The risk transmission from the COVID-19 to MENA stock markets: what is the best safe haven asset during the pandemic?

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Abstract:
This paper investigates potential safe haven assets for MENA stock markets during the uncertainty period of the COVID-19 pandemic. We apply the DCC-GARCH model and the Diebold-Yilmaz spillover index for ten MENA stock markets, three precious metals and Bitcoin for the period 2013-2021. Empirical results show on the one hand that the COVID-19 crisis risk has been transmitted to MENA stock markets through volatility spillover across markets. This has increased the conditional volatility for all markets. On the other hand, findings point out that dynamic correlation between the precious metals/Bitcoin and stock markets is not stable and switches between low positive and negative values during the period under studies. Extending our analysis to portfolio management, results reveal that investors should include precious metals/Bitcoin in their portfolio of stocks in order to reduce the risk of portfolio. Finally, for the period of COVID-19 the analysis concludes that gold preserves its traditional role as a safe haven for MENA stock markets during the pandemic while Bitcoin fails to provide this propriety.

JEL classification: C32, G1, G11, G32
Keywords: COVID-19, Safe haven, connectedness, MENA stock markets**,** Bitcoin, precious metals.

1. Introduction

The world has recently experienced the appearance of the novel coronavirus that emerged from Wuhan, China, in December 2019. The pandemic has propagated rapidly worldwide. In addition, this health pandemic has had multidimensional negative impacts in most countries around the world and in consequence an acute economic crisis has emerged for both developed and emerging countries. More interestingly, their repercussions have also transmitted to financial industry, amplifying the volatility of international stock markets. In a second step, its harmful effects were spread to emerging markets including MENA equity markets.

Zhang et al. (2021) examine the reaction of stock markets to the global coronavirus outbreak. They find that financial markets have seen dramatic movement during the recent health crisis. More precisely, their results reveal that global financial market risks have increased greatly in response to the pandemic and consequently markets become highly volatile and unpredictable. Using a Markov switching model, Baek et al. (2020) find significant increase in total risk for the US stock market and industry indices. Li et al. (2021) examine the effect of the COVID-19 pandemic on the evolution of risk transmission and the volatility spillovers of G20 stock markets. The Empirical results indicate that the total volatility connectedness among G20 stock markets has increased substantially during the COVID-19 era. The harmful impact of COVID-19 on the stock market volatility and risk across globe is also discussed by Bakry et al., 2021; Liu et al., 2021; Abuzayed et al., 2021; Zehri, 2021; Uddin et al, 2021; Corbet et al., 2021; Xu, 2022 among others. These studies conclude that the pandemic has increased stock market fluctuations which in turns has intensified risk uncertainty.

Given this circumstance, national and international investors seek to reduce the risk of their investments by achieving the optimal portfolio diversification. This requires an appropriate modeling of volatility spillover between markets given that volatility is quantified as uncertainty and it becomes a key input to investment decisions, portfolio diversification and risk management. In addition, risk-managers and financial analysts should help and advise investors to determining the appropriate portfolio allocation through the optimal sharing of wealth. Such task requires a better specifying and choosing between safe haven assets.

The most existing studies have been limited to the role of gold and/or Bitcoin as a safe haven for stock market movements (see eg. Akhtaruzzaman et al., 2021b ; Bahloul et al., 2021 ; Salisu et al., 2021 ; Shahzad et al., 2020; Shahzad et al., 2019 ; Mensi et al., 2016; 2021). These studies have focused to developed markets while marginalizing emerging countries. Therefore, the analyze of emerging stock markets including these of the MENA region becomes crucial

nowadays given the diversification opportunities that offered to international investors. Such analysis should take into consideration the effect of the recent COVID-19 crisis.

The objective of the paper is to investigate on the one hand the risk transmission of COVID-19 for MENA stock markets. On the other hand, the paper searches the best safe haven asset for investors in the MENA region during the recent pandemic crisis. The paper contributes to previous research in several ways. Firstly, the paper interests to MENA stock markets that experienced the last decade a substantial development in terms of market capitalization and number of listed firms. To our knowledge, ours is the first that investigate the dynamic correlation between MENA stock markets and four potential safe haven assets including three precious metals and Bitcoin. Such analysis allows us to better evaluation of the interdependence between stock, commodity and Bitcoin markets and to verify how this interdependence evolves over time. Secondly, while papers that have interested to MENA region have limited to ability of gold as hedge and safe haven, we extend our analysis to encompass three precious metals (Gold, Palladium, Platinum) and the Bitcoin. Thirdly, our study period covers the recent COVID-19 crisis that affected all the considered markets as showed in Fig 1. During the crisis, the MENA stock markets have experienced a fall in their indices with substantial volatility and uncertainty for their future evolution. Therefore, a further analysis is needful in order to determining the potential safe haven for this turbulent period.

Empirically, we use two types of models namely the DCC-GARCH model and the Diebold-Yilmaz spillover model. The GARCH model allows us to test the extent of risk transmission from COVID-19 to MENA stock markets. More precisely, we examine the evolution of conditional volatility of each market during the period under study in order to verify how the stock market behavior has varied during the health crisis. We also investigate the dynamic conditional correlation between the potential safe haven assets and the MENA stock markets for the full period and the pandemic period. The Diebold-Yilmaz methodology is applied to determine the directional of volatility spillovers between markets by identifying the net receiver and transmitter of shocks. Finally, we analyze the implications of our results to portfolio design through the compute of the optimal portfolio weight and the hedging ratios. Such analysis should be completed by verifying the effectiveness of the diversification and hedging strategies. The results of our study provide new recommendations to portfolio managers, financial analysts and investors in MENA region. Firstly, the GARCH model confirms the risk transmission of the recent health crisis to worldwide. In this circumstance, both models show that volatility spillover between stock markets has been intensified during the COVID-outbreak leading to an increase in future investment uncertainty. Secondly, results suggest that gold preserve its

traditional role as a hedge and safe haven assets for all considered markets. However, the cryptocurrency cannot act as a safe haven for the stock markets of the MENA region during the COVID-19 pandemic.

The rest of the paper is organized as follows. Section 2 presents the literature review. Section 3 describes the empirical methodology. Section 4 explains the data and descriptive statistics. Section 5 discusses the empirical results obtained from the estimation of our models. Section 6 presents some conclusions.

2. Literature review

The reaction of stock markets to the economic and political events represents an interesting topic for academics, portfolio managers, international investors as well as policy makers. This interest is due to the extent of risk transmission to stock markets during the turmoil periods. In fact, such events increase the volatility on the equity markets which raise the uncertainty for future investment. In this circumstance, investors try to reduce the risk of their investments through an optimal portfolio allocation. Thereby, they seek the best safe haven assets during extreme market movements. Recently, several studies have been developed to specify the best safe haven for stock market during COVID-19 pandemic. Lahiani et al. (2021) explore the safe haven propriety of five metals against the S&P 500 index volatility during the COVID-19 era. The main results show that in short-term, palladium, copper and gold act as a safe haven against S&P 500 index. However, all the metals lost their safe haven effect in the long-term. Hasan et al. (2021) compare the safe haven propriety of twelve assets against the US stock market movements during the subprime crisis and the COVID-19 pandemic. Their findings suggest that safe-haven assets are not consistent but change over time. In addition, Islamic stock index, Tether, gold and Bitcoin demonstrate strong safe haven behavior against extreme stock market movements during the COVID-19 era.

