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In search of hedges and safe havens during the COVID–19 pandemic: Gold versus Bitcoin, oil, and oil uncertainty

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1. Introduction

The interest in alternative investments (including commodities) as an independent asset class is not new. It has originated from the dynamic role of these investments in portfolio and risk management within the forever evolving global financial markets. The opening of emerging market economies to international capital flows, the liberalization of their financial markets, and the harmonization of financial regulations and accounting standards have lead to increased equity market integration, undermining the opportunities for diversification benefits. Thus, even markets that were once segmented, such as those of the Gulf Cooperation Council (GCC) member countries (Yu & Hassan, 2008), have progressively become more integrated with developed markets (Neame, 2012). Moreover, the occurrence of several crises, including the bursting of the dot-com bubble, the global financial crisis of 2007–2008 (GFC), and the ongoing COVID–19 pandemic and their associated contagion risks, motivated a keen search for alternative investments that can provide diversification benefits and protection for equity portfolios. Numerous studies have explored the linkages between equity markets and several alternative investments, most notably gold and other precious metals, crude oil, and cryptocurrencies, as well as their potential hedging and diversification benefits. However, there has been no clear consensus on which alternative investment asset possesses the best hedging and diversification benefits across different countries, sectors, and periods. Indeed, most researchers have focused on Gold due to its unique features. In particular, several studies have shown that the

A B S T R A C T

This paper investigates the potential hedging and safe-haven properties of several alternative investment assets, including gold, Bitcoin, oil, and the oil price volatility index (OVX), against the risks of the Saudi stock market and its constituent sectors in different phases of the COVID–19 pandemic. Using daily data, we employ the bivariate dynamic conditional correlation-generalized autoregressive conditional heteroskedasticity (DCC–GARCH) technique to model volatilities and conditional correlations. Our findings show that all investigated alternative investment assets had a time-varying hedging role in the Saudi stock market, which became expensive during the early stages of the COVID–19 pandemic. Our results also show that the optimal weights for gold were substantially higher than those of other assets, reaching a peak during the pandemic, implying that investors consider gold a flight-to-safety asset. Additionally, we find that gold and OVX were strong hedges and could have served as weak safe havens for investors during the early stages of the COVID–19 pandemic, while the remaining assets generally lacked these properties and could be merely used as diversifiers. Our empirical findings offer several key implications for policymakers and portfolio managers in Saudi Arabia that may be applicable to similar markets. In particular, we show that OVX-based products can serve as a promising hedging asset for stock markets in oil-exporting countries.

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1 Several investment vehicles have been developed to facilitate investors’ access to commodities (futures and exchange-traded funds (ETFs)).

2 Arnold and Auer (2015) elegantly delineate these features as follows: “First, gold’s intrinsic value neither depends on prospective cash flows nor carries a default risk. Second, gold is universally acceptable and scarce. Third, the relative inelasticity of the gold supply and the observed counter-cyclical demand qualify gold as a store of value. Finally, and probably most importantly, a protection property is commonly attributed to gold by many investors, individuals, and the media.”
protection property of gold is present not only against inflation (Lucey et al., 2017; Salisu et al., 2019; Shahbaz et al., 2014; Worthington & Pahlavani, 2007), but also in the face of adverse market movements by serving as a safe haven and/or a hedge in turbulent times, which was evident in the wake of several crises including the 9/11 terrorist attacks, the GFC, and the ongoing COVID–19 pandemic (Akhtruzzaman et al., 2021a; Baur & McDermott, 2010, 2016; Baur & Lucey, 2010). Nonetheless, the hedging and protection properties of gold are not uniform across markets and sample periods. Baur and McDermott (2010) find little evidence for the ability of gold to serve as a hedge and/or a safe haven in emerging markets, namely Brazil, China, India, and Russia. Further, Lucey and Li (2015) find other precious metals to be stronger safe havens for US equities than gold during several market downturns.

Another alternative investment that regularly makes headline news is crude oil. The crude oil shock in 1973 sparked an interest in understanding the linkages between oil prices and the global economy. As the stock market is the channel through which these linkages are rapidly manifested, a substantial literature has accumulated on various aspects of the crude oil–stock nexus (Alqahtani et al., 2019; Aroui et al., 2011; Driesprong et al., 2008; Hamdi et al., 2019). The findings that emerged from these studies initiated a stream of research specifically aimed at studying risk–return spillovers, portfolio construction, and hedging implications between oil prices and their uncertainty measured by the Chicago Board Options Exchange (CBOE) crude oil volatility index (OVX) on one hand and stock prices on the other (Al-Yahyae et al., 2019; Jalkh et al., 2020; Kang et al., 2021; Mensi et al., 2022).

The widespread public distrust of the financial system after the failure of Lehman Brothers coincided with the emergence of Bitcoin, a revolutionary digital currency based on peer-to-peer networking without the need for financial intermediaries and with complete independence from monetary authorities. The Bitcoin market has experienced exponential growth over the past decade, with its prices soaring by 90-fold and its market capitalization reaching 11373% in 2021 from its levels at the start of 2016. Moreover, Luther and Salter (2017) posit that Bitcoin maintained its upward trend despite the European debt crisis and the Cypriot banking crisis, which earned it the label “new gold” by several media outlets. Despite its relatively short history, Bitcoin shares several distinctive features with gold, suggesting its potential to perform a similar role to gold as a hedge and a safe haven. While we have alluded to some of the commonalities between Bitcoin and gold, Shahzad et al. (2019) cogently delineate these common features. Given the short history of Bitcoin, most studies that evaluate its efficacy as a hedge or a safe haven are clustered during the COVID–19 pandemic (Chemkhia et al., 2021; Chkilil et al., 2021; Dwita Mariana et al., 2021; Ustaoglu, 2022). The results from these studies are complex but suggest that Bitcoin is generally a diversifier while possessing hedging and safe-haven abilities in some cases.

In general, the findings of the aforementioned studies are complex and difficult to reconcile, with no certain commodity standing out as the best choice for hedging and risk diversification across different markets and under all circumstances. Therefore, we aim to extend the extant literature by exploring the dynamic correlations between the major alternative investment price returns and daily returns of the Saudi broad market index along with its constituent sectoral indices before and during the COVID–19 pandemic. Additionally, we use the resulting dynamic correlations to compute the optimal portfolio allocation and optimal hedge ratio in a dynamic fashion covering both sample periods to investigate their hedging and safe-haven properties. The selected alternative investments are Gold, Bitcoin, WTI crude oil, and the OVX. Our choice is justified on the following grounds: Besides expanding the repertoire of alternative investments available to investors, we intend to substantiate the available empirical evidence on the previously investigated alternative investments in the context of the Saudi market (namely, gold, crude oil, and Bitcoin) and examine whether the results obtained by prior studies including Mensi et al. (2015), Maghyereh et al. (2017), Mensi et al. (2021,2019), and Ustaoglu (2022) hold in the wake of the COVID–19 pandemic and transcend uniformly to various sectors. The addition of the newly investigated OVX in the context of the Saudi market is motivated by empirical evidence from Alqahtani et al. (2019), who document a negative correlation between the OVX and the GCC stock markets, including Saudi Arabia.

