher absolute values during the GFC than those in other periods they investigate.

In line with the findings during the COVID-19 period, we have found no evidence of short memory, meaning lagged gold prices impacting gold prices, supporting our view that the gold market is efficient and validating the market efficiency hypothesis and random walk theory (Fama, 1970). As stated earlier, our finding is in line with Goldman (2000), who investigates USD → GBP exchange rate under the gold

### Table 4
NARDL estimation (restricted) (Exchange Rates → Gold Prices).

| x: | (1)   | (2)   | (3)   | (4)   | (5)   | (6)   | (7)   |
|----|-------|-------|-------|-------|-------|-------|-------|
|    | USD → GBP | USD → EUR | USD → CAD | USD → JPY | USD → CHF | USD → NOK | USD → DKK |
| $y_{0 - 1}$ | -0.004 | 0.008 | 0.005 | -0.001 | 0.004 | 0.006 | 0.009 |
|     | [0.02] | [0.02] | [0.02] | [0.02] | [0.02] | [0.02] | [0.02] |
| $x_{0 - 1}$ | 0.036 | 0.042 | 0.029** | 0.229* | 0.236** | 0.184 | 0.450 |
|     | [0.26] | [0.64] | [0.13] | [0.13] | [0.12] | [0.48] | [0.47] |
| $y_{1 - 1}$ | 0.148 | -0.696 | -0.083 | 0.564 | 0.435 | 0.676 | 0.450 |
|     | [0.14] | [0.68] | [0.45] | [0.60] | [0.43] | [0.68] | [0.47] |
| $x_{1 - 1}$ | 0.138 | -1.541*** | 0.020 | -0.833* | 0.141 | -1.141* | 0.606 |
|     | [0.55] | [0.51] | [0.02] | [0.46] | [0.79] | [0.62] | [0.51] |
| $y_{1 - 2}$ | 0.781 | -0.365 | -0.573 | 0.611 | 0.49 | 0.48 | 0.606 |
|     | [0.13] | [0.14] | [0.14] | [0.14] | [0.14] | [0.14] | [0.14] |
| $x_{1 - 2}$ | 0.008 | -0.934 | 0.339 | -0.802 | -0.91 | -0.339 | 0.276 |
|     | [0.09] | [0.19] | [0.91] | [0.99] | [0.62] | [0.35] | [0.14] |
| Constant | 0.032 | -0.036 | 0.007 | -0.028 | -0.045 | -0.066 | 0.032 |
|     | [0.14] | [0.14] | [0.14] | [0.14] | [0.15] | [0.15] | [0.14] |

Statistics and diagnostics:

- **Obs. (weeks)**: 67
- **F-Statistic**: 2.696
- **RMSE**: 0.010
- **$R^2$ Serial Corr.**: 9.571

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|-----|-----|-----|-----|-----|-----|-----|
| 67  | 67  | 67  | 67  | 67  | 67  | 67  |
| 2.696 | 2.010 | 1.466 | 1.348 | 1.033 | 0.233 | 2.519 |
| 0.010 | 0.011 | 0.014 | 0.011 | 0.011 | 0.011 | 0.010 |
| 9.571 | 6.331 | 2.898 | 2.447 | 2.584 | 4.765 | 2.403 |

Study Period: January 1, 2020 to April 19, 2021; y: Gold Price (GLDP).

Notes: (1) Standard errors are presented in brackets. (2) p-values are noted in parentheses. (3) $p < 0.1$, $p < 0.05$, $p < 0.01$. (4) k, the order of integration, is 1. (5) The superscripts + and − denote positive and negative variations, respectively. (6) The different indicators were individually sampled (not in a panel) and then compiled into the table. (7) STATA omitted insignificant coefficients because we have constrained those to zero. (8) GLDP is a dependent variable, whereas the rest (USD → GBP, USD → EUR, ..., USD → DKK) are independent variables, and each independent variable is framed under different equations, in line with the dependent variable (GLDP). (9) GLDP is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.
Table 5
Additional test (restricted NARDL estimation) (Exchange Rates $\rightarrow$ Gold Prices).