Omane-Adjepong and Alagidede (2021) apply the DCC-GARCH model for six African stock markets, four precious metals and Bitcoin. More precisely, the authors seek to identify the potential safe-haven assets for Africa's stock markets. Empirical findings reveal that the safe haven capabilities of precious metals, especially gold have dwindled, failing to provide efficient safety to African investors. Besides, Bitcoin fails to play this role, offering only complementary services. Ji et al. (2020) investigate the effectiveness of few potential safe-haven assets toward equity index under the current market conditions due to the COVID-19 turmoils. Their empirical results show that gold and soybean can be regarded as strong safe-haven assets during this health crisis.

Akhtaruzzaman et al. (2021a) test the role of gold as a hedge and safe haven against different financial and commodity markets during the two waves of COVID-19. Their results reveal that gold acted as safe haven during the first wave of the pandemic. However, the gold lost this propriety during the second wave. Salisu et al. (2021) note that gold offers better safe haven prowess for US stocks than other precious metals like silver, palladium and platinum.

The cryptocurrencies have attracted the last decade the interest of investors as new safe haven and hedging instruments. In this context, several recent studies have attempted to verify these proprieties for emerging and developed equity markets. Goodell and Goutte (2021) employ several econometric procedures, including wavelet coherence, and neural network analyses to investigate the co-movements between seven equity indices and four cryptocurrencies during the COVID-19 pandemic. the results show that co-movements between cryptocurrencies and equity indices substantially increased after the emergence of the coronavirus. suggesting that cryptocurrencies in general do not provide a diversification benefit during either normal or turbulent periods. Conlon et al. (2020) test the safe haven features of the three cryptocurrencies having the higher capitalization namely Bitcoin, Ethereum and Tether. They conclude that Bitcoin and Ethereum cannot regarded as a safe haven for the majority of the considered equity markets. Mariana et al. (2021) note that Bitcoin exhibits a high volatility during the pandemic. However, the Bitcoin lose its safe haven propriety during the health crisis. Melki and Nefzi (2021) employ a smooth transition approach to study the hedge and safe-haven properties of the most popular cryptocurrencies-Bitcoin, Ethereum and Ripple-against commodity and stock markets. Their findings indicate the ability of the considered cryptocurrencies to act as safe-haven assets against extreme market downturns. However, this efficiency differs across cryptocurrencies and markets.

Another strand of empirical literature has attempted to compare the safe haven properties of gold and Bitcoin during the COVID-19 crisis. Chemkha et al. (2021) examine the safe haven effect of gold as a traditional asset and Bitcoin which considered as a new virtual gold. The authors apply the Asymmetric DCC-GARCH model to major world stock market indices and currencies. Their main conclusion reveals that during the COVID-19 pandemic, gold play a weak safe haven for all the considered assets while Bitcoin fails to play this role given its intensify volatility.

Using the wavelet approach, Shehzad et al. (2021) compare the safe-haven properties of gold in contrast to bitcoin for investors of major stock markets of Asia, Europe, and the US. They point out that during the COVID-19, gold investments proved to be more beneficial than

bitcoin. Bahloul et al. (2021) find that gold is a strong hedge and weak safe haven during the COVID-19 period while Bitcoin is only a weak hedge.

Disli et al. (2021) investigate the role of gold, crude oil and Bitcoin as safe haven instruments during the economic downturns that due to the COVID-19 pandemic. More precisely they apply both Wavelet coherence analysis and spillover index methodologies to check the validity of various potential safe-haven assets for different types of equity market investors (traditional, sustainable, and Islamic) during the pandemic. The results show intense return volatility across financial assets during the outbreak of the pandemic suggesting that gold, oil, and Bitcoin do not exhibit safe-haven characteristics.

The specifying of the best safe haven asset for stock portfolios remains an interesting topic during the COVID-19 pandemic. In this context, we extend the existing literature to the MENA countries given the fast development of their stock markets during the last years. Empirically, we apply the DCC-GARCH model and the Diebold-Yilmaz spillover methodology in order to discover the time-varying nexus between different assets.

3. Methodology

Empirically, we use two types of models: the DCC-GARCH model and the Diebold-Yilmaz spillover index (Diebold and Yilmaz, 2012; 2014). The Dynamic correlation model allows us to investigate the risk transmission during the COVID-19 crisis. However, the volatility spillover between precious metals, Bitcoin and MENA stock markets will be detected by the Diebold-Yilmaz spillover index. To choose the best safe haven for MENA stock markets, we calculate the optimal portfolio weight, the optimal hedging ratio and the hedging effectiveness for each precious metal or Bitcoin with each stock market. We also verify the hedging instrument efficiency involving each considered asset during the COVID-19 outbreak. Finally, we identify the safe haven feature of precious metals and Bitcoin for each country by inserting in the DCC equation a dummy variable for COVID-19 period. We also verify whether haven proprietary varies across oil-importing countries and oil-exporting countries.

3.1. Dynamic conditional correlation GARCH model

The first step of our examination consists on the one hand to verify the transmission of risk from the COVID-19 to MENA stock markets. On the other hand, it is to investigate the dynamic correlation between some potential safe havens and the considered equity markets. For this purpose, we apply the dynamic conditional correlation DCC-GARCH model. This model employs two-stage estimation process. The first stage estimates the parameters of GARCH(1,1) model for each return series. Let r_{it} the vector of return series of stock indices, precious metals and Bitcoin, the conditional mean equation is formulated as follow:

$$\begin{cases} r_{it} = \mu_{it} + \gamma_i r_{it-1} + \varepsilon_{it} \\ h_{it} = \omega_i + \alpha_i \varepsilon_{it-1}^2 + \beta_i h_{it-1} \\ \varepsilon_{it}/\varphi_{it-1} \sim N(0, h_t) \end{cases} \quad (1)$$

Where $\varphi_{it-1}$is the information set available at time $t-1$

The second stage consists in estimating the dynamic conditional correlation framework defined as follows:

$$H_t = D_t R_t D_t \quad (2)$$

Where D_t is the $(N \times N)$ diagonal matrix for the conditional variances of the univariate GARCH-class models, and R_t is the matrix of conditional correlations between markets that formulated as:

$$D_t = diag\left(h_{1,t}^{1/2}, \dots, h_{n,t}^{1/2}\right) \quad (3)$$

$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}$$

Where $Q_t = (1-a-b)\bar{Q} + a(\mu_{t-1}\mu_{t-1}') + bQ_{t-1}$. In this equation, a and b are nonnegative scalars that satisfy the condition $(a+b) < 1$. $\bar{Q}$ is the unconditional variance matrix of the standardized residuals $\mu_{it} = \varepsilon_{it}/\sqrt{h_{i,t}}$.