We suggest that the Saudi market is conduite to such a study for several reasons. First, the Saudi market is the largest in the Middle East and North Africa (MENA) region and among the world’s largest seven markets. The Saudi market accounts for 80% of the GCC region’s total market capitalization and reflects the country’s significance as the largest economy in the MENA region. Second, the Saudi market witnessed unprecedented growth in terms of new initial public offerings (IPOs), specifically the listing of Saudi Aramco, the second largest company after Apple in market capitalization worldwide. Third, the government has been taking serious measures to diversify the economy as part of Vision 2030 by privatizing government companies in several industries and implementing far-reaching energy reforms (Aldubyan & Gasim, 2021).

The contribution of the present study is twofold. First, in this study, we conduct a country-level analysis of the commodity-stock nexus, which has been called for by previous research. Specifically, prior studies that evaluate the hedging and diversification properties of alternative investments for the Saudi market have focused on the broad market index (Al-Yahyae et al., 2019; Maghyereh et al., 2017; Mensi et al., 2015, 2021) or one sector, namely the banking sector (Mensi et al., 2019) normally within the context of the GCC region. Indeed, Aroui et al. (2011) highlight the differences between GCC markets in several aspects, which drive the heterogeneity of the findings documented by subsequent studies across the GCC countries and their constituent sectors (Hammoudeh et al., 2009). Indeed, Balli et al. (2013) show that portfolios diversified across GCC-wide sectors outperform portfolios diversified across GCC national equity markets, which is commensurate with Chemkhia et al. (2021), who argue that the importance of analyzing different sectors in the economy stems from the heterogeneity of these sectors, which are subjected to different market structures. Moreover, Mensi et al. (2022) emphasize that the aggregation effect that results from using regional sectoral indices outweighs the different country-level impacts in terms of the extent of the dependence of its underlying economies on a certain commodity. Second, while most related studies compare the hedging and diversification capabilities of gold against either crude oil or cryptocurrencies, mainly Bitcoin, the
present study expands the range of commodities to include gold, bitcoin, oil, and OVX as well to evaluate the performance of these investments on an equal footing.

On the methodological front, we employ Engle’s bivariate dynamic conditional correlation-generalized autoregressive conditional heteroskedasticity (DCC–GARCH) technique (Engle, 2002) to model the conditional correlations among stock indices and alternative investments that are subsequently used to calculate hedge ratios and optimal portfolio weights. Moreover, following Akhtaruzzaman et al. (2021b), we utilize the “safe-haven” analysis proposed by Baur and Lucey (2010) to examine the safe-haven properties of the alternative investments during two distinctive phases of the COVID–19 pandemic based on the announcement of government stimulus packages.

Our analysis shows that the DCCs between Saudi indices and the alternative investment assets under consideration display distinctively different behaviors. On the one hand, the DCCs between Saudi indices and oil and, to a lesser extent, Bitcoin peaked during the COVID–19 crisis, highlighting the oil’s role in transmitting financial contagion into the Saudi stock market. On the other hand, the DCCs between Saudi indices and gold as well as the OVX reached a trough at the same time, affirming the role of gold and potential of the OVX as refuge assets during turbulent times. In particular, the optimal weights of gold in the main Saudi market and sectoral portfolios were far higher than their alternative asset counterparts, reaching a peak amid the COVID–19 pandemic, suggesting a “flight-to-safety” episode during the crisis. Further, optimal hedge ratios spiked in the early stages of the pandemic, implying that hedging costs increased. The “safe-haven” analysis results corroborate these findings by showing that only gold and the OVX were persistently strong hedges and possessed weak safe-haven capabilities during the early phases of the COVID–19 crisis that were diminished after the government announcement of stimulus packages.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature. Section 3 describes the data and outlines the methodology. Section 4 reports the empirical results. Section 5 summarizes the main conclusions.

2. Related studies

Following the seminal work of Baur and Lucey (2010), a large body of empirical evidence has accumulated regarding the potential hedging and safe-haven benefits that gold can provide to equity portfolios (Chkilii, 2016; Ciner et al., 2013; Creti et al., 2013; Hood & Malik, 2013). However, several studies have suggested that the increased financialization of gold and speculative investment in it, combined with a near-zero interest rate policy after the GFC, hindered the ability of gold to perform its safe-haven function (Baur & Glover, 2012; Bekiros et al., 2017; Klein, 2017; Shahzad et al., 2019), paving the way for several alternative investment assets, mainly crude oil and cryptocurrencies. Compared to other alternative investments, several researchers have demonstrated that the safe-haven role of gold vs. other alternative investments is time-varying and not uniform across different stock market indices (Lucey & Li, 2015; Shahzad et al., 2019). Further, the COVID–19 pandemic, with the sheer economic damage it caused and the unprecedented associated collapse in financial markets,10 has brought the hedging and safe-haven abilities of gold, as compared to other commodities, back to center stage (Chkilii et al., 2021; Dwita Mariana et al., 2021; Ji et al., 2020; Mensi et al., 2022).

10 See Phan and Narayan (2020) for a comprehensive account of the impact of the COVID–19 pandemic on financial markets.

Although a detailed literature review is beyond the scope of this study, the appendix provides a summary of the relevant and recent studies on the dynamic linkages between equity markets and alternative investment assets, including gold, Bitcoin, oil, and the OVX, as well as their respective role as hedges, safe havens and/or diversifiers for equity portfolios. The general theme that can be gleaned from surveying the extant literature is that the findings obtained in a certain context cannot be directly generalized to other contexts, which is evident by the continuously expanding body of empirical work and the associated heterogenous results. While gold maintains its prestige as a traditional safe haven and hedge (Al-Yahyaee et al., 2019; Będowska-Sójka & Kliber, 2021; Ciner et al., 2013; Ji et al., 2020; Junttila et al., 2018), the performance of other alternative investments is quite promising. On a few occasions, several alternative investments, including oil, the implied volatility index (VIX), and OVX, proved to be better than gold in hedging and portfolio diversification. Bashier and Sadorsky (2016) show that crude oil displays a superior hedging performance compared to gold in emerging markets. Kang et al. (2021) find that crude oil is the most effective hedge for all US sector ETFs. Based on 22 sector subindices of the STOXX 600 index covering the European Union (EU), Mensi et al. (2022) find that oil offers better hedging effectiveness than gold for all cases. Further, Raza et al. (2018), Junttila et al. (2018), and Tiwari et al. (2022) find that oil provides the best hedging effectiveness for some sectors only. Hood and Malik (2013) show that the VIX performs better than gold as a hedging tool and a safe haven than gold against the US S&P 500 index. Likewise, Ahmad et al. (2018) and Raza et al. (2019) show that the VIX displays better hedging performance for clean energy stocks and Islamic-convention portfolios. Jalkh et al. (2020) find that the OVX, rather than oil prices, provides the best hedging performance for travel and leisure stock indices for the US, the UK, and France.

