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Does oil impact gold during COVID-19 and three other recent crises?

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ABSTRACT

The ongoing COVID-19 pandemic has inspired an examination of the oil–gold price nexus during four recent crises: the COVID-19 pandemic, the gold market crash, the European sovereign debt crisis, and the global financial crisis. Using daily data from May 2007–August 2021, we employ the nonlinear autoregressive distributed lag method to reveal five novel findings. First, this study contrasts with much of the literature, which infers that the relationship between oil and gold prices is strongly positive. Second, we find no oil and gold price relationship in the long term during all the crisis periods. Third, oil prices have substantially lost their power to predict gold prices in recent times and the oil–gold price linkage is not functional across all crisis periods. Fourth, in the short term, only negative Brent and negative West Texas Intermediate price changes cause positive gold price changes during the pandemic and gold market crash, respectively. Fifth, Brent prices have shown no link to gold prices before COVID-19. We argue that gold prices are less sensitive to oil prices than ever, and the uncertainty resulting from the COVID-19 crisis has attracted investors to gold. Our main findings hold under robustness analyses using fractional cointegration/integration models, lag length, and heteroskedasticity-consistent standard errors.

1. Introduction

The world economy currently deals with two major issues—the COVID-19 pandemic and the current oil price collapse—both of which have caused a significant loss of human lives and damage to the global economy (Hung and Vo, 2021). Movements between crude oil prices and gold prices have crucial implications for the economy (Reboredo, 2013). The COVID-19 crisis has particularly created a contagion impact on bitcoin, oil, gold, and exchange markets and the resulting market shocks have caused a significant loss of human lives and damage to the global economy (Reboredo, 2013). Movements between crude oil prices and gold prices have crucial implications for the economy (Reboredo, 2013). The COVID-19 crisis has particularly created a contagion impact on bitcoin, oil, gold, and exchange markets and the resulting market shocks have caused a significant loss of human lives and damage to the global economy (Reboredo, 2013).

Gold is perceived as a safe-haven asset\textsuperscript{2} (Beckmann et al., 2019; Harris and Shen, 2017; Ji et al., 2020; Mensi et al., 2017; Tanin et al., 2022, Tanin et al., 2021b, Tanin et al., 2021c), and investors buy gold as a hedging instrument (Singhal et al., 2019). Further, gold helps investors diversify their portfolios, thereby minimizing macroeconomic risk (Agayi-Ampomah et al., 2014; Balcilar et al., 2016; Baur and Lucey, 2010; Baur and McDermott, 2010; Beckmann et al., 2019, Beckmann et al., 2015; Bilgin et al., 2018; Bouoiyour et al., 2018; Gürgün and Ünlümiş, 2014; Reboredo, 2013). Gold provides diversification opportunities for different investors, namely traditional, sustainable, and Islamic, across longer time horizons and various investment periods (Disli et al., 2021; Tanin et al., 2021a).

International investors prefer to shift to gold investments when the economy underperforms, as in recessions (Jain and Biswal, 2016) and...
periods of economic uncertainty, or when global oil prices are highly volatile (Bouri et al., 2017), Singh et al. (2019), Shahzad et al. (2019), and Lee and Lin (2012) have reported that gold prices are tightly knitted to oil prices, meaning a decline in oil prices follows an extreme drop in gold prices and vice versa. Hence, given that the COVID-19 crisis has had an unprecedented impact on oil prices (Sharif et al., 2020) and is expected to cause substantial economic and social damage to financial markets and global institutions (Goodell, 2020), an in-depth analysis of the relationship between oil and gold prices during crisis periods is necessary. This study helps evaluate how this relationship may affect investment decisions during four recent crisis periods: COVID-19, GMC, ESDC, and GFC. Investors invariably seek a better choice for their diversification purposes (Do et al., 2020). Our study draws on the assumption that financial traders’ portfolio diversifications should be changed if the financial crisis periods impact commodity prices, especially the nexus between oil and gold prices.

Using time-varying Granger causality tests, Gharib et al. (2021) identify the bilateral contagion effects of bubbles from oil to gold markets during the early COVID-19 pandemic (March 19 to 27, 2020 and April 9 to 17, 2020). Using high-frequency data from April 23, 2018 to April 24, 2020, Mensi et al. (2020) examine the impact of the COVID-19 crisis on asymmetric multifractality of gold and oil prices and report that multifractal behavior of the series increased asymmetry during the COVID pandemic. Salsi et al. (2020) investigate the role of gold as a safe haven or hedging instrument against crude oil price risks during the early pandemic. They employ the asymmetric VARMA-GARCH model, with daily data from January 2016 to August 2020, partitioning pre-COVID and COVID sample periods, and note that gold has a significant safe-haven property against oil price risks during early COVID-19. Using the nonlinear threshold cointegration models, Sephton and Mann (2018) investigate how a shock to oil prices affects gold prices, finding that the effects depend on the magnitude of the shock and the area in which the system is located at the time the shock happens. The authors find a long-term relationship between crude oil and gold prices and conclude that energy policy should not be planned without considering their interactions with financial policies. Further, Kumar (2017) finds that (1) oil prices unidirectionally Granger-cause gold prices in both the short and long-terms; (2) the relationship between oil prices and gold prices is nonlinear; and (3) positive shock in oil prices is more persistent than negative shock in oil prices on gold prices.

Our study differs from the prior studies in several ways. We examine whether (1) gold prices are susceptible to oil prices, (2) the impact of oil prices on gold prices has been positive during four recent crisis periods: COVID-19, GMC, ESDC, and GFC, and (3) the COVID-19 crisis is different from others. A focus on these four different crises can offer new insights into the oil–gold prices nexus because they perceive various unique sources of uncertainty, including the pandemic outbreak of COVID-19, the commodity crash during GMC, and the financial turmoil during GFC and ESDC. We present an extended and most up-to-date period estimate spanning from May 1, 2007, to August 12, 2021. Furthermore, we use the nonlinear autoregressive distributed lag (NARDL) approach, developed by Shin et al. (2014), to examine the relationship between oil prices and gold prices in the short and long term during the aforementioned periods. To this end, we use daily time series data on Brent, West Texas Intermediate (WTI), and Dubai crude oil prices and gold prices. Finally, we test the robustness of our findings using the fractional cointegration vector autoregressive (FCVAR) model originally proposed by Johansen (2008) and then analyzed by Johansen and Nielsen (2012).