Finally, the dynamic conditional correlation between assets is formulated as follows:

$$\rho_{ij,t} = q_{ij,t}/\sqrt{q_{ii,t}q_{ij,t}} \qquad i,j = 1,2,\dots,n \qquad \forall i \neq j \quad (4)$$

3.2. Diebold-Yilmaz spillover model

The Diebold-Yilmaz (2012) spillover model is developed to examine the time-varying volatility spillover across markets. Let z_t the volatility series that can be modeled as a vector autoregressive process (VAR) as follows:

$$z_t = \sum_{i=1}^{P} \Phi y_{t-1} + \epsilon_t \quad (5)$$

Where $z_t = (z_{1t}, z_{2t}, \dots, z_{Nt})$ is a vector of considered variables of the model and Φ is an $(N \times N)$ matrix of estimated parameters. Thus, $\epsilon_t \sim N(0, \sum)$ is the vector of error terms that identically and independently distributed. Thereafter, the generalized forecast error variance decomposition of the moving average representation of the Eq. (5) is used to calculate total, directional and net spillover across considered markets. This framework is based on the generalized VAR (GVAR) scheme that developed by Pesaran and Shin (1998). Finally, the H-step ahead forecast error variance decomposition is computed as:

$$\lambda_{ij}(H) = \frac{\sigma_H^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \sum e_j\right)^2}{\sum_{h=0}^{H-1} (e_i' A_h \sum A_h' e_i)} \quad (6)$$

Where $\sum$ designs the variance matrix of the vector of errors ε and σ_{ij} measures the standard deviation of the error term of the j^{th} series. Note that e_i is a selection vector which takes the value of one for the i^{th} element and zero otherwise. Finally, given that the decomposition of diagonal and off diagonal elements do not sum to one, each entry of the matrix is normalized by its row sum as follows:

$$\check{\lambda}_{ij}(H) = \frac{\lambda_{ij}(H)}{\sum_{j=1}^{N} \lambda_{ij}(H)} \quad (7)$$

By definition, $\sum_{j=1}^{N} \check{\lambda}_{ij}(H) = 1$ and $\sum_{i,j=1}^{N} \check{\lambda}_{ij}(H) = N$. This allows us to compute the total volatility spillover index using the Eq. 7 as follows:

$$S(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \check{\lambda}_{ij}(H)}{\sum_{i,j=1}^{N} \check{\lambda}_{ij}(H)} \times 100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \check{\lambda}_{ij}(H)}{N} \times 100 \quad (8)$$

This index is applied to measure the total transmission of shocks across all precious metals, Bitcoin and stock markets considered in our study. In other terms, this index represents the sum of proportions of the forecast error variance of market *i* generated by shocks in market *j* for all $i \neq j$.

For better analysis, we can also define the volatility spillover received by market *i* from all other sample markets as follows:

$$S_{i\bullet}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \check{\lambda}_{ij}(H)}{\sum_{j=1}^{N} \check{\lambda}_{ij}(H)} \times 100 \quad (9)$$

The model allows us to compute the transmitted by market i to other markets in the sample as:

$$S_{\bullet i}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \check{\lambda}_{ji}(H)}{\sum_{j=1}^{N} \check{\lambda}_{ij}(H)} \times 100 \quad (10)$$

Finally, the net transmission of volatility from asset *i* to all other assets is calculated as the difference between Eq. (9) and Eq. (10) as

$$S_i(H) = S_{i\bullet}(H) - S_{\bullet i}(H) \quad (11)$$

Two situations arise. A positive value of net transmission index denotes that market *i* is a net transmitter of shock while a negative value indicates that market *i* is a net receiver of volatility.

3.3.Optimal portfolio weight

To achieve an optimal investment strategy, portfolio managers and financial analysts should propose to investor the best combination between assets. This required determining the optimal portfolio weight composed by one of the precious metals or Bitcoin and each MENA stock index. Such portfolio allows to reduce the risk without diminishing the expected returns. Following Kroner and Ng (1998), Chkili et al. (2021), the optimal holding weight of asset *i* (*i* denotes gold, palladium, platinum or Bitcoin) in a one dollar invest in asset i/MENA stocks portfolio is calculated as follows:

$$w^{is} = \frac{h^{s} - h^{is}}{h^{i} - 2h^{is} + h^{s}} \tag{12}$$

This equation should respect the following condition

$$w^{is} = \begin{cases} 0 \; if \; w^{is} < 0 \\ w^{is} \; if \; 0 < w^{is} < 1 \\ 1 \; if \; w^{is} > 1 \end{cases} \tag{13}$$

Where h_t^i and h_t^s denote respectively the conditional variances of the asset *i* and the stock market at time *t*. h_t^{is} refers to the conditional covariance between asset *i* and stock market index at time *t*. All the series are obtained from the estimation of the multivariate GARCH model. The optimal weight of the stocks in a one-dollar asset *i* / MENA stocks portfolio is calculated as follows $(1 - w_t^{is})$.

3.4. Hedging strategies

In order to verify the effectiveness of precious metals and Bitcoin to hedge MENA stock market risks, we use two practical methods. Firstly, we compute the optimal hedge ratio β_t^{is} using the estimation results of our GARCH model. This means that a short position in the MENA stock market should be hedged by a long position of β_t^{is} dollar in the asset *i*. The optimal hedge ratio can be calculated using the formula developed by Kroner and Sultan (1993) as follows:

$$\beta_t^{is} = \frac{h_t^{is}}{h_t^{i}} \tag{14}$$

Secondly, to check the performance of the applied hedging strategy, we calculate the hedging effectiveness (*HE*) index. This index determines to what extent the hedging strategy has reduced or increased variance of hedged portfolio compared to the unhedged portfolio. The hedging effectiveness index is calculated from the following equation:

$$HE = \left[\frac{variance_{unhedged} - variance_{hedged}}{variance_{unhedged}}\right] \quad (15)$$

Where $variance_{unhegged}$ refers to the risk of portfolio contains only MENA stocks and $variance_{hedged}$ represents the variance of portfolio composed by stocks and precious metals or Bitcoin. This index measures the efficiency of the hedging strategy. In other words, a higher value of HE index refers to an effectiveness hedging strategy.

3.5. Safe haven property of precious metals and Bitcoin

To test the safe haven effect of the considered four assets (gold, palladium, platinum, Bitcoin) during the COVID-19 pandemic, we follow Akhtaruzzaman et al. (2021a) approach. Empirically, we estimate the following equation:

$$DCC_{ijt} = \delta_0 + \delta_1 DCC_{ijt-1} + \delta_2 COV_t + \varepsilon_t \quad (16)$$

Where DCC_{ij} is the dynamic conditional correlation between potential safe haven asset *i* and stock market *j*. *COV* is a dummy variable which equal to 1 if the period is in the pandemic crisis and 0 otherwise. This methodology is applied by some previous studies such as Chkili (2016) and Akhtaruzzaman et al. (2021a). In fact, Baur and Lucey (2010) and Baur and McDermott (2010) define an asset as a safe haven if it is negatively correlated or uncorrelated with another asset during extreme market movements. Given that, the asset *i* is regarded as a safe haven for stock market if the estimated parameter δ_2 is zero or negative.

4. Data and preliminary analysis

To achieve our objective, we collect data for twenty MENA stock markets namely (Egypt, Morocco, Tunisia, Jordan, Turkey, Saudi Arabia, Bahrain, Oman, Qatar, and the United Arab Emirates). The overall sample covers the period from January 2013 to July 2021, while the pandemic outbreak period spans from December 31, 2019 to July 20, 2021. For potential safe havens, we consider three precious metals (Gold, Palladium, Platinum) and the most liquid crypto-currency namely Bitcoin which is regarded by several previous studies as a new virtual gold. Data for stock indices and precious metals prices are collected from Bloomberg database. Bitcoin are extracted from coindesk.com. The return series are calculated as follows:

$$r_{it} = lnP_{it} - lnP_{it-1}$$

Where r_{it} is the return of market *i* at time *t* and P_{it} is the price of the considered market.

Table 1 reports descriptive statistics for all the time series returns. Panel A shows that all stock markets exhibit positive mean returns except Oman. The stock market of the United Arab Emirates is the most profitable with an average return of 0.0443 followed by the Egyptian stock

market (0.0299) and Turkish stock market (0.0245). The standard deviation shows some dissimilarity in the volatility of MENA stock markets. The most volatile markets are these of Turkey, Egypt and KSA with a standard deviation of 1.4091, 1.3605 and 1.0383, respectively. The most stable is Tunisian stock exchange. The Skewness coefficients are negative except for Jordan stock market and Bitcoin while the Kurtosis coefficients are higher than three for all the considered series suggesting the departure from normal distribution. This result is confirmed by the Jarque-Bera test. The calculated statistics of the test are all significant at conventional level rejecting thus the normal distribution. The Ljung-Box applied to square residuals at 10 lags and the ARCH-LM test show the presence respectively of both serial correlation and the ARCH effect in return series of all the stock, precious metals and Bitcoin markets.