The independence of cryptocurrencies from monetary authorities worldwide and their weak correlations with conventional asset classes indicate their potential to serve as safe havens in financial crises. In particular, the resilience of Bitcoin during the European debt crisis, the Cypriot banking crisis (Luther & Salter, 2017), the 2016 US election, Brexit, and the burst of the Chinese stock market bubble (Stensås et al., 2019) has reinforced this belief. However, other studies, including Bouri et al. (2017) and Shahzad et al. (2020) reach opposite conclusions. Examining a broad range of stock and commodity markets, Bouri et al. (2017) find that Bitcoin is generally a poor hedge against adverse movements in these markets and can serve as a diversifier only, except for sharp drops in Asian stocks on a weekly frequency where Bitcoin successfully serves as a strong safe haven. Investigating the G7 countries’ broad market indices, Shahzad et al. (2020) show that while gold is a safe haven and a hedge for several G7 markets, Bitcoin plays these roles only for Canada.

Notwithstanding the significance of the major events and crises that occurred after the advent of cryptocurrencies, the COVID–19 pandemic, with its accompanied unprecedented damage to the world economy, served as an acid test as to the ability of cryptocurrencies to fulfill the safe-haven role during exceptionally turbulent times. Consequently, there has been a proliferation of studies examining various aspects of the potential role of cryptocurrencies (with more emphasis on Bitcoin) as safe havens during the pandemic. Conlon and McGee (2020) argue against Bitcoin’s ability to act as a safe haven during the COVID–19 pandemic, showing that Bitcoin moved in tandem with the S&P500 during the bear market. Moreover, they find that even a minimal exposure to Bitcoin significantly increases the portfolio’s downside risk. Będowska-Sójka and Kliber (2021) compare the performance of gold and two cryptocurrencies (Bitcoin and Ether) with respect to their safe-haven ability against major stock markets in the US and Europe. They report that gold is the only proper safe haven for all markets, particularly in the period before the COVID-19 pandemic. However, gold
did not act as a strong safe haven for any market during the current pandemic. Meanwhile, none of the two cryptocurrencies are strong safe havens for any market. Nonetheless, Bitcoin and Ether occasionally possess weak safe-haven capabilities, but just against a subset of stock markets.

Examining the safe-haven capabilities of gold and Bitcoin against major world stock markets and currencies, Chemikh et al. (2021) find that gold could only serve as a weak safe haven during the pandemic (for all but one market), while Bitcoin’s heightened volatility precluded it from offering refuge to any market during the pandemic. Using intraday data, Arbi Madani et al. (2021) investigate Bitcoin’s hedging and safe-haven performance over a short investment horizon against three asset classes: stocks, crude oil, and currencies. Their results indicate that Bitcoin performs as a weak hedge during moderate fluctuations, with little evidence as to its usefulness against all three asset classes. During severe fluctuations, Bitcoin is a strong (weak) safe haven for crude oil (stocks and currencies). In the same vein, Wen et al. (2022) verify the superiority of gold as a safe haven compared to Bitcoin. They show that only gold, but not Bitcoin, has been a safe haven for oil and stock markets during the COVID–19 pandemic. Moreover, the safe-haven ability of gold for the stock market has improved during periods of high spread of the COVID–19 virus. More findings regarding the efficacy of Bitcoin as a safe-haven asset are reached by Chikili et al. (2021), who extend the analysis to six broad and regional Islamic stock market indices. They show that dynamic correlations between Bitcoin and Islamic equity markets are quite low and usually negative during turbulent times, indicating that Bitcoin possesses a safe-haven ability for Islamic markets.

Focusing on the COVID–19 pandemic impact on volatility dynamics, Fitti et al. (2021) use high-frequency data in modeling and forecasting four cryptocurrencies (Bitcoin, Ethereum Classic, Ethereum, and Ripple). Their findings show that the volatility dynamics differ between the pre- and post-COVID–19 pandemic periods. This difference is driven by the negative jump component in the pandemic period, that is, future volatility is explained by the bad volatility during the pandemic period. The implication of this finding is that cryptocurrency traders over-react to negative news during turbulent times.

Raheim (2021), Mokni et al. (2022) and Hasan et al. (2022) investigate the safe-haven ability of Bitcoin from a different perspective, that is, against measures of uncertainty rather than conventional asset classes. Raheim (2021) investigates Bitcoin’s safe-haven ability against the VIX, economic policy uncertainty (EPU), and oil shocks, finding that, while Bitcoin was successful as a safe haven prior to the COVID–19 pandemic, its ability to play that role vanished after it. Mokni et al. (2022) compare the hedging and safe-haven properties of five cryptocurrencies and gold against the EPU index, reaching two main conclusions. First, the results obtained based on Baur and Lucey (2010) “safe-haven” approach show that neither gold nor cryptocurrencies perform as a hedge against EPU during the entire sample period and the post-COVID–19 period. Regarding the safe-haven property, only gold and two cryptocurrencies (Tether and Ethereum) seem to have weak safe-haven abilities that were further diminished at the commencement of the pandemic. Second, the results based on the safe haven index (SHI) benchmark show limited success for gold and Tether as safe havens confined to the period preceding the pandemic. Hasan et al. (2022) offer an alternative perspective on the safe-haven ability of several asset classes by considering the relationship between cryptocurrency policy uncertainty (UCRY) and gold, Bitcoin, the US dollar, DJ Islamic index, Sukuk, and crude oil. They document a positive relationship between UCRY and the returns of gold, DJ Islamic Index, and Sukuk and infer that these assets have the potential to function as safe havens, whereas others, namely, Bitcoin, the US dollar, and crude oil do not have this ability.

On balance, the scarcity yet the importance of country-specific studies at the sectoral level coupled with the heterogeneity of the findings not only across countries but also across different sectors motivate and justify the present study to address this urgent and important research question in new settings.

3. Data and methodology

This section describes the dataset used to conduct the empirical analysis and outlines the econometric methodology employed to examine the dependencies between the Saudi stock sectors and selected alternative investments, including gold, Bitcoin, oil, and the VIX, as well as the portfolio construction and hedging implications based on the documented dependencies.

3.1. Data and preliminary analysis

The dataset used in this study contains daily time series of closing prices for the Tadawul All Share Index (TASI) and 19 out of its 21 constituent sectoral indices,11 in addition to daily time series of closing prices of the alternative investments investigated: gold ((ozt)/US Dollar 1:1 (XAUUSD)), Bitcoin (CoinDesk price index), Crude oil (West Texas Intermediate Spot Price FOB, Dollars per Barrel, WTI). To account for the impact of oil uncertainty, we include the market’s 30-day forward-looking expectation of the VIX. The length of the sample period is dictated by data availability, as the Saudi stock exchange embarked on a restructuring exercise of its underlying sector indices according to the global industry classification standard (GICS) in 2016. Therefore, we base our analysis on the period between January 5, 2016 and September 22, 2021, covering the COVID–19 pandemic period. All the time series are obtained from DataStream, except the Bitcoin price series are collected from CoinDesk (https://coinmarketcap.com/). Continuously compounded daily returns are calculated as \( r_t = 100 \ln \left( \frac{p_{t+1}}{p_t} \right) \), where \( r_t \) and \( p_t \) represent percentage daily return and closing index price at day \( t \), respectively.

Fig. 1 plots the evolution of the considered stock indices and alternative investment prices. From the figure, we can see that most series, with few exceptions, exhibit an upward trend over the entire sample period with a noticeable fall during the initial phase of the COVID–19 pandemic before rebounding upon the announcement of governmental stimulus packages on March 14, 2020.12 Indeed, the magnitude of these declines and the time these indices took to recover vary across sectoral indices and commodities.