| $x$: | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|------|-----|-----|-----|-----|-----|-----|-----|
| $y_{t-1}$ | -0.004 | -0.005 | -0.002 | -0.003 | -0.004 | -0.003 | -0.003 |
| [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] |
| $\Delta y_{t-1}$ | -0.131** | -0.003 | [0.06] | [0.03] | [0.03] | [0.03] |
| $\Delta x_{t-1}$ | 0.062 | -0.059 | 0.140 | 0.931*** | 1.029*** | 0.376** | 0.536*** |
| [0.13] | [0.21] | [0.19] | [0.20] | [0.22] | [0.18] | [0.20] |
| $\Delta x_{t-2}$ | -0.037 | -0.429** | 0.061 | 0.454*** | 0.487** | -0.487** |
| [0.18] | [0.20] | [0.26] | [0.16] | [0.22] | [0.22] |
| $\Delta x_{t-3}$ | 0.228 | 0.019 | -0.188 | -0.191 | -0.058 | -0.058 | -0.191 |
| [0.25] | [0.21] | [0.16] | [0.26] | [0.22] | [0.22] |
| $\Delta x_{t-4}$ | 0.426*** | 0.398* | 0.632*** | 0.785*** | 0.200 | 0.299 | 0.323 |
| [0.16] | [0.21] | [0.23] | [0.24] | [0.28] | [0.21] | [0.25] |
| $\Delta x_{t-5}$ | -0.272 | -0.135 | 0.040 | 0.346* | 0.346* | -0.026 | -0.026 |
| [0.19] | [0.27] | [0.28] | [0.06] | [0.06] | [0.06] |
| $\Delta x_{t-6}$ | 0.489** | 0.058 | 0.017 | 0.017 | 0.017 | 0.017 | 0.017 |
| [0.20] | [0.21] | [0.06] | [0.06] | [0.06] | [0.06] |
| Constant | 0.032 | 0.038 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 |
| [0.06] | [0.19] | [0.22] | [0.06] | [0.05] | [0.05] | [0.05] |
| RMSE | 3.153 | 1.719 | 2.405 | 8.458 | 6.670 | 2.465 | 4.025 |
| $f^2$ Serial Corr. | 0.401 | 0.416 | 0.784 | 4.112 | 1.749 | 1.783 | 2.008 |
| 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

Study Period: January 1, 2017 to December 31, 2019; y: Gold Price (GLDP).

Notes: (1) Standard errors are presented in brackets. (2) $p$-values are noted in parentheses. (3) $^*$ $p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$. (4) $k$, the order of integration, is 1. (5) The superscripts $+$ and $-$ denote positive and negative variations, respectively. (6) The different indicators were individually sampled (not in a panel) and then compiled into the table. (7) STATA omitted insignificant coefficients because we have constrained those to zero. (8) GLDP is a dependent variable, whereas the rest (USD $\rightarrow$ GBP, USD $\rightarrow$ EUR, ..., USD $\rightarrow$ DKK) are independent variables, and each independent variable is framed under different equations, in line with the dependent variable (GLDP). (9) GLDP is the gold price, USD$\rightarrow$GBP is one United States dollar (USD) to one United Kingdom pound, USD$\rightarrow$EUR is one USD to one Euro, USD$\rightarrow$CAD is one USD to one Canadian dollar, USD$\rightarrow$JPY is one USD to one hundred Japanese yen, USD$\rightarrow$CHF is one USD to one Swiss franc, USD$\rightarrow$NOK is one USD to one Norwegian krone, and USD$\rightarrow$DKK is one USD to one Danish krone.

standard between 1890 and 1906. Our finding, however, contrasts Kirkulak Uludag and Lkhazhapov’s (2014) findings in the Turkish gold market and Narayan et al.’s (2010) in the gold-oil futures markets’ nexus.

3.5. Diagnostic test

The diagnostic test on data during and before COVID-19 periods (Tables 4 and 5) suggests that the models are free from the serial correlation problem. With that, it confirms the reliability of this paper’s findings in formulating strategies.

3.6. Cumulative dynamic multiplier effects

These multipliers show an array of gold price adjustments toward a new long-term equilibrium caused by any positive or negative shock to exchange rates over a 40-week forecast period. The multipliers are generated using the best possible estimation offered by the constrained NARDL method. Fig. 2(i and iv) suggests that a negative change only in USD $\rightarrow$ EUR and USD $\rightarrow$ JPY would supersede any positive changes over the following 40-week period, whereas a positive change in USD $\rightarrow$ GBP, USD $\rightarrow$ CAD, USD $\rightarrow$ CHF, USD $\rightarrow$ NOK, or USD $\rightarrow$ DKK (Fig. 2, iii, v-vii) would supersede any negative changes. In all cases, the outcome is close to zero.