Table1
Descriptive statistics for stock market, precious metals and Bitcoin returns

	Mean	**S.D.**	**Skewness**	**Kurtosis**	**JB**	**$Q^2(10)$**	**ARCH(5)**
Panel A: Stock markets							
REGY	0.0299	1.3605	-1.2358	22.401	35540.4**	533.97**	110.82**
RMOR	0.0117	0.6582	-1.6473	33.427	97034.7**	1638.05**	238.38**
RTUN	0.0208	0.4528	-1.1854	15.185	14138.6**	580.95**	57.084**
RJOR	0.0038	0.4825	0.1338	16.963	18122.9**	122.27**	20.349**
RTUR	0.0245	1.4091	-0.8181	8.5894	3151.65**	132.77**	13.374**
RBAH	0.0176	0.5091	-3.0644	61.731	323990**	83.861**	14.541**
RKSA	0.0203	1.1492	-2.4374	37.807	114781**	177.85**	26.730**
ROMA	-0.0155	0.6549	-1.2340	47.573	185171**	243.58**	24.660**
RQAT	0.0111	1.0383	-0.9318	25.038	45453.4**	79.099**	8.832**
RUAE	0.0443	1.0788	-1.2208	27.908	58202.6**	1288.47**	163.80**
Panel B Potential safe haven							
RGOL	0.0032	1.6505	-0.0089	18.023	20970.6**	462.71**	140.09**
RPAL	0.0596	1.8682	-0.7691	20.572	29238.5**	719.37**	24.503**
RPLA	-0.0164	1.4633	-0.5384	11.784	7277.5**	753.88**	90.021**
RBTC	0.3459	6.6311	3.8524	130.62	151897**	226.54**	41.686**

Note: SD is the standard deviation. JB is the Jarque-Bera test for normality. $Q^2(20)$ is the Ljung–Box statistics for serial correlation applied to standardized squared residuals. ARCH(5) is the test for conditional heteroskedasticity.

Table 2 provides results for some unit root and stationarity tests applied to return series. As shown, the statistics of the augmented Dickey Fuller (ADF) and Philips-Perron (PP) unit root tests are significant in all cases at conventional level. So, we can reject the null hypothesis of unit root and all the considered series are stationary. This result is confirmed by the KPSS stationarity test as the calculated statistics are lower than critical values at all conventional level.

Table2
Unit root and stationary test results

	ADF test	PP test	KPSS test
REGY	29.1706**	-43.3950**	0.2316
RMOR	-40.4134**	-40.7443**	0.0563
RTUN	-36.4791**	-36.8175**	0.0858
RJOR	-41.3746**	-41.6631**	0.2273
RTUR	-47.9993**	-47.9924**	0.0559
RBAH	-17.050**	-47.144**	0.1080
RKSA	-18.1699**	-48.8835**	0.1287
ROMA	-21.8814**	-42.5855**	0.1481
RQAT	-46.4884**	-46.5542**	0.1171
RUAE	-25.4884**	-47.0518**	0.1979
RGOL	-29.5813**	-72.2255**	0.2947
RPAL	-43.5042**	-49.4998**	0.1549
RPLA	-45.8321**	-45.8127**	0.1355
RBTC	-22.8329**	-48.5598**	0.1645

Note: ADF and PPt sand for the empirical statistics of Augmented Dickey-Fuller and Phillips-Peron unit root tests. KPSS is the empirical statistics of Kwiakowski-Phillips-Shmidt-Shin test for d stationarity.

Fig. 1 plots the time series for stock market indices, precious metal prices and Bitcoin. As shown all the considered stock markets exhibit an increasing trend during the period under study with some observed drops that vary across markets and periods. More interestingly, all MENA equity markets have fallen significantly at the end of 2019 as response to the emergence of the coronavirus. The health crisis has emerged in China and has propagated swiftly to developed and emerging countries. Afterwards, the stock market indices resumed their increasing trend.

The gold and palladium have continued their up growing trend during the COVID-19 outbreak. This result is not surprising since gold is considered as a traditional safe haven while palladium exhibits this property at time of bearish market. Bitcoin price is stable and displays low values during the period 2013-2019. However, Bitcoin price has jumped significantly during the last two years to reach its maximum value at the end of 2020.

Fig. 2 exhibits the return series for stock markets, precious metals and Bitcoin. As we can see all series display the phenomenon of volatility clustering. More precisely, large (small) variations in the time series tend to be followed by large (small) variations of either signs. This feature characterizes all the considered series and can be considered using the GARCH-class model. Such model allows us describing the dynamic correlation between assets over time and to specify potential diversification opportunities between them.

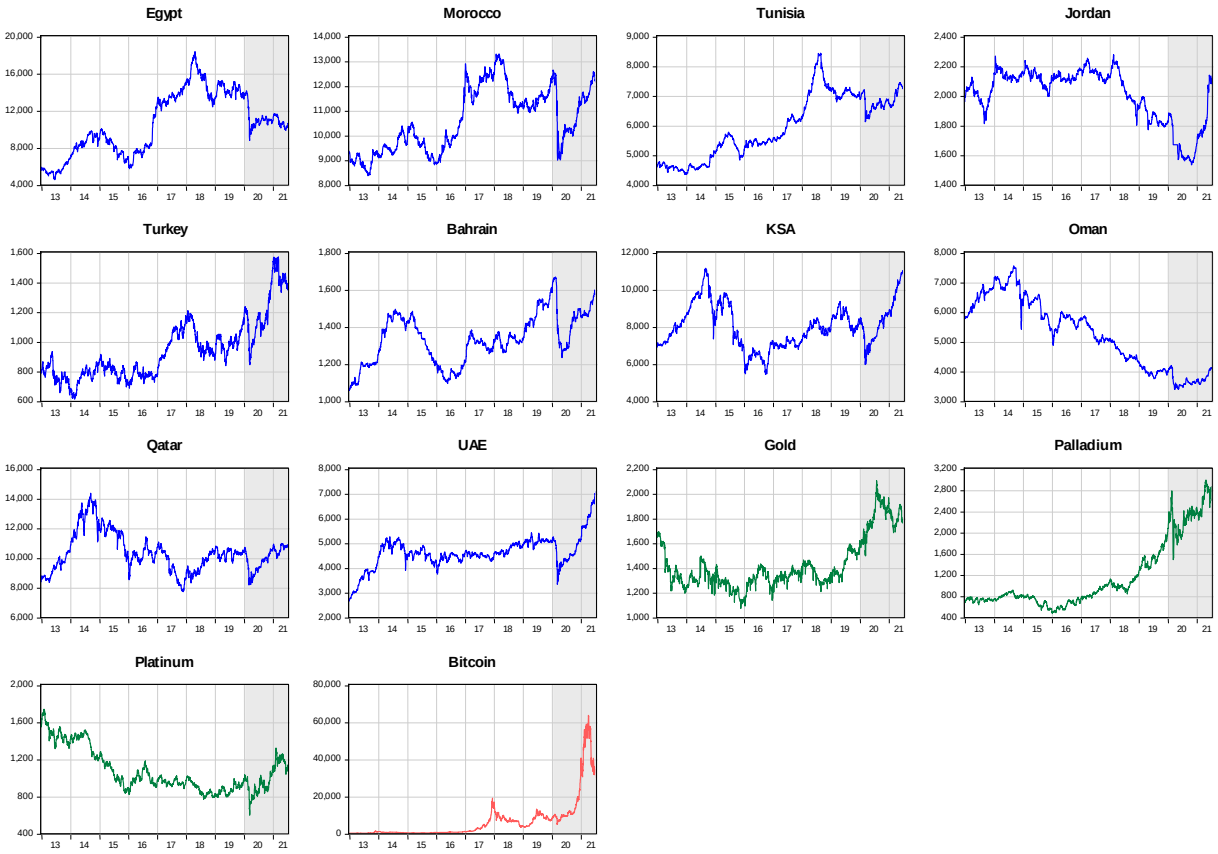

Fig 1. Evolution of the MENA stock market indices, precious metal prices and Bitcoin (The shaded area denotes the COVID-19 period)