Table 1 presents the descriptive statistics of daily returns for TASI and its 19 constituent sectoral indices, in addition to the selected alternative investments during the entire sample period. Regarding the 19 sectoral indices in Panel A of Table 1, the mean daily return values are mostly positive, albeit quite small and close to zero. Only four out of the 19 sectoral indices have negative means, namely, S3 (Commercial & Professional services), S4 (Consumer Durables & Apparel), S5 (Consumer Services), S8 (Food & Beverages), and S15 (Real Estate Management Development). The best performing sectors in terms of mean return, on the other hand, are S13 (Media and Entertainment) followed by S1 (Banks). The broad market index, TASI, displays a positive mean return. For each index, the standard deviation of returns is larger than its corresponding mean value. Notably, the sector indices S13 and S14 stand out from the remaining sectors as the most volatile, with standard deviations of 3.16% and 2.007%, respectively.

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11 We exclude the REITs and Software & Services indices index from our analysis due to the relatively short history.

12 https://www.spa.gov.sa/viewfullstory.php?lang=en&newsid=2047656
Moving to the results of alternative investments in Panel B of Table 1, we can see that Bitcoin records a staggering positive average return of 0.41%, which is 4.5 times the best-performing sector index (S13). However, Bitcoin is very volatile, with a standard deviation of 5.299%, only preceded by the OVX with the highest standard deviation among stock market indices and alternative investments.

Meanwhile, gold has the lowest volatility across the board. The kurtosis and skewness statistics in Panels A and B of Table 1 show that all the return series deviate from the normal distribution. In all considered series, the returns are skewed to the left except for sector indices S9, S13, and S14. The same holds for alternative investments except for the OVX. Additionally, all series seem to be fat-tailed, which is evident from the large kurtosis values. The Jarque–Bera test statistics confirm the departure from the normal distribution at the 1% significance level for all return series. The outcomes of the augmented Dickey and Fuller (ADF) test show that none of the return series contains a unit root.

Given that we use daily frequency, it is useful to conduct the serial correlation test using the Ljung-Box Q-statistics and the conditional heteroscedasticity test using the autoregressive conditional heteroscedasticity-Lagrange multiplier (ARCH-LM) test to determine the appropriate analysis model. The results confirm the presence of autocorrelation and ARCH effects in the returns for all series. Therefore, such effects warrant attention when modeling the return series.

Next, Table 2 (Panel A) reports the pairwise unconditional correlations between TASI and its 19 constituent sectoral indices and the selected alternative investments. From Table 2, we can see that the correlations between gold and both sectors and the TASI index are negative, with few exceptions that are close to zero (namely, S4, S8, S10, S14, S16, and S19). This finding indicates the potential of gold to serve as a hedge or safe-haven asset. The correlations between both sectors and the TASI index and Bitcoin are relatively low, suggesting that Bitcoin has the potential to serve as a diversifier for the TASI and sector indices. The correlation between the Saudi market and oil is positive and higher in magnitude, suggesting that the Saudi and oil markets are more integrated. Remarkably, we find highly negative correlations between the Saudi market and the OVX, in line with the results of Alqahtani et al. (2019), thus making the OVX a good candidate as a hedge and a safe haven. Overall, the Saudi market exhibits mixed correlations with the selected alternative investments, indicating the potential for short-run portfolio diversification benefits (lower portfolio variance). However, these results should be taken with a grain of salt as Forbes and Rigobon (2002) show that the unconditional correlation coefficient is biased, particularly during episodes of market turbulence. Therefore, we conduct a more refined analysis using the bivariate DCC-GARCH Fig. 1. Time series plots of stock indices levels and alternative investment prices. Notes: TASI denotes the Saudi main stock market index. We employ the following notation for sectors indices: S1(Banks), S2(Capital goods), S3(Commercial & Professional services), S4(Consumer Durables & Apparel), S5(Consumer Services), S6(Diversified Financials), S7(Energy), S8(Food & Beverages), S9(Food & Staples Retailing), S10(Health Care Equipment & Services), S11(Insurance), S12(Materials), S13(Media and Entertainment), S14(Pharma, Biotech & Life Science), S15(Real Estate Management & Development), S16(Retailing), S17(Telecommunication Services), S18(Transportation), S19(Utillities).
model, which yields time-varying conditional correlation coefficients. The volatility and correlation estimates obtained by the DCC–GARCH model are ultimately used to determine whether gold, Bitcoin, oil, and the OXV are hedges, safe-havens, and/or diversifiers for the Saudi market and its respective sectors. In the next subsection, we present the methodology including a brief account of the DCC approach.

### 3.2. Methodology

#### 3.2.1. Dynamic conditional correlation analysis

Engle’s bivariate DCC–GARCH technique (Engle, 2002) is one of the workhorses for modeling the co-movement of financial returns. It has two desirable features compared to other variations of the GARCH model family, such as the Baba-Engle-Kraft-Kroner (BEKK)
and constant conditional correlation (CCC) models. First, it has the ability to capture time-varying conditional covariance with fewer computational complications compared to the BEKK model. Second, the DCC model relaxes the assumption of the CCC model in that the correlations are constant over time. The parsimony of the bivariate DCC model is particularly desirable in our context given the large number of return series. Additionally, this approach directly accounts for heteroscedasticity as the DCCs are calculated from standardized residuals (Chiang et al., 2007). Thus, the DCCs do not contain any bias stemming from volatility clustering, which addresses the concern raised by Forbes and Rigobon (2002). Moreover, the inherent ability of this approach to generate accurate estimates of time-varying volatilities and correlations that reflect the most recent news and innovations in the presence of multiple regime shifts in response to shocks and crises enables a thorough analysis of the correlation over time (Chiang et al., 2007), ultimately leading to more informed asset allocation and hedging decisions.

The DCC model estimation involves a two-step procedure to obtain conditional correlations. In the first step, we estimate a univariate GARCH model for each return series to obtain the conditional variance. In the second step, we calculate dynamic conditional correlations from standardized residuals. Following Bauwens and Laurent (2005), the model is defined as follows

$$ R_t = \mu + \sum_{i=1}^{q} \epsilon_i z_t, $$

where the return vector $R_t = (r_{t1}, r_{t2})'$ defines the vector composed of TASI and sector indices, $r_{tj}$ and the selected alternative investments (i.e., gold, Bitcoin, oil, and the OVX), $\mu$ is the conditional mean process, and $z_t \sim i.i.d. N(0,1)$ is an $(2 \times 1)$ independent identically distributed random variables vector. The conditional covariance matrix $\Sigma_t$ is given by

$$ \Sigma_t = D_t \Sigma C_t D_t, $$

where the conditional correlation matrix

$$ C_t = [\rho_{ij}^{(k)}] = \text{diag}(Q_t)^{-1/2} Q_t \text{diag}(Q_t)^{-1/2} $$

and $D_t = \text{diag}(\sqrt{h_{t1}}, \sqrt{h_{t2}})$.