These graphs confirm a weak asymmetric link and prior findings presented in Table 4. Fig. 2 also confirms why the $f_{roc}$ test (Table 3) failed to capture asymmetry between gold prices and exchange rates.

4. Conclusions

This study has asked and answered the central research question of whether and how exchange rates have impacted gold prices during the ongoing COVID-19 crisis. The analysis reveals that none of the leading seven exchange rates has demonstrated a long-term impact on gold prices during or before the crisis. During the crisis period, changes in exchange rates have mostly increased gold prices regardless of the degree and direction of change in the short term. However, exchange rates have, as a result of the stress of the pandemic, sometimes exhibited unpredictable behavior compared to that in the normal period preceding COVID-19. Over the 40-week forecasted horizon, all exchange rates show a weak asymmetric link with gold prices, and the positive impacts of exchange rates most likely outweigh the negative impacts. Although gold prices may have occasionally decreased during the ongoing COVID-19 pandemic and during the normal period prior to the pandemic in the short term, gold’s safe-haven properties are most likely to remain intact over time.

This research has the potential to benefit scholars, researchers, investors, and policymakers in this field. For instance, our findings highlight the efficiency of the gold market, in agreement with the market efficiency hypothesis and random walk theory. We endorse the idea that gold can serve as a hedging instrument for nearly 1 year and as a safe-haven asset. Investors may consider adding gold to their portfolios, despite the fact that this study confirms the recent uneven effects of exchange rates on gold prices have been due to COVID-19. Our study follows a suggestion by Harris and Shen (2017) that a price index free of global exchange rates would safeguard gold from changes in such rates.
Out of the seven exchange rates, USD to Swiss franc and USD to Norwegian krone have no impact on gold prices. Thus, investors may add these two exchange rates to their investment portfolios to diversify risk in the short term. A dedicated study could confirm this view.

Future research ought to consider an analysis of the nexus between exchange rates and gold prices from a different perspective or by applying a different approach. Researchers also may wish to investigate whether other exchange rates, including those concerning G20 member countries not studied here, could serve as a hedging instrument. If COVID-19 were to continue for years, researchers could test whether

---

**Fig. 2.** Cumulative dynamic multipliers (Exchange Rates → Gold Prices).
(i) USD → GBP, (ii) USD → EUR, (iii) USD → CAD, (iv) USD → JPY, (v) USD → CHF, (vi) USD → NOK, and (vii) USD → DKK on GLDP.
Notes: (1) 95% bootstrap CI is based on 1000 replications. (2) GLDP is a dependent variable, whereas the rest (e.g., USD → GBP, USD → EUR, …, USD → DKK) are independent variables. (3) The time period is measured in weeks (i.e., 40 weeks). (4) GLDP is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.
gold remains a hedging tool for global equity and debt markets for a year or more in light of this pandemic.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix

A.1. Descriptive statistics/summary of raw data

| Variable | Obs. | Mean | Std. Dev. | Min. | Max. | Pearson correlation | p-value |
|----------|------|------|-----------|------|------|---------------------|---------|
| GLDP     | 339  | 1775.256 | 128.156 | 1475.030 | 2052.500 | 1.0000*** | (0.0000) |
| USD → GBP| 339  | 1.305 | 0.054 | 1.149 | 1.413 | 0.3028*** | (0.0000) |
| USD → EUR| 339  | 1.156 | 0.047 | 1.071 | 1.234 | 0.3116*** | (0.0000) |
| USD → CAD| 339  | 0.757 | 0.027 | 0.689 | 0.806 | 0.3048*** | (0.0000) |
| USD → JPY| 339  | 0.937 | 0.019 | 0.892 | 0.977 | 0.3725*** | (0.0000) |
| USD → CHF| 339  | 1.074 | 0.035 | 1.014 | 1.138 | 0.7925*** | (0.0000) |
| USD → NOK| 339  | 0.109 | 0.007 | 0.085 | 0.121 | 0.3676*** | (0.0000) |
| USD → DKK| 339  | 0.155 | 0.007 | 0.143 | 0.166 | 0.7190*** | (0.0000) |

Notes: (1) Standard errors are presented in brackets. (2) \( \gamma \) is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.