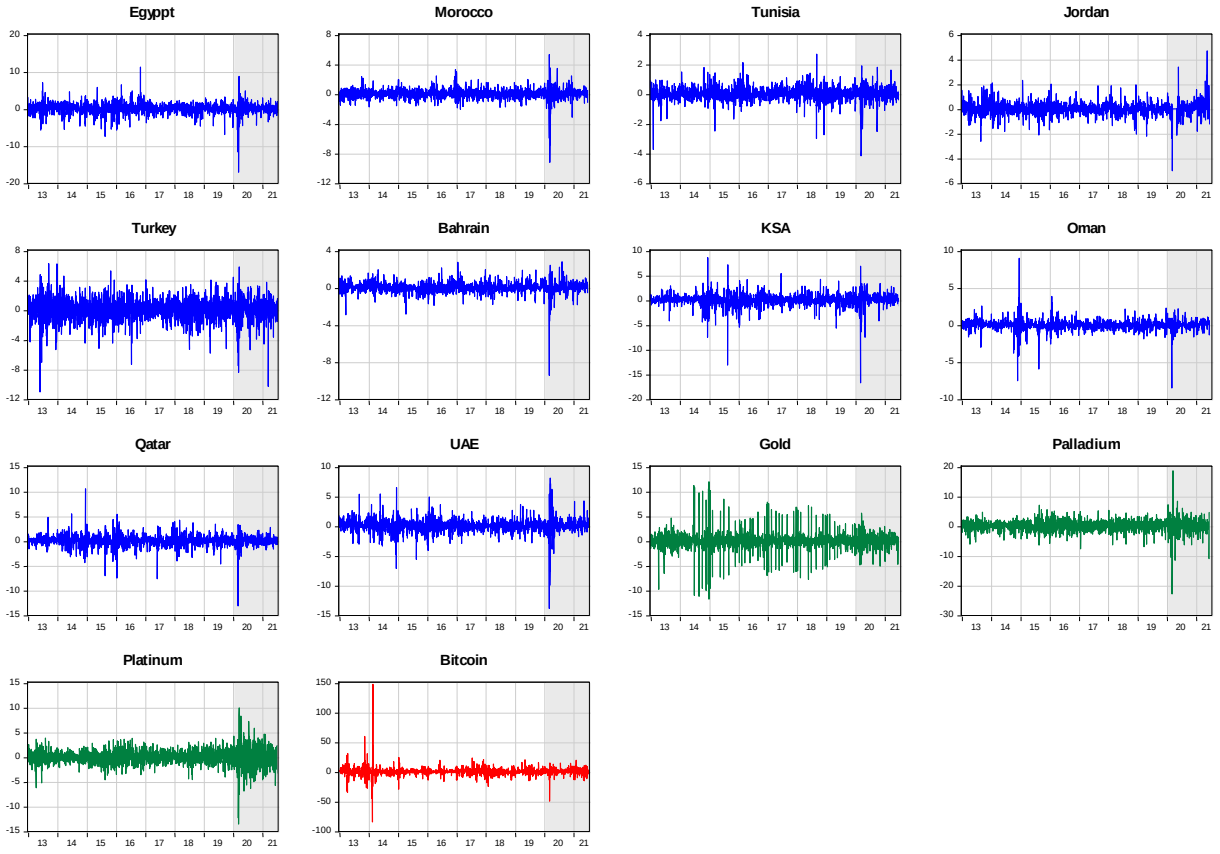

Fig 2. Return series of the MENA stock markets, precious metals and Bitcoin (The shaded area denotes the COVID-19 period)

5. Empirical results

5.1. GARCH estimation results

The estimation results of the DCC-GARCH model for the MENA stock markets with gold, palladium, platinum and Bitcoin are reported in Table 3. Panel A presents the estimation coefficients of the mean and variance equations. We start by identifying the lag number of the mean equation. According to the Akaike information criterion and the Schwartz information criterion, the optimal lag length is equal to one. The autoregressive parameter of the mean equation is statistically significant in all cases except for palladium, Bitcoin, Turkey and Bahrain suggesting that current return depends on its past values.

Table 3 Estimation results of the bivariate AR(1) DCC-GARCH

	Mean equation		Variance equation			Average correlation				Diag. test
	C(m)	AR(1)	C(*v*)	A	β	ρ_1	ρ_2	ρ_3	ρ_4	$Q^2(20)$
Panel A first step univariate GARCH										
Gold	-0.0788***	-0.228***	1.021**	0.190***	0.371*	-	-	-	-	10;006
	(-3.009)	(-7.405)	(2.171)	(4.553)	(1.587)					[0.587]
Palladium	0.065*	-0.002	0.077	0.058**	0.918***	0.2136***	-	-	-	25.542
	(1.938)	(-0.094)	(1.362)	(2.181)	(23.21)	(7.958)				[0.181]
Platinum	-0.032	0.041*	0.008	0.046***	0.951***	0.3691***	0.5044***	-	-	14.013
	(-1.320)	(1.634)	(1.517)	(2.829)	(59.65)	(10.94)	(28.82)			[0.830]
Bitcoin	0.215**	0.015	1.351***	0.221***	0.768***	0.0397	0.0606*	0.0588*	-	20.858
	(2.404)	(0.434)	(3.287)	(5.035)	(25.94)	(1.566)	(1.752)	(1.775)		[0.405]
Egypt	0.045*	0.119***	0.130***	0.095***	0.833***	-0.0155	0.0244	0.0431	0.0039	33.216
	(1.703)	(5.089)	(3.084)	(3.560)	(23.72)	(-0.556)	(0.955)	(1.614)	(0.143)	[0.032]
Morocco	0.017	0.103***	0.041**	0.163***	0.715***	-0.0007	0.0269	-0.0010	-0.0023	15.913
	(1.465)	(4.287)	(2.124)	(2.963)	(6.839)	(-0.031)	(1.231)	(-0.041)	(-0.097)	[0.722]
Tunisia	0.017*	0.248***	0.034***	0.233***	0.589***	-0.0078	0.0409*	0.0142	0.0075	6.281
	(1.584)	(9.596)	(2.789)	(4.985)	(5.819)	(-0.380)	(1.813)	(0.551)	(0.292)	[0.998]
Jordan	-0.005	0.101***	0.018**	0.088***	0.830***	-0.0064	0.0341	0.0454	0.0416	11.311
	(-0.558)	(4.031)	(2.384)	(3.248)	(15.77)	(-0.322)	(1.217)	(1.590)	(1.286)	[0.938]
Turkey	0.068**	-0.001	0.171***	0.077***	0.837***	0.0304	0.1503***	0.1311***	0.0504*	9.352
	(2.283)	(-0.002)	(3.477)	(3.387)	(22.93)	(1.256)	(5.747)	(5.145)	(1.808)	[0.978]
Bahrain	0.036*	0.031	0.032***	0.134	0.765***	-0.0177	0.0581***	0.0332	0.0112	5.272
	(1.941)	(0.352)	(5.085)	(0.986)	(15.30)	(-0.736)	(2.885)	(1.425)	(0.241)	[0.999]
KSA	0.076***	0.053	0.032***	0.104***	0.881***	0.0034	0.0801***	0.0793***	0.0278	30.794
	(3.499)	(1.298)	(2.929)	(3.392)	(43.30)	(0.102)	(3.373)	(2.983)	(0.755)	[0.058]
Oman	-0.004	0.230***	0.026***	0.143***	0.811***	0.0773*	0.0404*	0.0601**	0.0187	11.181
	(-0.261)	(5.349)	(3.376)	(2.943)	(34.56)	(1.850)	(1.818)	(2.103)	(0.454)	[0.941]
Qatar	0.050**	0.059**	0.046***	0.111***	0.858***	0.0322	0.0641***	0.0655**	0.0056	24.246
	(2.260)	(2.343)	(2.866)	(3.335)	(41.74)	(1.102)	(2.717)	(2.527)	(0.146)	[0.232]
UAE	0.072***	0.048*	0.059***	0.131***	0.812***	0.0293	0.1008***	0.0688***	-0.0134	14.658
	(3.844)	(1.878)	(4.785)	(3.667)	(32.55)	(1.231)	(4.422)	(2.932)	(-0.573)	[0.796]