Since we assume that portfolio holdings are fully invested with no short positions permitted, the portfolio weights are constrained to be nonnegative and to sum to one as follows:

$$ w_t^{(j)} = \begin{cases} 
0 & \text{if } w_t^{(j)} < 0 \\
0 & \text{if } 0 \leq w_t^{(j)} \leq 1 \\
1 & \text{if } w_t^{(j)} > 1.
\end{cases} $$

where $w_t^{(j)}$ is the weight of an alternative investment $j$ in a one-dollar Saudi portfolio defined above at time $t$, and the terms $h_{t1}^j$ and $h_{t2}^j$ represent the volatilities of the Saudi indices and the alternative investment assets, respectively. The term $h_t^{(j)}$ is the conditional covariance between TASI and its sector indices on the one hand and each of the four alternative investments at time $t$ on the other. The corresponding weight of the Saudi market index, TASI, and each sector index in this portfolio is $1 - w_t^{(j)}$.

Similarly, the hedging ability of the above-mentioned alternative investments for the Saudi stock market indices is measured by Kroner and Sultan (1993) optimal hedge ratio using the conditional variances and covariances estimates of the bivariate DCC–GARCH (1,1) model. Kroner and Sultan (1993) consider a portfolio of two assets and show that the risk of the investment portfolio is minimized when the acquisition of one dollar of one asset is hedged by a short position of $\rho_t^{(k)}$ in the other asset. The optimal hedge ratio is given by:

$$ \rho_t^{(k)} = \frac{h_{t1}^{(k)}}{h_{t2}^{(k)}}. $$

3.2.3. The hedge and safe-haven abilities of alternative investments

The empirical approach originally proposed by Baur and Lucey (2010), referred to in the literature as the “safe-haven” analysis, has been widely used by several studies (Baur & McDermott, 2010; Baur & Lucey, 2010; Ciner et al., 2013; Hood & Malik, 2013). Ratner and Chiu (2013) modify the econometric specification using the dynamic conditional correlations from a DCC–GARCH model. As a natural extension to our analysis, we employ the specification proposed by Ratner and Chiu (2013) to examine the hedge and safe-haven abilities of gold, Bitcoin, oil, and the OVX against the risks of the Saudi market index (TASI) and each sector index. To this end, the dynamic conditional correlations are extracted from the DCC–GARCH model in Eq. 6 into 80(4 ×20) separate time series $\rho_t^{(k)}$ representing combinations of dynamic conditional correlations between each of the 20 Saudi indices and each of the corresponding four alternative investments (gold, Bitcoin, oil, and the OVX). The extracted DCCs ($\rho_t^{(k)}$) are, subsequently, regressed on dummy variables representing the COVID–19 pandemic period as follows:

$$ \rho_t^{(k)} = m_0 + m_1 D(\text{covid}_t) + m_2 D(\text{covid}_2) + m_3 \rho_{t-1}^{(k)} + e_t, $$

where $D(\text{covid}_t)$ represents dummy variables that capture the COVID–19 outbreak period and $e_t$ is the error term. Following Akhtaruzzaman et al. (2021b), we divide the COVID–19 pandemic into two phases. Phase I is captured by $D(\text{covid}_1)$, which equals one from 31/12/2019–16/03/2020, and zero otherwise. Phase II is represented by $D(\text{covid}_2)$, which equals one from 17/03/2020 to the end of the sample period, and zero otherwise. The gold, Bitcoin, oil, and the OVX are strong hedges if $m_0$ is negative and statistically significant, weak hedges if $m_0$ is insignificant, and diversifiers if $m_0$ is positive and significant. Additionally, they are strong safe havens if...
$m_1$ or $m_2$ is negative and statistically significant, whereas they are a weak safe haven if $m_1$ or $m_2$ is insignificant.

4. Results and discussion

4.1. Dynamic correlations analysis

Table 2 (Panel B) reports the mean values of the DCC coefficients between each of the 20 indices (the Saudi main market index (TASI) and its constituent sector indices) paired with each of gold, Bitcoin, oil, and the O VX, over the full sample period. The detailed estimation results of the DCC–GARCH model are not reported. We focus on extracting the DCCs calculated based on Eq. (6) and analyzing their behavior and practical implications for portfolio design and hedging.\textsuperscript{13} The mean values of the DCC coefficients associated with gold are low and negative with few exceptions, including S4, S8, S14, and S19, which is in line with the results obtained by Maghvere et al. (2017) for the market index and Mensi et al. (2019) for the banking sector. Additionally, consistent with Alqahtani et al. (2019), we find that the DCC coefficients associated with the O VX are universally negative and larger across the board. These findings imply that a drop in most Saudi stock index levels is related to an increase in the gold levels. The same interpretation holds even more strongly for the Saudi main market index (TASI) and all sector indices in the case of the O VX, which qualifies it as a potential candidate for hedging the risks of all sectors within the Saudi stock market.

Further, the DCC coefficients are generally positive and low between Bitcoin and the Saudi indices, except for S2, S6, and S15, which are negative, suggesting the ability of Bitcoin to be a diversifier for most sectors within the Saudi market while having the potential to serve as a hedge for the S2, S6, and S15 sectors in line with the results of Kamran et al. (2021) and Bouri et al. (2017), among others. The DCC coefficients associated with oil are universally positive across the board, reaching as high as 0.269 for the heavily oil-dependent material sector. Simultaneously, the lowest DCC of 0.125 is recorded for S6 (Diversified Financials). These results are in accordance with expectations about the correlation between the stock and crude oil markets for the largest oil-exporting economy worldwide and with results reported by previous research.

While the above static analysis is informative, it is worthwhile to inspect the time-varying DCCs between each of the Saudi market index and its constituent sector indices paired with the alternative investments (i.e., gold, Bitcoin, oil, and the O VX) to ascertain whether the COVID–19 crisis and other market turbulences had an impact on the respective DCCs. Fig. 2 shows that the DCCs can deviate substantially from their respective mean values, despite having no clear trend. Looking at the DCCs between the Saudi main market index (TASI) paired with each of the alternative investments, gold, Bitcoin, oil, and the O VX, in the left upper corner of Fig. 2, we can see that the DCCs associated with each alternative investment has a distinctive pattern. The DCCs associated with oil are consistently

\textsuperscript{13} The estimation results are available from the authors upon request.
positive, soaring to 0.77 amid the COVID–19 pandemic, which is in line with the literature on contagion theory by Dimitriou et al. (2013), Md Akhtaruzzaman et al. (2014), Kim et al. (2015), Ahmad et al. (2018) and Md Akhtaruzzaman et al. (2021a). Conversely, the DCCs associated with the OVX are consistently negative and naturally behave similarly to oil but in the opposite direction, reaching a trough of −0.70 in the pandemic period. The remaining alternative investments, that is, gold and Bitcoin, display weaker DCCs, alternating between −0.22 and 0.10 for gold and −0.19 and 0.22 for Bitcoin. Notably, the DCCs of Bitcoin, but not gold, spiked slightly, showing traces of contagion, confirming the unique competence of gold as a refuge asset. The sectoral indices exhibit the same general patterns as the market index with some variations depending on the structure of the industry and its existing linkages with each alternative investment. Therefore, paying attention to the heterogeneity of sectoral indices is of great importance when making risk and portfolio management decisions. Next, we discuss the implications for risk and portfolio management.