Overall, our study delivers five significant findings. First, we find no oil and gold price relationship in the long term during all the crisis periods. The relationship may, however, exist in the short term. Second, only negative Brent and negative West Texas Intermediate price changes cause positive gold price changes in the short term during the pandemic outbreak and gold market crash, respectively. Third, the relationship is not even across different crisis periods, and oil prices significantly lose their power to predict gold prices in recent times. Fourth, only negative Brent price changes cause positive gold price changes during the ongoing COVID-19 crisis so far, while only negative WTI price changes result in positive gold prices changes during the GMC. Fifth, Brent oil prices have had no functional bond with gold prices preceding the COVID-19 crisis.

The novelty of this study is sixfold. First, this study serves as the first examination of the effect of oil prices on gold prices during the period in question, including COVID-19, GMC, ESDC, and GFC, allowing for a unique investigation of the nexus of the price of oil, a major global energy source, and gold prices during periods of heightened financial uncertainty. Second, this study finds that while oil prices used to enhance gold prices, the relationship has weakened in recent years. Third, this study relates to the work of Antonakakis and Kizys (2015), who suggest that the impacts of oil prices on gold prices are time- and event-dependent. Fourth, the results demonstrate that not all crude oil prices contribute evenly to gold prices; hence, using one crude oil price as a proxy for all could produce misleading results, validating the argument of Mann and Sephton (2016) that there is presently no global crude oil benchmark. Fifth, we find that different crisis periods show varying results; hence, examining each period separately is crucial. Sixth, we argue that the current positive impact of Brent oil prices on gold prices is due to the widespread adversity and uncertainty of the ongoing COVID-19 crisis.

The remaining parts of this paper is organized as follows. We describe the data and research methods in Section 2. Section 3 discusses the empirical results emerged from the NARDL approach and subsequently, presents the robustness analyses derived using the fractional cointegration/integration models. Finally, Section 4 delivers concluding remarks.

2. Data and research methods

2.1. Data

Table 1 provides an overview of dependent and independent variables. We transform oil prices (\(x\)) and gold prices (\(y\)) into natural logarithms, define the dependent and independent variables, and describe the data and research methods in Section 2. Section 3 discusses the empirical results emerged from the NARDL approach and subsequently, presents the robustness analyses derived using the fractional cointegration/integration models. Finally, Section 4 delivers concluding remarks.
logarithmic forms.

Over the sample of daily time-series data from May 1, 2007 to August 12, 2021, we focus on four different time horizons, representing different crisis periods. These horizons are the ongoing COVID-19 crisis (422 daily observations from January 1, 2020 to August 12, 2021), GMC (783 daily observations from January 1, 2013 to December 31, 2015), ESDC (1001 daily observations from March 2, 2009 to December 31, 2012), and GFC (479 daily observations from May 1, 2007 to February 27, 2009). Fig. 1(i) visualizes the choice of these crisis periods. This approach of dividing data into different horizons helps us achieve a more granular and coherent view of the outputs.

Fig. 1(i–iv) presents gold prices and three oil prices during the horizons under investigation. During COVID-19, gold prices have so far fluctuated between USD 1475.03 and 2052.5; the highest value was on August 6, 2020 (Fig. 1i). The gold prices sharply declined from USD 1692.84 to USD 1051.97 during the GMC with a downward trend, significantly increased from USD 868.1 to 1898.25 during the ESDC with an upward trend, and find fluctuations between USD 642.45 and 1011.6 during the GFC (Fig. 1i).

Furthermore, all oil prices have significantly fluctuated during those four horizons while the lowest and highest oil prices were USD 14.24 and 141.07, USD 37.63 and 145.66, and USD 20.66 and 140.56 for Brent, WTI, and Dubai oil prices, respectively (Fig. 1ii–iv). We can see that WTI has experienced negative WTI oil prices in history for the first time during COVID-19, precisely on April 20, 2020. The drops in oil prices (Fig. 1ii–iv) were quite substantial and showed extreme volatility. As of May 1, 2007, the starting oil prices, were USD 67.39, 64.41, and 64.24 for Brent, WTI, and Dubai, respectively. As of August 12, 2021, the ending oil prices were USD 72.26, 69.07, and 68.73 for Brent, WTI, and Dubai, respectively, which are not much different from 2007 equivalents. Accounting for inflationary processes, oil prices were even lower in 2021 than in 2007.

2.2. Model specification

The NARDL model allows us to study the asymmetric relationship between gold prices ($y$) and oil prices ($x$), expecting asymmetric adjustments throughout the business cycle (De Long and Summers, 1986; Falk, 1986; Neftci, 1984), given that Apergis and Eleftheriou (2016) have recently shown that business cycles asymmetrically affect gold prices. The NARDL method (Shin et al., 2014) is a nonlinear, dynamic, and asymmetric model that can differentiate between short- and long-term effects. The short-term estimation measures the immediate impacts of changes in the exogenous variable on the dependent variable,
while the long-term estimate assesses the reaction time and speed of adjustment toward a level of equilibrium.

Although the nonlinear threshold vector error correction model can capture these features, it exhibits a convergence issue when the parameters proliferate. The NARDL model, on the other hand, is free from restrictions in the existence of an asymmetric long-term relationship, we obtain the following:

\[ y_t = \rho y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{q-1} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{p-1} x_{t-i} \epsilon_{t-i} + \epsilon_t. \]  

(2)

where \( y_t \) is a k x 1 vector of multiple regressors defined in such a way that \( x_t = x_0 + x_t^\gamma + x_t^- \); \( \theta_j^\gamma \) is the autoregressive parameter, \( \theta_j^- \) are the asymmetrically distributed lag parameters, and \( \epsilon_t \) is an i.i.d. process with zero mean and constant variance \( \sigma^2 \). First, the long-term equation is the following:

\[ y_t = \beta^\gamma x_t^\gamma + \beta^- x_t^- + \epsilon_t. \]  

(3)

\[ \Delta y_t = v_t, \]  