A.2. Unrestricted NARDL estimation (Exchange Rates → Gold Prices)

\[
\begin{align*}
\Delta y_t & = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \beta_3 y_{t-3} + \beta_4 x_{t-1} + \beta_5 x_{t-2} + \epsilon_t \\
\Delta x_t & = \gamma_0 + \gamma_1 \Delta y_{t-1} + \gamma_2 \Delta y_{t-2} + \gamma_3 \Delta y_{t-3} + \gamma_4 \Delta x_{t-1} + \gamma_5 \Delta x_{t-2} + \epsilon_t
\end{align*}
\]

Table: (1) USD → GBP, (2) USD → EUR, (3) USD → CAD, (4) USD → JPY, (5) USD → CHF, (6) USD → NOK, (7) USD → DKK

| Variable | (1) \( \beta_1 \) | (2) \( \beta_2 \) | (3) \( \beta_3 \) | (4) \( \beta_4 \) | (5) \( \beta_5 \) | (6) \( \gamma_4 \) | (7) \( \gamma_5 \) |
|----------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| USD → GBP| 0.001           | 0.009           | -0.009          | -0.009          | 0.000           | 0.000           | 0.000           |
| USD → EUR| [0.02]          | [0.02]          | [0.02]          | [0.02]          | [0.02]          | [0.02]          | [0.02]          |
| USD → CAD| -0.909***       | 0.117           | 0.114           | -0.855          | -0.464          | 0.028           | 0.028           |
| USD → JPY| 0.551           | 1.276**         | -0.623          | -0.076          | 0.956           | 0.009           | 0.009           |
| USD → CHF| 0.043           | 0.063           | -0.061          | -0.004          | -0.004          | 0.25            | 0.25            |
| USD → NOK| 0.252           | 0.238           | -0.179          | 0.111           | 0.028           | 0.188           | 0.188           |
| USD → DKK| 0.143           | 0.137           | 0.135           | 0.138           | 0.134           | 0.134           | 0.134           |
| \( \Delta y_t \) | 0.330           | 0.846**         | -0.400          | 1.047           | 0.514           | 0.514           | 0.514           |
| \( \Delta x_t \) | 0.075           | 0.044           | 1.468           | 0.149           | 0.149           | 0.149           | 0.149           |

Notes: (1) \( ^* \) p < 0.1, \( ^{**} \) p < 0.05, \( ^{***} \) p < 0.01. (2) All variables used in this study have 224 observations/data points. (3) GLDP is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.

Declaration of interest statement

None.

Acknowledgments

We sincerely thank the editor Brian M. Lucey and two anonymous reviewers for their insightful comments, which have helped us enhance the quality of this manuscript.

Study Period: January 1, 2020 to April 19, 2021; \( \gamma \) is Gold Price (GLDP).

Notes: (1) Standard errors are presented in brackets. (2) p-values are noted in parentheses. (3) \( \gamma < 0.1, \gamma^{**} < 0.05, \gamma^{***} < 0.01. \) (4) (4) \( k \), the order of integration, is 1.
(5) The superscripts + and − denote positive and negative variations, respectively. (6) The different indicators were individually sampled (not in a panel) and then compiled into the table. (7) STATA omitted insignificant coefficients because we have constrained those to zero. (8) GLDP is a dependent variable, whereas the rest (USD → GBP, USD → EUR, …, USD → DKK) are independent variables, and each independent variable is framed under different equations, in line with the dependent variable (GLDP). (9) GLDP is the gold price, USD → GBP is one United States dollar (USD) to one United Kingdom pound, USD → EUR is one USD to one euro, USD → CAD is one USD to one Canadian dollar, USD → JPY is one USD to one hundred Japanese yen, USD → CHF is one USD to one Swiss franc, USD → NOK is one USD to one Norwegian krone, and USD → DKK is one USD to one Danish krone.