### 4.2. Portfolio management and hedging strategies

A more detailed analysis can help investors accomplish optimal portfolio allocation and effective hedging during both normal and turbulent periods. Based on the DCC–GARCH model estimation, Table 3 reports optimal portfolio weights and hedge ratios of gold, Bitcoin, oil, and the OVX, against the Saudi stock market indices over the full sample period. From Table 3, gold has the largest optimal weight across all Saudi broad and sectoral stock market portfolios. Specifically, the mean value of the weight of the TASI/Gold is 0.529, implying that for a one-dollar portfolio, 53 and 47 cents should be invested in gold and the Saudi broad market index, respectively, to minimize the risk of the portfolio without lowering its expected returns. The optimal allocations to the remaining alternative investments (i.e., bitcoin, oil, and the OVX) are much less than gold. The results for gold and oil are consistent with those of Mensi et al. (2015), Maghreyeh et al. (2017), Mensi et al. (2019, 2021), while the Bitcoin results are close to those of Ustaoglu (2022) on the market index level. The OVX results are consistent with those reported by Jalkh et al. (2020), but new in the context of the Saudi market, nicely complementing the results of Alqahtani et al. (2019) by providing fresh insights to investors.

In a similar vein to the DCCs, to gain an understanding of how the allocation decision between the Saudi indices and alternative investments changes, particularly, in response to the COVID–19 pandemic, Fig. 3 plots the optimal time-varying portfolio weights between each of the 20 indices (the Saudi market index and its constituent sector indices) paired with the alternative investments. Taking the Saudi market index paired with each alternative investment as an example, we can see by looking at the left-upper corner of Fig. 3 that portfolio weights were far from stable over the sample period. Further, the weights allocated to gold reached as high as 0.70 amid the COVID–19 pandemic, indicating a flight-to-safety episode triggered by the crisis, before declining to as low as 0.18 after the announcement of government stimulus packages and relief, in line with the findings obtained by Akhtaruzzaman et al. (2021b). Meanwhile, the weights allocated to Bitcoin were more stable relative to the remaining alternative investments with a strong spike to 0.69 amid the COVID–19 crisis before reverting to its average value, which confirms the results obtained by Chkili et al. (2021) and Ustaoglu (2022). Interestingly, we can see that the allocation to oil hit the rock-bottom of zero after the negative prices event of WTI, among other instances. The OVX weights were the most stable, albeit generally assuming less allocation, which is understandable given its extremely high volatility. Indeed, one can observe some inconsistencies among different sectors in the weights allocated to each alternative investment and the ordering of the alternative investments in terms of the weights for each sector index. Taken altogether, the time-varying behavior of portfolio weights necessitates

### Table 3

| Portfolio | Optimal portfolio weights (OPW) | Optimal hedge ratios (OHR) |
|-----------|---------------------------------|---------------------------|
|           | GOLD   | BTC   | WTI   | OVX   | GOLD   | BTC   | WTI   | OVX   |
| TASI      | 0.529  | 0.058 | 0.084 | 0.069 | −0.047 | 0.014 | 0.112 | −0.041 |
| S1        | 0.624  | 0.081 | 0.161 | 0.088 | −0.062 | 0.02  | 0.132 | −0.046 |
| S2        | 0.796  | 0.145 | 0.274 | 0.113 | −0.063 | −0.003 | 0.095 | −0.048 |
| S3        | 0.661  | 0.111 | 0.21  | 0.095 | −0.057 | 0.009 | 0.114 | −0.041 |
| S4        | 0.689  | 0.135 | 0.263 | 0.108 | 0.012  | 0.007 | 0.097 | −0.042 |
| S5        | 0.723  | 0.151 | 0.298 | 0.121 | −0.075 | 0.009 | 0.118 | −0.045 |
| S6        | 0.711  | 0.143 | 0.251 | 0.115 | −0.019 | −0.003 | 0.082 | −0.045 |
| S7        | 0.588  | 0.098 | 0.159 | 0.093 | −0.097 | 0.008 | 0.135 | −0.049 |
| S8        | 0.644  | 0.089 | 0.189 | 0.089 | 0.016  | 0.015 | 0.119 | −0.041 |
| S9        | 0.694  | 0.122 | 0.259 | 0.101 | −0.061 | 0.02  | 0.095 | −0.032 |
| S10       | 0.626  | 0.098 | 0.189 | 0.088 | −0.013 | 0.017 | 0.111 | −0.037 |
| S11       | 0.676  | 0.116 | 0.242 | 0.098 | −0.137 | 0.077 | 0.131 | −0.051 |
| S12       | 0.597  | 0.076 | 0.121 | 0.085 | −0.032 | 0.017 | 0.131 | −0.051 |
| S13       | 0.894  | 0.334 | 0.624 | 0.277 | −0.089 | 0.041 | 0.259 | −0.071 |
| S14       | 0.781  | 0.165 | 0.325 | 0.132 | 0.032  | 0.013 | 0.167 | −0.052 |
| S15       | 0.651  | 0.115 | 0.228 | 0.093 | −0.069 | 0.009 | 0.083 | −0.039 |
| S16       | 0.623  | 0.093 | 0.186 | 0.087 | −0.051 | 0.019 | 0.096 | −0.041 |
| S17       | 0.663  | 0.109 | 0.234 | 0.092 | −0.091 | 0.007 | 0.097 | −0.033 |
| S18       | 0.656  | 0.116 | 0.216 | 0.098 | −0.061 | 0.009 | 0.098 | −0.046 |
| S19       | 0.794  | 0.171 | 0.392 | 0.137 | 0.037  | 0.025 | 0.074 | −0.031 |

Notes: TASI is the Saudi main stock market index. We employ the following notations for sector indices: S1 (Banks), S2 (Capital goods), S3 (Commercial & Professional services), S4 (Consumer Durables & Apparel), S5 (Consumer Services), S6 (Diversified Financials), S7 (Energy), S8 (Food & Beverages), S9 (Food & Staples Retailing), S10 (Health Care Equipment & Services), S11 (Insurance), S12 (Materials), S13 (Media and Entertainment), S14 (Pharma, Biotech, & Life Science), S15 (Real Estate Management & Development), S16 (Retailing), S17 (Telecommunication Services), S18 (Transportation), S19 (Utilities).
frequent portfolio rebalancing. Further, the variation of weights across different indices reflects the importance of considering each sector separately for successful portfolio optimization.

Table 3 shows that the hedge ratios’ mean values of gold against each Saudi index are negative and low with few exceptions, including S4/GOLD, S14/gold, and S19/GOLD pairs. These results are consistent with Maghrebeh et al. (2017), confirming that gold is a cheap hedge for the Saudi stock market. The hedge ratios of the OVX against each Saudi index are consistently negative and much larger than those of gold, which is in line with the findings of Ahmad et al. (2018) and Iglesias-Casal et al. (2020) in the context of clean energy equities and Brazilian socially responsible investment, respectively. For Bitcoin, the hedge ratios are positive and close to zero, on average, for most sectors, except for the S2/BTC and S6/BTC pairs which are negative. Considering oil, the mean values of its hedge ratios are consistently positive and high across the board, in line with Mensi et al. (2015), Maghrebeh et al. (2017), Mensi et al. (2019), Al-Yahyae et al. (2019), and Mensi et al. (2021). These documented negative hedge ratios for the Saudi indices against gold, the OVX, and Bitcoin means that an investor holding a long position in any of these indices can potentially reduce his/her risk during adverse market movements by opening a long position in the respective alternative investment asset (gold, OVX or Bitcoin). The size of the position in the alternative investment asset is determined by the hedge ratio. For example, to hedge the main market index (TASI) using gold, an investor holding a one-dollar portfolio long in TASI can minimize his/her risk by taking a long position of about five cents in gold. Meanwhile, a positive hedge ratio, which is the case of oil, dictates a short position in the alternative asset and oil to hedge a long position in any of the Saudi indices. Indeed, Fig. 4 furnishes our understanding of the hedging dynamics. Based on Fig. 4, the optimal hedge ratios do not show a clear trend but do behave differently across pairs. One distinctive feature in all pairs is the presence of spikes in the hedge ratio series, most notably in the midst of the COVID–19 pandemic, implying an increase in hedging costs during the crisis, which is in line with the results of Md Akhtaruzzaman et al. (2021b). Interestingly, all hedge ratio series reverted back to their mean values after the announcement of government stimulus packages and relief in accordance with the findings of Akhtaruzzaman et al. (2021b). One important takeaway is that the time-varying nature of optimal hedge ratios highlights the importance of monitoring and revising hedge positions in response to changing market conditions.