(4)

where \( y_t \) (gold prices) and \( x_t \) (oil prices) are scalar variables. Here, \( x_t \) is decomposed as \( x_t = x_0 + x_t^\gamma + x_t^- \), where \( x_t^\gamma \) and \( x_t^- \) are partial sum processes of the positive and negative changes in \( x_t \):

\[ x_t^\gamma = \sum_{j=1}^{t} \Delta x_j^\gamma = \sum_{j=1}^{t} \max (\Delta x_j, 0), \quad x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min (\Delta x_j, 0). \]  

(5)

The symmetric short-term coefficients are examined using the Wald test, following an asymptotic \( \chi^2 \) distribution. To test short-term dynamic asymmetries in the response of oil prices to a fall in gold prices, we indirectly impose the long-term symmetry restrictions \( \theta^\gamma = \theta^- = \theta \), which can be simplified as

\[ \Delta y_t = \rho y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{q-1} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{p-1} x_{t-i} \epsilon_{t-i} + \epsilon_t. \]  

(6)

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

\[ \Delta y_t = \rho y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{q-1} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{p-1} x_{t-i} \epsilon_{t-i} + \epsilon_t. \]  

(7)

Following the principles of the NARDL model, we limit insignificant lags of the first-differenced terms to formulate the final NARDL. With that, the most restricted model is attained when assuming nonlinearity of the long-term relationship in combination with short-term asymmetric adjustments (Shin et al., 2014):

\[ \Delta y_t = \rho y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{q-1} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{p-1} x_{t-i} \epsilon_{t-i} + \epsilon_t. \]  

(8)

Finally, to graphically illustrate asymmetry, we visually represent the cumulative dynamic multiplier effects of a change in \( x_t^\gamma \) and \( x_t^- \) to expose the nexus between asymmetric gold prices (\( y_t \)) and oil prices (\( x_t \)). The asymmetric and cumulative dynamic multiplier effects of \( x_t^\gamma \) and \( x_t^- \) on \( y_t \) are as follows:

\[ m_t^\gamma = \sum_{j=0}^{h} \frac{\partial y_t}{\partial x_j^\gamma}, \quad m_t^- = \sum_{j=0}^{h} \frac{\partial y_t}{\partial x_j^-}, \quad h = 0, 1, 2, \ldots \]  

(9)

where \( \beta^\gamma = -\theta^\gamma/\rho \) and \( \beta^- = -\theta^-/\rho \) are the asymmetric long-term coefficients, \( p, q \) is the lag order, and \( h \) denotes the horizon. The original Shin et al. (2014) approach that accommodates stepwise regression determines the optimal lag order for this study.

We followed four steps in conducting the NARDL estimation, following Tanin et al. (2022, 2021b, 2021c). First, we performed unit root tests to confirm whether our variables were I(1). Second, although the classic OLS was the first estimation point, we followed a general-to-specific procedure (Sukmana and Ibrahim, 2017) to limit insignificant lags from our model and achieve the final specification (presented in Tables 4-7). Third, we conducted NARDL cointegration and asymmetry tests by analyzing the \( \text{f}-\)statistic (\( \text{f}_{\text{NARDL}} \) (Shin et al., 2014) and the \( \text{f}-\)statistics (\( \text{f}_{\text{BDM}} \) (Banerjee et al., 1998) to determine whether a long-term relationship exists between gold prices and oil prices. Finally, we depicted the cumulative dynamic multiplier effects of a 1% change in \( \Delta x_t^\gamma \) and \( \Delta x_t^- \) to vividly determine the asymmetric relationship between \( x \) (oil prices) and \( y \) (gold prices) (Shin et al., 2014).

3. Results and discussion

3.1. Unit root tests

As previously mentioned, we first conducted unit root tests. We confirm that our dependent variable (gold prices) and independent variables (oil prices) are non-stationary, except for the WTI prices during the COVID-19 period as shown by the modified augmented Dickey-Fuller (ADF-GLS) test (also known as DF-GLS test), and during the ESDC period as shown by the augmented Dickey-Fuller (ADF) test. Both the ADF and Phillips-Perron (PP) tests (Table 2A: I-IV) confirm that all variables are stationary in their first difference forms over all of the time horizons investigated. We present the results of ADF-GLS tests in Table 2B. In generally, the ADF-GLS test results are highly consistent with those from the ADF and PP unit root tests. Overall, this indicates that we can safely empirically examine the dynamics of gold and oil prices.
prices to investigate how these dynamics might affect investment decisions during periods of financial uncertainty, such as COVID-19, GMC, ESDC, and GFC.

3.2. Cointegration and asymmetry

To proceed with the estimation, we test for asymmetric cointegration relationships among the variables. The tests for cointegration ($t_{tBDM}$) and asymmetry ($f_{PSS}$) are presented in Table 4. The $t$-statistics of the BDM test ($t_{tBDM}$) suggests that gold prices and oil prices are not cointegrated at the 5% level, but NARDL estimation—a much superior model—may suggest otherwise. The $f$-statistics of the PSS test ($f_{PSS}$) suggests the non-existence of a long-term asymmetric relationship or an asymmetric cointegration between gold prices and oil prices, except for the GMC period (bold). These results infer that the cointegration and asymmetry between gold prices and oil prices could be weak. We seek to substantiate this view through NARDL estimation.

### Table 2A

| ADF and PP unit root tests. |
|-----------------------------|
| Full Study Period: May 1, 2007–August 12, 2021. |

#### I: Ongoing COVID-19 Crisis (January 1, 2020–August 12, 2021)

| Variable | Z(0) $t$-stat. | 5% C. V. | Result | Z($\rho$) $t$-stat. | 5% C. V. | Result |
|----------|----------------|----------|--------|----------------|----------|--------|
| GLDP     | -2.498         | -2.877   | NS     | -5.824         | -14.000  | NS     |
| Brent    | -1.684         | NS       | -2.753 | NS             | NS       | NS     |
| WTI      | -1.791         | NS       | -11.852| NS             | NS       | NS     |
| Dubai    | -1.269         | NS       | -4.560 | NS             | NS       | NS     |
| dGLDP    | -19.436        | S        | -269.865| S              |          |        |
| dBrent   | -6.467         | S        | -252.000| S              |          |        |
| dWTI     | -8.017         | S        | -208.241| S              |          |        |
| dBahai   | -17.604        | S        | -231.085| S              |          |        |