Panel B second step DCC

a	*b*	*Student-df*	*Log L*	*AIC*	*BIC*	*SIC*	*HQIC*
0.0047** (2.494)	0.9425*** (24.82)	4.937 (31.92)	-41201.406	34.7904	34.7805	35.2104	34.9437

As regards the variance equation, all the estimation parameters of the GARCH model are significant for all the considered series. This indicates that conditional variances of stock markets, precious metals and Bitcoin are affected by their own past shocks and volatilities. In addition, the value of the GARCH coefficients is higher for most markets suggesting high persistence of volatility over time. We also observe that the stationarity condition is respected since the sum of ARCH and GARCH coefficients is less than one. Finally, the average correlation between MENA stock indices and precious metals and Bitcoin is low and sometimes negative suggesting the presence of potential diversification opportunity between assets. Such investigation requires thorough analysis through sophistical methods.

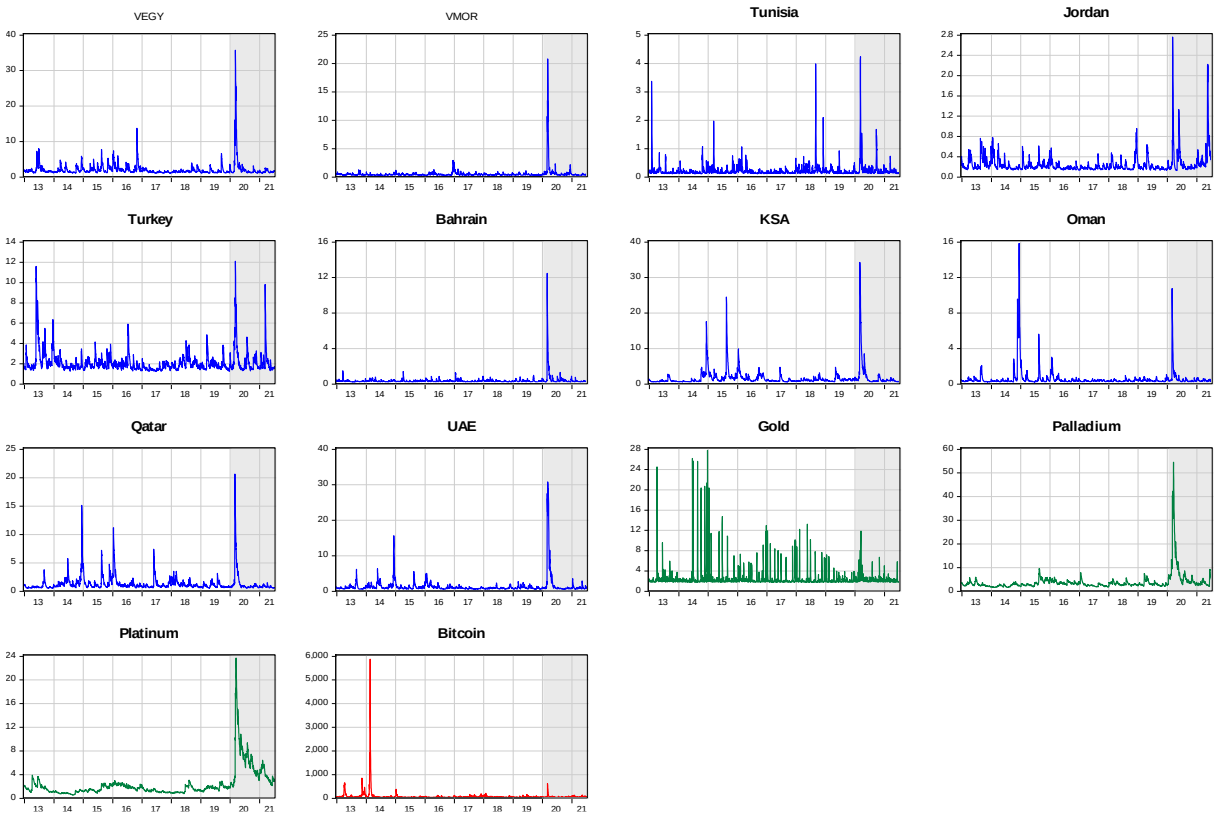

Fig 3. Conditional variance from GARCH model estimation

Fig. 3 displays the evolution of the conditional volatility of the MENA stock markets, precious metals and Bitcoin for the period under investigation. The series are obtained from the estimation results of the multivariate GARCH model. From the plots we can see that all the considered stock market indices have experience a substantial volatility during the first wave of the COVID-19 pandemic. This result is not surprising as crisis the health has propagated swiftly for both developed and emerging economies. This indicates risk transmission from COVID-19 to MENA equity markets which requires an in-depth analysis in terms of portfolio diversification and hedging instrument choice. Zhang et al. (2020) reveal that the rapid spread

of coronavirus has affected dramatically financial markets all over the world. Consequently, global financial market risks have increased substantially in response to the pandemic. Baek et al. (2020) also find significant increase in total risk for the US stock market with the inception of COVID-19. Akhtaruzzaman et al. (2021b) suggest that dynamic link between Chinese and G7 financial and nonfinancial stock returns has increased significantly during the COVID–19 outbreak.

The precious metals have reacted differently to the coronavirus. The conditional variance plots of palladium and platinum show a significant jump for their price volatilities. However, gold market exhibits a low volatility during the pandemic. This confirms the traditional role of gold as refuge asset. Finally, Fig. 3 shows that the health event did not affect the Bitcoin market which has kept its period of stability. The divergence in the reaction of precious metals and Bitcoin to the recent COVID-19 crisis leads us to determine their ability to cover the risk on MENA stock markets.

5.2. Dynamic Conditional correlation

The dynamic correlations between the four potential haven assets and each stock market are reported in Fig. 4. We can see that for all the considered MENA stock markets, the dynamic correlation is not stable and switches between low positive and negative values during the period under investigation. This indicates on whole that some opportunities of diversification exist between assets. However, some dissimilarities appear between markets according to precious metals or cryptocurrency considered in the estimation. Bouri et al. (2020) reveal that the overall dependence between Bitcoin/gold/commodities and the stock markets is not very strong at various time scales and that the benefits of diversification change considerably in the time frequency space. Chemkha et al. (2021) show that correlation levels are low or negative and vary throughout the periods and markets suggesting that gold and Bitcoin can play significant role in hedging against developed stock markets.