4.3. Hedge and safe haven analysis

What sets the “safe-haven” analysis apart from the static and dynamic hedging and portfolio weight allocation analytics discussed.
in the preceding subsection is that it focuses on the hedging capabilities of a certain asset when it is needed the most, for example, during unusually volatile times such as the COVID-19 pandemic. Table 4 presents the results of the hedging ($m_0$) and safe-haven abilities ($m_1$ and $m_2$) of gold, Bitcoin, WTI, and OXV during the COVID-19 crisis. We divided the COVID-19 crisis period into two sub-periods: PHASE1 from 31/12/2019–16/03/2020 and PHASE2 from 17/03/2020 to the end of our sample period. The coefficient $m_0$ shows negative relationships between gold and the OXV with stock indices in each sector at the 1% significance level (except for the relationships between gold and S4, S6, S14, and S8, which are found to be significant at the 5% level, while S10 shows no statistical significance). This suggests that gold and the OXV are strong hedges against stock sector risk. Additionally, the predominantly positive and significant coefficient estimates of $m_0$ for Bitcoin (except for bitcoin being a strong (weak) safe haven for S2 (S4, S6, and S15)) and the persistently positive and significant coefficient estimates of $m_0$ for WTI show that these alternative investments can be only considered as diversifiers for sector risk in general. Regarding the safe-haven ability of our selected alternative investments, we can see that, during PHASE1 of the COVID-19 crisis, all coefficients estimate of $m_0$ for gold and the OXV were negative but lacked statistical significance. That is, gold and the OXV were weak safe havens in the first phase of COVID-19. However, $m_1$ estimates for Bitcoin and WTI were positive and insignificant, showing that these assets had relatively weaker safe-haven ability during the first phase of COVID-19. During Phase II, Gold and OXV lost most of their safe-haven ability, with most $m_2$ estimates turning positive but not differing from zero in a statistically meaningful manner, in line with the results reported by Akhtaruzzaman et al. (2021b).

To summarize, our results indicate that gold, Bitcoin, WTI, and the OXV show considerable differences in their hedging and safe-haven abilities for the Saudi stock market in general and across constituent sectors. Our findings show that gold and the OXV exhibit strong hedging abilities for TASI and almost all constituent stock sectors, whereas Bitcoin and (WTI) exhibit very limited (no hedging) capabilities. However, during PHASE 1, gold and the OXV showed weak safe-haven abilities for all stock sectors weakened during PHASE 2. Meanwhile, neither Bitcoin nor WTI shows meaningful safe-haven abilities during the COVID-19 crisis. The results regarding the relative advantage of gold over Bitcoin as a hedge and a safe haven against various sectors’ risks are largely in line with those of Hasan et al. (2022), who focus on the abilities of gold and Bitcoin, among other assets, to act as safe havens against risks stemming from crypto policy uncertainty. They are also consistent with the findings of Wen et al. (2022), who focus on their role against the US stock and crude oil markets, considering the spread of the COVID-19 virus. The results regarding the WTI safe-haven ability are generally in accordance with Tiwari et al. (2022), who find that crude oil is a safe haven only for the financial sector, but not for...
Table 4
The safe haven effects of alternative investments against the Saudi market during the COVID–19 crisis.