#### II: Gold Market Crash (January 1, 2013–December 31, 2015)

| Variable | Z(0) $t$-stat. | 5% C. V. | Result | Z($\rho$) $t$-stat. | 5% C. V. | Result |
|----------|----------------|----------|--------|----------------|----------|--------|
| GLDP     | -1.970         | -2.860   | NS     | -4.317         | -14.100  | NS     |
| Brent    | 0.675          | NS       | 1.694  | NS             | NS       | NS     |
| WTI      | 0.622          | NS       | -0.820 | NS             | NS       | NS     |
| Dubai    | 1.127          | NS       | -0.365 | NS             | NS       | NS     |
| dGLDP    | -9.486         | S        | -511.700| S              |          |        |
| dBrent   | -9.328         | S        | -469.000| S              |          |        |
| dWTI     | -20.326        | S        | -563.216| S              |          |        |
| dBahai   | -13.345        | S        | -557.743| S              |          |        |

#### III: European Sovereign Debt Crisis (March 2, 2009–December 31, 2012)

| Variable | Z(0) $t$-stat. | 5% C. V. | Result | Z($\rho$) $t$-stat. | 5% C. V. | Result |
|----------|----------------|----------|--------|----------------|----------|--------|
| GLDP     | -1.305         | -2.860   | NS     | -2.204         | -14.100  | NS     |
| Brent    | 2.844          | S/NS*    | 5.803  | NS             | NS       | NS     |
| WTI      | -3.383         | S        | -13.949| NS             | NS       | NS     |
| Dubai    | -2.847         | S/NS*    | -7.757 | NS             | NS       | NS     |
| dGLDP    | -13.424        | S        | -605.970| S              |          |        |
| dBrent   | -11.565        | S        | -600.000| S              |          |        |
| dWTI     | -30.138        | S        | -648.422| S              |          |        |
| dBahai   | -32.447        | S        | -688.165| S              |          |        |

#### IV: Global Financial Crisis (May 1, 2007–February 27, 2009)

| Variable | Z(0) $t$-stat. | 5% C. V. | Result | Z($\rho$) $t$-stat. | 5% C. V. | Result |
|----------|----------------|----------|--------|----------------|----------|--------|
| GLDP     | -1.521         | -2.875   | NS     | -3.711         | -14.000  | NS     |
| Brent    | 0.169          | NS       | 0.282  | NS             | NS       | NS     |
| WTI      | -0.261         | NS       | 0.008  | NS             | NS       | NS     |
| Dubai    | -0.353         | NS       | -0.282 | NS             | NS       | NS     |
| dGLDP    | -18.598        | S        | -257.833| S              |          |        |
| dBrent   | -8.486         | S        | -287.000| S              |          |        |
| dWTI     | -9.795         | S        | -301.724| S              |          |        |
| dBahai   | -9.826         | S        | -343.648| S              |          |        |

* NS at 1% Critical Value (−3.430).

Notes: (1) NS and S denote non-stationary and stationary, respectively. (2) d represents first-differenced variables. (3) CV denotes critical value. (4) GLDP denotes gold prices, Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices. (5) We determine the optimal lag lengths for the unit root tests using the Akaike Information Criteria (AIC).
3.3. Short- and long-term relationships

Using Brent, WTI, and Dubai oil prices, which are all spot prices, we examined both the short- and long-term impacts of oil prices on gold prices. We first run an estimation for COVID-19 followed by other crisis periods.

3.3.1. Ongoing COVID-19 crisis

During COVID-19, we find no long-term relationships between oil and gold prices (Table 4). In the short term, however, only negative Brent oil price changes cause gold price changes. This result somewhat contradicts the claims of Singh et al. (2019), Shahzad et al. (2019), Kumar (2017), and Lee and Lin (2012), who argue that oil prices determine gold prices. The authors did not clarify whether this oil–gold price nexus is in short- or long-term considerations. Instead, we find that the oil–gold price nexus may exist only in the short term if not in the long term; all oil price changes do not, however, influence short-term gold price changes.

This finding is somewhat in line with those of Apergis and Eleftheriou (2016), who argue that gold prices increase more during the recessionary phase of the business cycle (because of oil prices, consumer prices, and macromacroeconomic factors) than during the boom phase. The COVID-19 crisis has caused oil prices to fall and has brought about uncertainty, volatility, and economic and financial consequences on a global level, potentially affecting the decisions of investors. In addition, the ongoing COVID-19 period may be considered a recession or may usher in a recession. However, we find that gold prices already indicate a recession, being positively affected by negative Brent prices at the time of the current pandemic.

We see that gold prices are not dependent on their own lags, in the short and long terms. By examining results over the other time horizons studied, we thus seek to confirm whether the ongoing pandemic is the exclusive cause of this scenario.

3.3.2. Gold market crash

During the GMC, we find no connection between gold prices and the three oil prices in the long term (Table 5). In the short term, negative WTI price changes cause positive oil price changes. During COVID-19, we find that negative Brent price changes result in positive oil price changes, which is true for negative WTI price changes during the GMC. This result infers that oil prices weakened and/or failed to determine gold prices during COVID-19.

We further note that gold prices depend on their own lags, and lagged gold prices negatively affect gold prices in the long term. This is valid for all oil prices. The long-term effects of lagged gold prices signify the presence of long memory, indicating that past oil prices could curb future oil prices over the long term (Kirkulak Uludag and Lkhazhapov, 2014). This hypothesis violates the efficient market assumption and is contrary to a martingale or random walk behavior (Fama, 1970), yet we find no such issue during COVID-19.

3.3.3. European sovereign debt crisis

Like the COVID-19 and GMC periods, we find no long-term impacts of three oil prices on gold prices during the ESDC (Table 6). Nevertheless, while positive WTI and Dubai oil price changes cause positive gold price changes, lagged negative WTI price changes cause negative gold prices in the short term. Lagged variables could represent investors’ sentiments and future expectations and hence may justify the latter result.

Unlike the COVID-19 and GMC periods, during the ESDC, we see that lagged gold price changes caused negative gold price changes in the short term, highlighting the presence of short memory in the gold market. Furthermore, we find that lagged gold prices decrease gold prices during the GMC in the long term (Table 5), but we find otherwise (they increase gold prices) during the ESDC. These results again validate the presence of long memory in the gold market. Both short and long memory, however, violate the efficient market hypothesis and are contrary to a martingale or random walk behavior (Fama, 1970).