Regarding COVID-19 period, the correlation between each stock market and the four hedging assets has increased slightly during the first wave of the pandemic. This is due to negative reaction of stock markets to the information related to the spread of virus worldwide, mortality rate, infection rates and interventions of health, social, economic and monetary authorities (Chemkha et al., 2021 and Baker et al., 2020). Besides, gold and Bitcoin have reacted inversely to shock following to the sharply raise in their prices. Such raise is assigned to the behavior of international investors who choose these two assets to accomplish optimal allocation strategies. In other words, investors lean to these two assets in order to reduce investment risk and protect their wealth (Bofinger et al., 2020). Disli et al. (2021) find that the linkage between each equity

market and the three hedging assets namely gold, oil and Bitcoin varies across time and investment horizon. Furthermore, the correlation has increased at the onset of the COVID-19 pandemic.

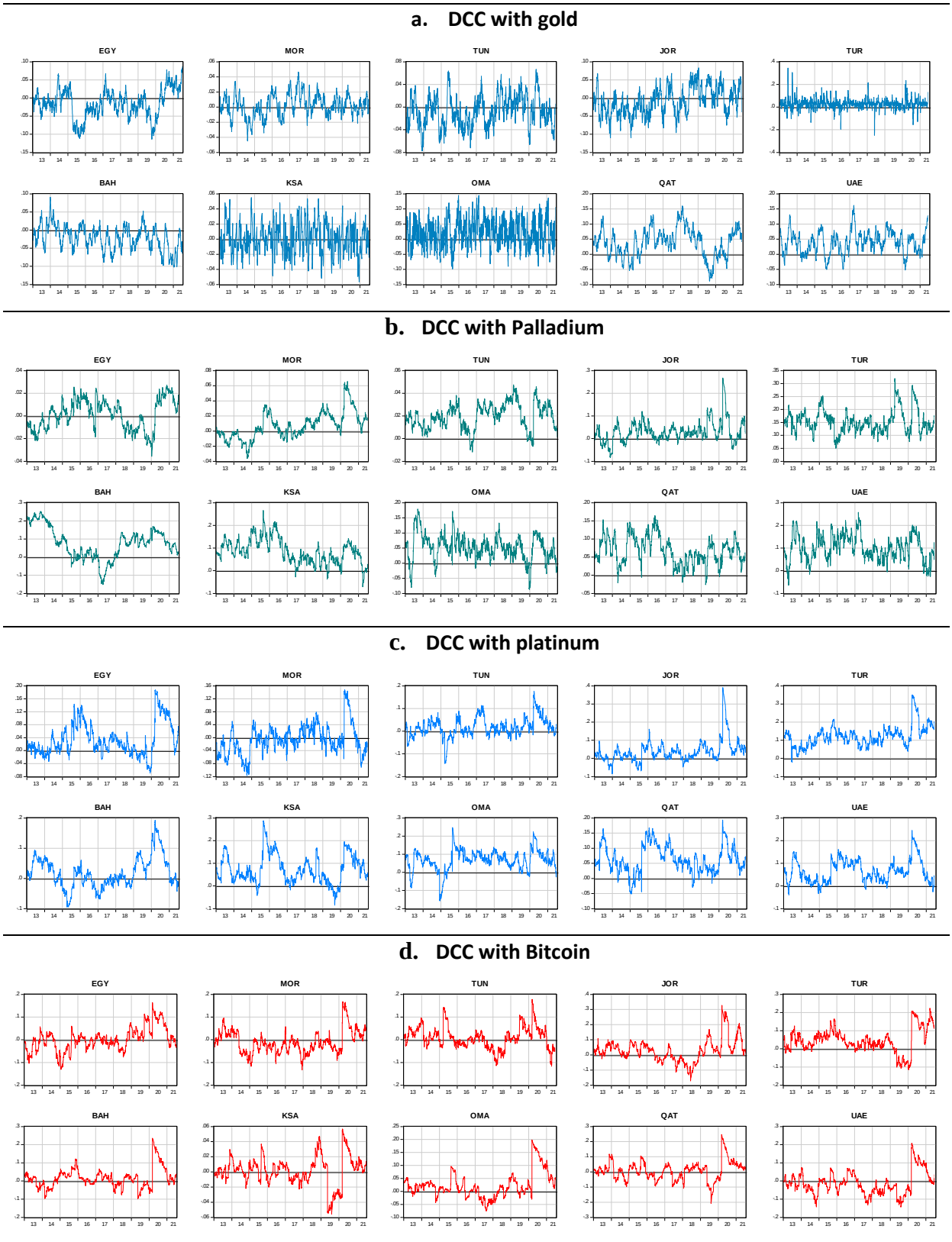

Fig. 4. Dynamic conditional correlation

5.3. Dynamic volatility spillover

Fig. 5 shows the time-varying total volatility index between MENA stock markets, precious metals and Bitcoin. The volatility spillover is not stable and affected by such events. More precisely, the volatility spillover has achieved its maximum value during the COVID-19 crisis. This suggests that precious metals, Bitcoin and MENA stock markets are affected by the health crisis caused by the emergence of the coronavirus in China. However, this plot exposes a global index which requires a more detailed analysis by pair of assets in order to better clarify the direction of volatility.

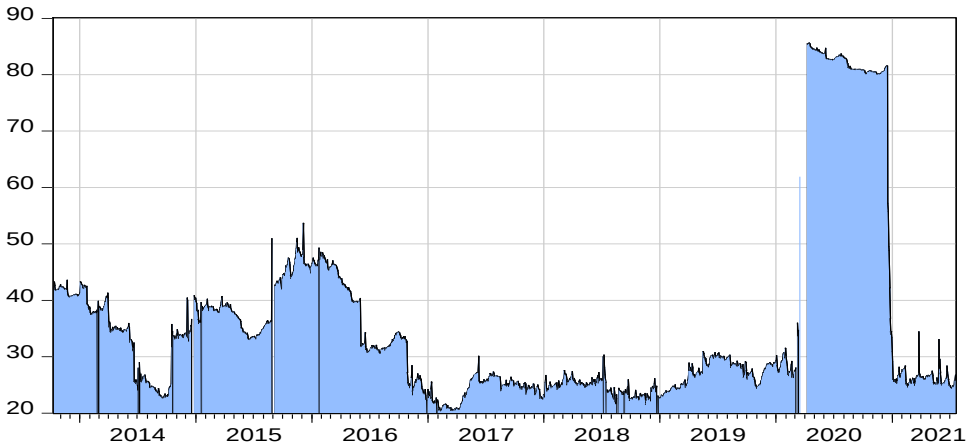

Fig 5. Dynamic of total volatility spillover index

Table 4 reports the results of the total volatility spillovers between all the considered markets. From the results we analyze the directional of volatility spillovers by identifying among studied markets the net receiver and net transmitter of shocks. As shown in the table, the total volatility spillover between MENA markets and potential refuge assets is 41,9% which is lower than 50% highlighting the existence of some diversification opportunity between them. In addition, we show that gold, platinum and Bitcoin are a net receiver of shocks while palladium is a transmitter of shocks to MENA stock markets. More interestingly, gold and Bitcoin have a lower impact on MENA stock equities. The two assets contribute to the MENA stock market volatilities by 0.4% and 0.2% respectively. This result is in line with most previous empirical and theoretical studies. Gold is usually considered as a traditional hedge instrument for stock markets. Besides, Bitcoin is regarded as a new virtual gold and so can substituted gold in their traditional role.