| Sector       | Gold | BTC | WTI | OVX |
|--------------|------|-----|-----|-----|
|              | Hedge | Safe haven | Hedge | Safe haven | Hedge | Safe haven | Hedge | Safe haven | Hedge | Safe haven | Hedge | Safe haven |
| TASI         | -0.905 *** | -0.009 | 0.000 | 0.897 *** | 0.003 ** | 0.004 | 0.001 | 0.927 *** | 0.015 *** | 0.014 | 0.000 | 0.943 *** | -0.020 *** | -0.016 | 0.000 | 0.908 *** |
| S1           | -0.005 *** | -0.009 | 0.000 | 0.872 *** | 0.004 ** | 0.004 | 0.001 * | 0.924 *** | 0.015 *** | 0.014 | 0.000 | 0.939 *** | -0.018 *** | -0.016 | 0.000 | 0.907 *** |
| S2           | -0.004 *** | -0.007 | 0.001 | 0.873 *** | -0.001 ** | 0.005 | 0.000 | 0.934 *** | 0.007 *** | 0.014 | 0.000 | 0.946 *** | -0.015 *** | -0.015 | 0.000 | 0.909 *** |
| S3           | -0.003 ** | -0.002 | -0.002 | 0.894 *** | 0.001 ** | 0.006 * | 0.001 | 0.913 *** | 0.010 ** | 0.015 | 0.000 | 0.944 *** | -0.013 *** | -0.016 | 0.000 | 0.913 *** |
| S4           | 0.001 *  | -0.007 | 0.001 | 0.888 *** | 0.001 | 0.004 | 0.001 | 0.902 *** | 0.009 ** | 0.013 | 0.000 | 0.937 *** | -0.013 *** | -0.014 | 0.000 | 0.909 *** |
| S5           | -0.004 *** | -0.004 | 0.000 | 0.898 *** | 0.001 *  | 0.003 | 0.001 | 0.926 *** | 0.010 ** | 0.012 | 0.000 | 0.941 *** | -0.012 *** | -0.013 | 0.000 | 0.913 *** |
| S6           | -0.001 ** | -0.004 | 0.000 | 0.885 *** | -0.001 | 0.004 | -0.001 | 0.921 *** | 0.007 ** | 0.013 | 0.000 | 0.937 *** | -0.014 *** | -0.012 | 0.000 | 0.907 *** |
| S7           | -0.007 ** | -0.003 | 0.000 | 0.893 *** | 0.001 ** | 0.005 | 0.001 | 0.916 *** | 0.013 ** | 0.016 | 0.000 | 0.946 *** | -0.016 *** | -0.016 | 0.000 | 0.922 *** |
| S8           | 0.001 *  | -0.005 | 0.000 | 0.893 *** | 0.004 ** | 0.005 | 0.000 | 0.917 *** | 0.013 ** | 0.014 | 0.000 | 0.938 *** | -0.015 *** | -0.015 | 0.000 | 0.906 *** |
| S9           | -0.004 *** | -0.004 | 0.001 | 0.903 *** | 0.005 ** | 0.002 | 0.001 | 0.893 *** | 0.010 ** | 0.010 | 0.000 | 0.932 *** | -0.009 *** | -0.011 | 0.000 | 0.916 *** |
| S10          | -0.001 | -0.003 | 0.000 | 0.906 *** | 0.002 ** | 0.002 | 0.001 | 0.905 *** | 0.010 ** | 0.014 | 0.000 | 0.935 *** | -0.020 *** | -0.013 | 0.000 | 0.891 *** |
| S11          | -0.008 *** | -0.003 | -0.001 | 0.906 *** | 0.003 ** | 0.004 | 0.001 | 0.918 *** | 0.011 ** | 0.012 | 0.000 | 0.937 *** | -0.013 *** | -0.015 | 0.000 | 0.900 *** |
| S12          | -0.003 ** | -0.006 | 0.001 | 0.883 *** | 0.003 ** | 0.003 | 0.001 | 0.927 *** | 0.016 ** | 0.013 | 0.000 | 0.937 *** | -0.023 *** | -0.014 | 0.000 | 0.904 *** |
| S13          | -0.003 ** | -0.002 | 0.002 | 0.902 *** | 0.006 ** | 0.004 | 0.000 | 0.891 *** | 0.012 *** | 0.012 | 0.000 | 0.932 *** | -0.010 *** | -0.013 | 0.001 | 0.906 *** |
| S14          | 0.002 *** | -0.004 | 0.001 | 0.896 *** | 0.006 ** | 0.005 | 0.000 | 0.921 *** | 0.014 ** | 0.015 | 0.000 | 0.937 *** | -0.014 *** | -0.015 | 0.000 | 0.911 *** |
| S15          | -0.005 *** | -0.006 | -0.001 | 0.880 *** | -0.001 | 0.002 | 0.000 | 0.913 *** | 0.008 ** | 0.013 | 0.000 | 0.941 *** | -0.013 *** | -0.013 | 0.000 | 0.913 *** |
| S16          | -0.004 ** | -0.001 | 0.001 | 0.909 *** | 0.004 ** | 0.005 | 0.001 | 0.916 *** | 0.009 ** | 0.015 | 0.000 | 0.944 *** | -0.014 *** | -0.015 | 0.000 | 0.917 *** |
| S17          | -0.007 ** | -0.009 | -0.001 | 0.875 *** | 0.001 *  | 0.002 | 0.001 | 0.920 *** | 0.009 ** | 0.012 | 0.000 | 0.940 *** | -0.012 *** | -0.015 | 0.000 | 0.905 *** |
| S18          | -0.005 *** | -0.003 | 0.000 | 0.884 *** | 0.001 ** | 0.004 | 0.001 | 0.929 *** | 0.010 ** | 0.013 | 0.000 | 0.937 *** | -0.016 *** | -0.012 | 0.001 | 0.909 *** |
| S19          | 0.002 *** | -0.007 | -0.002 | 0.893 *** | 0.005 ** | 0.002 | -0.001 | 0.908 *** | 0.006 ** | 0.012 | 0.001 | 0.925 *** | -0.008 *** | -0.012 | 0.000 | 0.904 *** |

Notes: The table reports the estimation results of the hedge and safe-haven model in Eq. (10). The hedging ability is measured by \( m_0 \), while the safe-haven ability is measured by \( m_1 \) during the COVID–19 crisis. TASI is the Saudi main stock market index. We employ the following notations for sector indices: S1(Banks), S2(Capital goods), S3(Commercial & Professional services), S4(Consumer Durables & Apparel), S5(Consumer Services), S6(Diversified Financials), S7(Energy), S8(Food & Beverages), S9(Food & Staples Retailing), S10(Health Care Equipment & Services), S11(Insurance), S12(Materials), S13(Media and Entertainment), S14(Pharma, Biotech, & Life Science), S15(Real Estate Management & Development), S16(Retailing), S17(Telecommunication Services), S18(Transportation), S19Utilities). ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
other sectors, including technology, telecom, real estate, energy, basic materials, utilities, industrials, and health care in the Australian stock market. Finally, the O VX documented success in acting as a safe haven confirms the results of Alqahtani et al. (2019).

5. Conclusions, policy implications, and recommendations

The interdependencies among financial markets, especially during turbulent periods, and their implications for portfolio design and risk management have received unprecedented attention due to the COVID–19 pandemic. Therefore, it is vital to investigate the degree of dependence between stock markets and other financial assets to understand their potential role in managing risk exposure. In this study, we explore whether the alternative investments of gold, Bitcoin, oil, and the O VX could potentially act as safe havens, hedges, and/or just a diversifier for the Saudi stock market and its constituent sectors in different phases of the COVID–19 pandemic. To this end, we use a DCC–GARCH model to analyze the degree of dependence between the Saudi indices and formulate hedging strategies and optimal portfolio designs. Further, we employ the Baur and Lucey (2010) “safe-haven” analysis to ascertain whether any of the candidate alternative investment assets would have served as a hedge, a safe haven, or just merely as a diversifier for the Saudi stock market during different phases of the pandemic.

The time-varying conditional correlation results show significant mixed time-varying correlations between Saudi market indices and the investigated alternative investments (i.e., gold, bitcoin, oil, and the O VX) at the pairwise level, indicating that these alternative investments play a crucial role in explaining the time-varying dynamics of the Saudi market. Additionally, our findings show that all the investigated alternative investment assets have a time-varying hedging role in the Saudi stock market, which became expensive in the wake of COVID–19 outbreak in line with the results of Akhtaruzzaman et al. (2021b), Chemhka et al. (2021), Mensi et al. (2021) and Ustaoglu (2022). Consistent with the results of Maghyerer et al. (2017), Al-Yahyae et al. (2019), and Akhtaruzzaman et al. (2021b), we find that the optimal weights allocated to gold are substantially higher compared to other assets, reaching a peak amid the pandemic, which implies that investors in the Saudi stock market consider gold as a flight-to-safety asset. Moreover, we find that while gold and the O VX were strong hedges and could have served as weak safe-havens for investors during the early stages of the COVID–19 pandemic, the remaining assets generally lacked these properties and could merely serve as diversifiers. Indeed, the results for gold are expected and not new. However, the role of the O VX as a hedge and a safe haven is quite interesting. To our knowledge, while the O VX results nicely complement those of Alqahtani et al. (2019), our findings on hedging and portfolio design management have strong implications that have not been explicitly reported before for any of the GCC markets. One important takeaway from our findings is that while gold has not lost its shine as a hedge and a safe haven, O VX-based products can serve as a promising protection asset for stock markets in oil-exporting countries.

On practical grounds, our findings coincide with the launch of the first domestic gold ETF in the Saudi stock market and the GCC region. However, no O VX-based products or volatility-based benchmark are currently available within the Saudi stock market. As a natural extension of the efforts to develop the financial sector in Saudi Arabia as part of Vision 2030, we recommend that Saudi financial regulators and institutions consider introducing O VX-based products or developing a similar index that captures the volatility of oil prices to facilitate the use of these instruments by domestic institutional investors for hedging and portfolio management purposes in real time. This proposition, however, warrants substantiation by further empirical work in different settings and with detailed policy analysis.

Conflict of interest

There are no conflicts of interests.

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