3.3.4. Global financial crisis

From Table 7, we find no long-term impacts of three oil prices on gold prices, which is consistent with the COVID-19 and GMC periods. Like the ESDC, we see that positive WTI and (lagged) Dubai oil price changes cause positive gold price changes in the short term during the GFC. While negative Dubai oil price changes cause positive gold price changes, negative WTI also shows the same. The former result is consistent with the ESDC (Table 6), but the latter contradicts with that period. The dissimilar observation during the ESDC could be an exception to the general findings of our study. Our results may confirm that oil price changes similarly impact gold price changes, discounting the only exception during the ESDC. We could conclude this with greater certainty through analyzing the findings from robustness tests in the FCVAR model.

During the GFC, we only find short memory in the gold market and only on one occasion, where Dubai experienced a lagged distortion of gold prices, violating the efficient market hypothesis and acting contrary to a martingale or random walk behavior (Fama, 1970). Nevertheless, this result is in line with the findings of Kirkulak Uludag and Lkhazhapov (2014), highlighting distrust in the weak form efficiency of the gold market, although they observe this for the Turkish gold market. The following robustness tests better illustrate this finding.

3.3.5. Summary of the results and further discussion

Table 8 presents the summary of the results. We find no long-term impact of oil prices on gold prices in all four recent crisis periods. This result contrasts with Septon and Mann (2018), who find otherwise for the full sample, and this could be because of their use of an old dataset (August 28, 2002 to May 27, 2014) with an estimation for a single sample in one setting. Notably, we divide our sample into four distinct periods (COVID-19, GMC, ESDC, and GFC) and estimate accordingly with robust and reliable econometric methods.
In the short term, Brent price changes cause gold price changes only during COVID-19, signifying that COVID-19 may be the exclusive cause of this impact. Clearly, Brent prices have a weak affiliation with, or no effect on, gold prices, except for during the ongoing COVID-19 crisis. Hence, a study of only one or two oil prices, or else an entire sample in one setting (i.e., without examining sub-samples or different periods separately), for example, as in Sephton and Mann (2018), may produce misleading results.

We further find that WTI oil price changes impacted gold price changes only during the GMC (Jan 2013–Dec 2015), the ESDC (Mar 2009–Dec 2012), and the GFC (May 2007–Feb 2009) in the short term. These results underscore that in the short term, WTI oil price changes predominantly caused positive gold price changes (they decreased oil prices only on one occasion and solely in the ESDC period) in the distant past (i.e., before January 2016), which has changed over time with no or positive impact on gold price changes. Besides, Dubai price changes caused gold price changes only during the ESDC (March 2009–December 2012) and the GFC (May 2007–February 2009). This indicates that whatever the situation, Dubai oil price changes positively impacted gold price changes during the two crises (i.e., the ESDC and the GFC) in question.

Supporting the findings of Kirkulak Uludag and Lkhambazhapov (2014), who studied Turkish gold spot returns and volatility, our data suggest the existence of long memory in the long term, although only during the GMC and the ESDC. Additionally, we find short memory only during the ESDC and GFC periods only on two and one occasion(s), respectively. The short- and long-term impacts of lagged gold prices during the GMC, the ESDC, and the GFC are attributable to those crises. These findings highlight that the presence of short and long memory could be spurious, rather than being a property of the data. During the GMC and the ESDC, and partially during the GFC, our results sharply indicate weak form efficiency within the gold market.

Our results confirm that oil–gold prices nexus has weakened over time. Although oil prices significantly and positively impacted gold prices in the past, except for lagged negative WTI prices over the ESDC period,7 that is no longer the case in recent times. During GMC, we see almost no bond between oil and gold prices. During COVID-19, oil prices appear to enhance gold prices only on one occasion. The COVID-19 result, as caused by Brent oil prices for the first time, could be explained by the chaos, tension, and fear created by the ongoing COVID-19 pandemic. The results suggest that oil prices have had minimal to no ability to predict gold prices in recent times. The above might explain why the BDM test in Table 3 failed to find cointegration between oil and gold prices.

These results underscore that in the short term, WTI oil price changes cause positive gold price changes. If we were analyzing the full sample, we could get biased results. Therefore, analyzing sub-samples is crucial for more robust findings.

### 3.4. Cumulative dynamic effects

Fig. 2(a–e: i–iii) graphically presents the findings by tracking asymmetric dynamic multipliers for the four crisis periods. These multipliers show how temporal adjustments to gold prices shifted to a new long-term equilibrium caused by any positive or negative shock to oil prices over the forty weeks.

We follow Shin et al. (2014) to calculate the multipliers using the constrained NARDL model specifications presented in Section 3.3, finalized applying the stepwise regression approach. The dashed green and red lines represent positive and negative changes in exchange rates toward the adjustment of gold prices, respectively. The changes presented are based on 1000 replications. The continuous blue line shows the difference between cumulative dynamic multipliers in terms of positive and negative shocks. The shaded blue area shows the upper and lower bounds of a 95% bootstrapped confidence interval, providing an estimation of the significance of the asymmetry.8

The figures show that the impacts of positive oil prices on gold prices are relatively more substantial than the effects of negative oil prices during COVID-19, GMC, ESDC, and GFC. These results validate the study of Kumar (2017), who investigated for a period of April 1990–April 2016 and found that a positive shock in oil prices is more persistent (than a negative shock in oil prices) on gold prices. However, the opposite is also true for the GMC for the impact of Dubai prices on gold prices (Fig. 2b: iii).

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7 We could confirm whether negative WTI negatively impacts gold prices during ESDC in robustness tests utilizing the fractional cointegration/integration models.

8 Sections 9.2 and 9.3 in Shin et al. (2014) provide more detailed information on this bootstrapping method.
a: Ongoing COVID-19 Crisis (January 1, 2020–August 12, 2021)

i

Cumulative effect of BREN on GLDP

ii

Cumulative effect of WTI on GLDP

iii

Cumulative effect of DUBAI on GLDP

b: Gold Market Crash (January 1, 2013–December 31, 2015)

i

Cumulative effect of DUBAI on GLDP

ii

Cumulative effect of WTI on GLDP

iii

Cumulative effect of DUBAI on GLDP

c: European Sovereign Debt Crisis (March 2, 2009–December 31, 2012)

i

Cumulative effect of BREN on GLDP

ii

Cumulative effect of WTI on GLDP

iii

Cumulative effect of DUBAI on GLDP

d: Global Financial Crisis (May 1, 2007–February 27, 2009)

i

Cumulative effect of BREN on GLDP

ii

Cumulative effect of WTI on GLDP

iii

Cumulative effect of DUBAI on GLDP

Fig. 2. Cumulative dynamic multipliers (oil prices → gold prices). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Full study period: May 1, 2007–August 12, 2021.