References

Agyei-Amponsah, S., Gounopoulos, D., & Mazouz, K. (2014). Does gold offer a better protection against losses in sovereign debt bonds than other metals? Journal of Banking and Finance, 40(1), 507–521. https://doi.org/10.1016/j.jbankfin.2013.11.014
Apergis, N., & Cooray, A. (2015). Asymmetric interest rate pass-through in the US, the UK and Australia: New evidence from selected individual banks. Journal of Macroeconomics, 45, 155–172. https://doi.org/10.1016/j.jmacro.2014.04.010
Baker, S., Bloom, N., Davis, S., & Terry, S. (2020). COVID-induced economic uncertainty. In National Bureau of Economic Research. https://doi.org/10.3386/w26983 (No. w26983)
Banerjee, A., Dolado, J., & Mestre, R. (1996). Error-correction mechanism tests for cointegration in a single-equation framework. Journal of Time Series Analysis, 19(3), 267–283. https://doi.org/10.1111/j.1467-9892.1996.00099.x
Baur, D. G., & Lucey, B. M. (2010). Is gold a hedge or a safe haven? A analysis of stocks, bonds and gold. Financial Review, 45(2), 217–229. https://doi.org/10.1016/j finrev.2010.04.004
Baur, D. G., & McDermott, T. K. (2010). Is gold a safe haven? International evidence. Journal of Banking and Finance, 34(8), 1886–1899. https://doi.org/10.1016/j.jbankfin.2009.12.008
Beckmann, J., Berger, T., & Czudaj, R. (2015). Does gold act as a hedge or a safe haven for stocks? A smooth transition approach. Economic Modelling, 48, 16–24. https://doi.org/10.1016/j.econmod.2014.10.044
Beckmann, J., Berger, T., & Czudaj, R. (2019). Gold price dynamics and the role of uncertainty. Quantitative Finance, 19(4), 663–681. https://doi.org/10.1080/14697688.2018.1508879
Bedouli, R., Breaux, S., Gouette, S., & Guesmi, K. (2018). On the study of conditional dependence structure between oil, gold and USD exchange rates. International Review of Financial Analysis, 59(April), 134–146. https://doi.org/10.1016/j.irfa.2018.07.001
Bilgin, M. H., Gozgor, G., Lau, C. K. M., & Sheng, X. (2018). The effects of uncertainty on the real exchange rate. International Review of Financial Analysis, 58(March), 1–7. https://doi.org/10.1016/j.irfa.2018.03.009
Bousojry, J., Selmi, R., & Wohar, M. E. (2018). Measuring the response of gold prices to uncertainty: An analysis beyond the mean. Economic Modelling, 75(June), 105–116. https://doi.org/10.1016/j.econmod.2018.06.010
Bouri, E., Jain, A., Biswal, P. C., & Rouboud, D. (2017). Cointegration and nonlinear causality amongst gold, oil, and the Indian stock market: Evidence from implied volatility indices. Resources Policy, 52(November), 201–206. https://doi.org/10.1016/j.resourpol.2017.02.002
Bredin, D., Conlon, T., & Poti, V. (2015). Does gold glitter in the long-run? Gold as a hedge and safe haven across time and investment horizon. International Review of Financial Analysis, 41, 320–328. https://doi.org/10.1016/j.irfa.2015.01.010
Connor, F. A., Lucey, B. M., & Batten, J. A., & Baur, D. G. (2015). The contagion effects of the COVID-19 pandemic: Evidence from gold and currency correlations. Finance Research Letters, 35. https://doi.org/10.1016/j.frl.2020.101554
Cumprayovat, P., & Kouwenberg, R. (2020). The discount factor for expected fundamentals: Evidence from a panel of 25 exchange rates. International Economics, 17(December). https://doi.org/10.1016/j.inteco.2020.12.005
Ding, L. (2021). Conditional correlation between exchange rates and stock prices. The Quarterly Review of Economics and Finance, 80, 452–463. https://doi.org/10.1016/j.qref.2021.02.004
Dong, M. C., Chen, C. W. S., Lee, S., & Srisomboonchita, S. (2019). How strong is the relationship among gold and USD exchange rates? Analytics based on structural change models. Computational Economics, 53(1), 343–366. https://doi.org/10.1007/s10694-019-00503-0
Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. The Journal of Finance, 25(2), 383–417. https://doi.org/10.2307/2325496
Goldman, E. (2000). Testing efficient market hypothesis for the dollar – Sterling gold standard exchange rate 1890–1906: MLE with double truncation. Economics Letters, 69, 253–259.
Goedtel, J. W. (2020). COVID-19 and finance: Agendas for future research. Finance Research Letters, 35, 101512. https://doi.org/10.1016/j.frl.2020.101512
Güröen, G., & Ünalın, İ. (2014). Is gold a safe haven against equity market investment in emerging and developing countries? Finance Research Letters, 11(4), 341–348.
Harris, R. D. F., & Shen, J. (2017). The intrinsic value of gold: An exchange rate-free price index. Journal of International Money and Finance, 79, 203–217. https://doi.org/10.1016/j.jimonfin.2017.09.007
He, Z., O’Connor, F., & Thijssen, J. (2018). Is gold a sometime safe haven or an always hedge for equity investors? A Markov-Switching CAFM approach for US and UK