Notes: (1) The 95% bootstrap CI is based on 1000 replications. (2) GLDP is a dependent variable, whereas the rest (Brent, WTI, and Dubai) are independent variables. (3) GLDP denotes gold prices. Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices. (4) Time periods are in weeks (e.g., 40 weeks).
Notes: (1) Standard errors are presented in brackets. (2) p-values are noted in parentheses. (3) Stars indicate the statistical significance such that, \( p < 0.1, \quad ** p < 0.05, \quad *** p < 0.01. \) (4) \( k = 4. \) The superscripts + and − denote positive and negative variations, respectively. (6) \( \text{STATA omitted insignificant coefficients, as we have constrained them to zero.} \) (7) \( \text{GLDP is a dependent variable, whereas the rest (Brent, WTI, and Dubai) are independent variables, and each independent variable is framed under different equations in line with our dependent variable, GLDP.} \) (8) \( \text{GLDP denotes gold prices.} \) Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices.

### Table 4
Ongoing COVID-19 Crisis (January 1, 2020–August 12, 2021).

| \( y_{-1} \) | \( \Delta x_{-1}^+ \) | \( \Delta x_{-1}^- \) | \( \Delta x_{-2}^+ \) | \( \Delta x_{-3}^- \) | Constant | RMSE | \( \chi^2 \) Serial Corr. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Brent | WTI | Dubai | Brent | WTI | Dubai | Brent | WTI | Dubai |
| -0.015 | -0.001 | -0.005 | [0.02] | [0.02] | [0.02] | 0.007 | [0.06] | 2.518 | 4.403 | 4.715 | (1.000) | (1.000) | (1.000) |

| Notes: (1) Standard errors are presented in brackets. (2) p-values are noted in parentheses. (3) Stars indicate the statistical significance such that, \( p < 0.1, \quad ** p < 0.05, \quad *** p < 0.01. \) (4) \( k = 4. \) The superscripts + and − denote positive and negative variations, respectively. (6) \( \text{STATA omitted insignificant coefficients, as we have constrained them to zero.} \) (7) \( \text{GLDP is a dependent variable, whereas the rest (Brent, WTI, and Dubai) are independent variables, and each independent variable is framed under different equations in line with our dependent variable, GLDP.} \) (8) \( \text{GLDP denotes gold prices.} \) Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices.

### Table 5
Gold market crash (January 1, 2013–December 31, 2015).

| \( y_{-1} \) | \( \Delta x_{-1}^+ \) | \( \Delta x_{-1}^- \) | \( \Delta x_{-2}^+ \) | \( \Delta x_{-3}^- \) | Constant | RMSE | \( \chi^2 \) Serial Corr. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Brent | WTI | Dubai | Brent | WTI | Dubai | Brent | WTI | Dubai |
| -0.023** | -0.024*** | -0.023*** | [0.01] | [0.01] | [0.01] | [0.08] | [0.09] | [0.12] | 0.015 | 0.131* | -0.022 | [0.04] | [0.07] | [0.09] | [0.06] | 6.073 | 5.676 | 8.724 | (1.000) | (1.000) | (1.000) |

| Notes: (1) Standard errors are presented in brackets. (2) p-values are noted in parentheses. (3) Stars indicate the statistical significance such that, \( p < 0.1, \quad ** p < 0.05, \quad *** p < 0.01. \) (4) \( k = 4. \) The superscripts + and − denote positive and negative variations, respectively. (6) \( \text{STATA omitted insignificant coefficients, as we have constrained them to zero.} \) (7) \( \text{GLDP is a dependent variable, whereas the rest (Brent, WTI, and Dubai) are independent variables, and each independent variable is framed under different equations in line with our dependent variable, GLDP.} \) (8) \( \text{GLDP denotes gold prices.} \) Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices.

### Table 6
European sovereign debt crisis (March 2, 2009–December 31, 2012).

| \( y_{-1} \) | \( \Delta y_{-2}^+ \) | \( \Delta y_{-2}^- \) | \( \Delta y_{-3}^+ \) | \( \Delta y_{-3}^- \) | Constant | RMSE | \( \chi^2 \) Serial Corr. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Brent | WTI | Dubai | Brent | WTI | Dubai | Brent | WTI | Dubai |
| 0.006* | 0.006* | 0.008** | [0.00] | [0.00] | [0.00] | [0.07] | [0.07] | [0.07] | 0.014 | 0.245*** | 0.242*** | [0.04] | [0.07] | [0.07] | [0.05] | 8.662 | 12.192 | 11.760 | (1.000) | (1.000) | (1.000) |

| Notes: (1) Standard errors are presented in brackets. (2) p-values are noted in parentheses. (3) Stars indicate the statistical significance such that, \( p < 0.1, \quad ** p < 0.05, \quad *** p < 0.01. \) (4) \( k = 4. \) The superscripts + and − denote positive and negative variations, respectively. (6) \( \text{STATA omitted insignificant coefficients, as we have constrained them to zero.} \) (7) \( \text{GLDP is a dependent variable, whereas the rest (Brent, WTI, and Dubai) are independent variables, and each independent variable is framed under different equations in line with our dependent variable, GLDP.} \) (8) \( \text{GLDP denotes gold prices.} \) Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices.

Meanwhile, the asymmetry is present for forty weeks for all cases, but the impact of those asymmetry seems weak and mostly negligible. What is the takeaway from these findings? The link between oil prices and gold prices seems weak, validating our findings of the PSS test in Table 3. These graphs further confirm the results of our estimation (Tables 4–7).

### 3.5. Robustness test

#### 3.5.1. Fractional (co)integration model

The NARDL modeling framework we employ so far can only account for the integer degrees of integration such as \( I(1) \) in the gold and oil prices. Therefore, to ensure the consistency of our main findings in case the integration degrees of our variables are fractional, we employ the FCVAR model proposed by Johansen (2008) and then analyzed by Johansen and Nielsen (2012). The rank test within the FCVAR framework can help identify whether there is any long-term relationship among the endogenous variables in the system, considering the possibility that their degrees of integration are in fractional values. The bivariate FCVAR model can be specified as follows:

\[
\Delta^d Y_t = \alpha_0 \Delta^d \text{LogPrices}_t + \sum_{i=1}^{n} \gamma_i \Delta^d \text{LogPrices}_{t-i} + \varepsilon_t
\]

where \( Y_t \) is the \((2 \times 1)\) vector of endogenous variables, collecting the gold prices \((y_t)\) and oil prices \((x_t)\), \( \text{LogPrices}_t = (y_t, x_t)^T \). The residual vector, \( \varepsilon_t \), is \( t \)-distributed, with \( \Omega \) being the \((2 \times 2)\) variance-covariance matrix of the error.
terms, denoted as $\Delta y_t$ (for gold) and $\Delta x_t$ (for oil). To account for the asymmetric effects of oil price changes on gold price changes as well as the possible difference between their fractional degrees of integration, we estimate the following univariate fractionally integrated model:

$$
\Delta^d y_t = \omega + \sum_{i=0}^{\bar{q}} \gamma_i \Delta^d y_{t-i} + \sum_{i=0}^{\bar{q}} \pi_i t^{\phi_i} \Delta^d y_{t-i} + \sum_{i=0}^{\bar{q}} \tau_i \Delta^d y_{t-i} + v_t,
$$

where $d$, $\Delta^d$, $\Delta^d x_t$ are the fractional degrees of the $\Delta y_t$, $\Delta x_t$ and $\Delta x_t$, respectively. We employ the two-step estimation method in a similar spirit of Yip et al. (2017) and Do et al. (2014), in which the fractional degrees are estimated in the first stage, and the remaining parameters are estimated in the second stage of the estimation procedure.

We present the estimation results for 12 cases (four sub-samples and three oil products in each sample) in Table 10. As the table shows, the results remain highly consistent with the main findings presented in Section 3.3 in the essence of the short-term relationship between oil and gold prices. A summary of the results for short-term oil and gold price relationship using the fractional integration technique is as follows: (1) During the COVID-19 period, no clear connection between oil and gold markets persists; only negative Brent price changes cause positive gold price changes. This is consistent with the NARDL method results. (2) During the GMC period, positive oil price changes cause positive gold price changes. This result is stronger than that obtained from the NARDL method, but it is consistent in the nature of the relationship. (3) During the ESAC period, strong evidence indicates a strong-term positive effect of oil prices on gold prices. More specifically, the fractional integration results suggest that negative WTI oil price changes positively impact gold price changes in four cases during the ESAC. This fractional integration result is much more consistent and more in line with the economic intuition than that obtained from the NARDL method. As a result, we lean on this fractional integration result and conclude that WTI oil price changes positively impact gold price changes in the short term during ESAC. (4) During the GFC period, we also find strong evidence that oil price changes positively impact gold price changes. Consistent with the NARDL approach’s analyses, we find that not all oil prices even impact gold prices in all crisis periods.

### 3.5.2. Lag length and heteroskedasticity-consistent standard errors

In the main analysis, we employ the original approach of Shin et al. (2014) in choosing the final specifications for the NARDL models, using the stepwise regression procedure to determine the maximum lag length and dropped predictive variables. Following this, our NARDL models determine a maximum lag length of three, which may raise a concern that the included lag information may not sufficiently capture day-of-the-week effects. Moreover, as per the standard stepwise regression procedure, the standard errors have not yet been adjusted to be heteroskedasticity-consistent. In other words, if heteroskedasticity is present, the statistical inference of our chosen NARDL models can be biased.\(^{11}\)

To address the two abovementioned concerns, we reestimate our NARDL models with a lag length of five and, at the same time, use the White heteroskedasticity-consistent errors. We summarize the estimated outputs for all 12 cases (four subsamples and three oil products in each sample) in Table 11. In general, most of the main conclusions we drew from the NARDL’s results in Section 3.3 and the fractional (co)integration approach in Section 3.5.1 remain consistent. These include the following: (1) there is evidence that negative Brent oil price changes have a positive impact on the gold price changes; (2) there is strong evidence that the oil price changes had a positive impact on gold price changes during the GFC and the ESAC periods; and (3) not all oil prices evenly affected gold prices in the four crisis periods. Furthermore, as is consistent with the main analysis, the overall result in this robustness

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\(^{10}\) We employ the FCVAR package version 1.4 to perform these tests (see Nielsen and Poppil, 2018). The lag order $k$ is selected based on AIC criteria.

\(^{11}\) We thank an anonymous referee for this suggestion.
term effect was estimated to result in an increase of between 0.1% and 0.01%, while the short-term effect of a 1% increase in WTI oil prices during the ESDC periods was estimated to correspond to a gold return increase. For example, the long-term effect of a Brent (WTI) prices on gold price changes during COVID-19 (ESDC) shows statistical evidence of this relationship, including the effect of oil market shocks. Considering their economic significance, however, we find that these long-term effects were approximately six to ten times less than the corresponding short-term effects. Except for the COVID-19 crisis periods, it is also evident that gold prices depend on their own lags in some instances. During the GMC and in the cases of Brent, WTI, and Dubai prices, lagged gold prices negatively impacted gold prices in the short term. During the GMC, lagged gold prices positively impact gold prices in the long term, while lagged gold price changes cause negative gold price changes in the short term. During the GFC, lagged gold price changes negatively impacted gold price changes in the short term, but only on one occasion. These results suggest the presence of long memory during GMC and ESDC and short memory during ESDC and GFC (only on one occasion), indicating weak form efficiency within the gold market only during the GMC and ESDC and partially during GFC. The cumulative dynamic multipliers support the finding that the relationship between oil prices and gold prices is somewhat weak, although the asymmetry was present for forty weeks in all cases.

4. Conclusions

We investigated the nexus between gold and three oil prices using time series data for the ongoing COVID-19 crisis, the gold market crash (GMC), the European sovereign debt crisis (ESDC), and the global financial crisis (GFC). We find no strong evidence to support a long-term relationship between oil and gold prices. Although oil prices negatively impacted gold prices positively in the past, the oil-gold prices nexus has weakened over time. During GMC and COVID-19, a very minimal connection exists between oil and gold prices. During the COVID-19, oil price changes enhanced gold price changes on one occasion. Notably, Brent oil price changes impacted gold price changes for the first time.

Table 8
Summary of the results.

|                         | Ongoing COVID-19 crisis (Jan 2020–Aug 2021) | Gold market crash (Jan 2013–Dec 2015) | European sovereign debt crisis (Mar 2009–Dec 2012) | Global financial crisis (May 2007–Feb 2009) |
|-------------------------|---------------------------------------------|---------------------------------------|----------------------------------------------|---------------------------------------------|
|                         | (1) (2) (3)                                 | (1) (2) (3)                           | (1) (2) (3)                                  | (1) (2) (3)                                 |
| Brent                   | +                                           | +                                     | –                                            | –                                           |
| WTI                     | –                                           | +                                     | –                                            | –                                           |
| Dubai                   | –                                           | –                                     | +                                            | –                                           |
| Oil market → Gold market: |                                             |                                       |                                               |                                              |
| Long term               |                                            |                                       |                                               |                                              |
| $x_t$                   |                                            |                                       |                                               |                                              |
| $x_{t-1}$               |                                            |                                       |                                               |                                              |
| $x_{t-2}$               |                                            |                                       |                                               |                                              |
| $x_{t-3}$               |                                            |                                       |                                               |                                              |
| Short term              |                                            |                                       |                                               |                                              |
| $\Delta x_t$            |                                            |                                       |                                               |                                              |
| $\Delta x_{t-1}$        |                                            |                                       |                                               |                                              |
| $\Delta x_{t-2}$        |                                            |                                       |                                               |                                              |
| $\Delta x_{t-3}$        |                                            |                                       |                                               |                                              |
| $\Delta y_t$            |                                            |                                       |                                               |                                              |
| Lagged Gold market → Gold market: |                                             |                                       |                                               |                                              |
| Long term               |                                            |                                       |                                               |                                              |
| $y_{t-1}$               |                                            |                                       |                                               |                                              |
| $y_{t-2}$               |                                            |                                       |                                               |                                              |
| $y_{t-3}$               |                                            |                                       |                                               |                                              |
| Short term              |                                            |                                       |                                               |                                              |
| $\Delta y_{t-1}$        |                                            |                                       |                                               |                                              |
| $\Delta y_{t-2}$        |                                            |                                       |                                               |                                              |
| $\Delta y_{t-3}$        |                                            |                                       |                                               |                                              |

Notes: (1) The superscripts $+$ and $-$ denote positive and negative variations, respectively. (2) This table presents only significant results. (3) GLDP denotes gold prices. (4) Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices.

In robustness analyses using the fractional cointegration/integration models, we could establish that whether negative WTI price changes had a negative influence on gold price changes during the ESDC.

period, in all time horizons, Brent prices (or price changes) do not significantly impact gold prices (or price changes), either positively or negatively, and not all oil prices (or price changes) evenly impact gold prices (or price changes) in all crisis periods. It indicates that studying one or two proxies of crude oil prices and/or failing to examine sub-samples may present misleading evidence. Our robustness analyses using the fractionally integrated and fractionally cointegrated frameworks ensure the consistency of our main findings.

It is also evident that gold prices depend on their own lags in some instances. During the GMC and in the cases of Brent, WTI, and Dubai prices, lagged gold prices negatively impacted gold prices in the long term. During the ESDC, lagged gold prices positively impact gold prices in the short term, while lagged gold price changes cause negative gold price changes in the short term. During the GFC, lagged gold price changes negatively impacted gold price changes in the short term, but only on one occasion. These results suggest the presence of long memory during GMC and ESDC and short memory during ESDC and GFC (only on one occasion), indicating weak form efficiency within the gold market only during the GMC and ESDC and partially during GFC. The cumulative dynamic multipliers support the finding that the relationship between oil prices and gold prices is somewhat weak, although the asymmetry was present for forty weeks in all cases.

This study suggests that asymmetric, dynamic, and nonlinear relationships exist between oil and gold prices. Although oil prices impacted gold prices positively in the past, the oil–gold prices nexus has weakened over time. During GMC and COVID-19, a very minimal connection exists between oil and gold prices. During the COVID-19, oil price changes enhanced gold price changes on one occasion. Notably, Brent oil price changes impacted gold price changes for the first time.
The chaos, tension, and fear spread by the present COVID-19 pandemic may explain this result. We therefore argue that in recent times, oil prices have had minimal to no ability to predict gold prices. We argue that while oil prices had a functional role in predicting gold prices, this role has nearly inexistent in recent times, except for one case of Brent prices only for the period from March 2, 2009, to February 27, 2009.

The study contrasts with the findings of Singh et al. (2019), Shahzad et al. (2019), Kumar (2017), and Lee and Lin (2012) that oil prices determine gold prices. We argue that while oil prices had a functional link with gold prices during the GFC period, the relationship has proven nearly inexistend in recent times, except for one case of Brent prices only during COVID-19 and WTI prices during the GFC—all of which have positively contributed to gold prices. We, therefore, conclude that...
Table 1

| Country          | Oil market | Gold market | Dubai |
|------------------|------------|-------------|-------|
| Brent            | 0.03       | 0.03        | -0.01 |
| WTI              | 0.02       | 0.04        | 0.01  |
| Dubai            | 0.01       | 0.02        | 0.02  |

Notes: (1) The superscript + denotes positive and − negative variations, respectively. (2) The superscript * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level. (3) Gold prices are the dependent variable, whereas the oil prices (Brent, WTI, and Dubai) are independent variables. (4) Brent indicates the Brent crude oil, WTI denotes the West Texas Intermediate crude oil, and Dubai refers to the Dubai crude oil prices. (5) We do not report the estimated coefficient of the lagged gold prices and the gold price changes to conserve space.

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**Declaration of Competing Interest**

None.

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**Appendix A. Supplementary data**

Supplementary data to this article can be found online at [https://doi.org/10.1016/j.ejene.2022.105938](https://doi.org/10.1016/j.ejene.2022.105938).

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