Table 4
Total volatility spillovers between precious metals, Bitcoin and MENA stock markets

	Gold	Palladium	Platinum	Bitcoin	Egypt	Morocco	Tunisia	Jordan	Turkey	Bahrain	KSA	Oman	Qatar	UAE	From others
Gold	95.5	0.1	0	0	0.1	0.2	0.3	0.1	0.1	0.3	0.6	1.7	0.5	0.2	4.1
Palladium	0.3	56.4	2.2	0	7.7	2.5	1.4	2.1	0.4	21.6	3.6	1.3	0	0.3	43.6
Platinum	0.6	17.5	53.1	0	1.2	5.5	0	1	0.4	18.3	1.8	0.1	0.1	0.3	46.9
Bitcoin	0.0	0.4	0	98.8	0	0	0	0	0.1	0.6	0	0	0	0	12
Egypt	0.2	10	12.7	0.1	57.3	2.4	0.2	1.5	2.4	11.1	1.8	0	0	0.3	42.7
Morocco	0.0	9.6	7.8	0	11.7	28.7	0.1	2.7	0.5	37.2	1.3	0	0	0.3	71.3
Tunisia	0.0	3.6	2	0	12	4.4	74	12	0.4	11.5	1.1	0	0.1	0.3	26
Jordan	0.1	5.5	5.7	0	3.7	5.2	0.6	66	0.3	11.9	0.9	0	0	0.1	34
Turkey	0.0	4.7	3.3	0	2.3	1.6	0.1	0.5	83.6	3.7	0.1	0	0	0	16.4
Bahrain	0.0	3.3	0.8	0	13	7.4	0.4	3.3	0.4	70.8	0.2	0	0	0.2	29.2
KSA	0.0	0.1	0.5	0	20	0.7	0.5	1.6	0.5	36	39.4	0.5	0.1	0	60.6
Oman	0.1	0.5	0.2	0.1	6.6	0.3	0.1	0.7	0.3	17.4	14.8	53.1	2.3	3.5	46.9
Qatar	0	0.1	0.1	0	13.2	0.9	0.3	1.3	0.2	33.7	14.3	10.7	23.8	12	76.2
UAE	0	7.2	5	0	22.1	10.5	0	1.5	0.8	33.4	6.1	0.4	0.2	12.7	87.3
To others	1.5	62.6	40.3	0.3	103.1	41.6	4.2	17.4	6.9	236.8	46.6	14.8	3.3	6.8	586.3
All	97.4	119	93.5	99.1	160.4	70.3	78.2	83.4	90.5	307.6	86	68	27.2	19.5	**41.9%**
Net	-2.6	19	-6.6	-11.7	60.4	-29.7	-21.8	-16.6	-9.5	207.6	-14	-32.1	-72.9	-80.5	

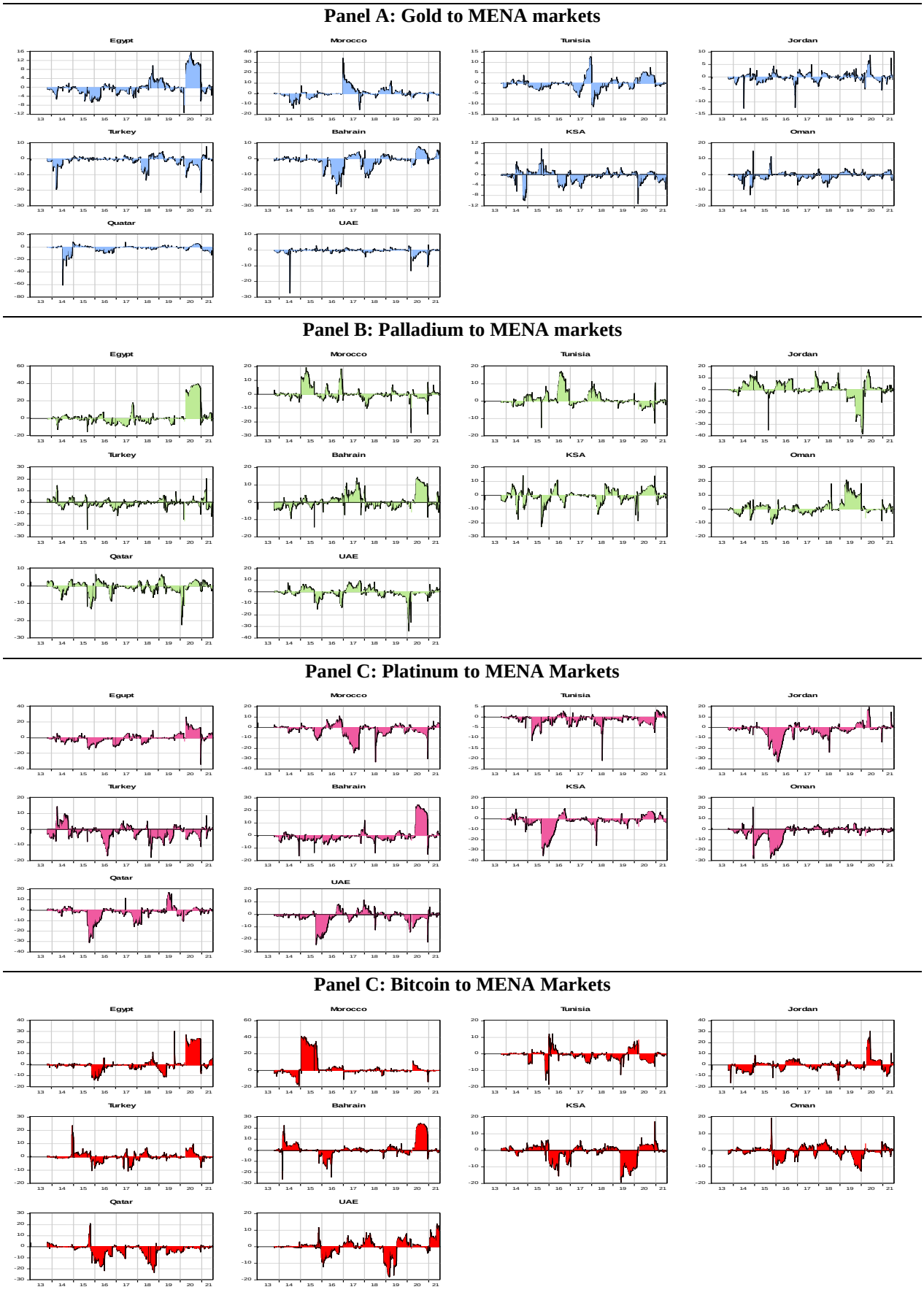

Fig 6. Pairwise directional net volatility spillovers between the precious metals, Bitcoin and MENA markets

The next step of our empirical investigation is to analyze the net volatility spillovers for precious metals and Bitcoin to each MENA stock market. Fig 6 depicts the time varying evolution of the net volatility spillover index of each equity markets. Starting with the net volatility spillovers from gold to each MENA stock market, we see that net volatility is weak and switch around zero. However, some dissimilarities can be observed across markets namely during the COVID-19 period. Overall, the gold market is net receiver of volatility spillovers from MENA markets with the greater spillovers from Egypt and Bahrain. this result is not surprisingly as these two markets are the greatest transmitters of volatility spillovers. This finding proves the ability of gold to hedge MENA stock market risks on average.

As regards the palladium, the plots show that all markets exhibit an important variability in net volatility spillovers. However, most times the palladium appear as net transmitter of volatility to other markets. This confirms results reported in Table 4.

Finally, platinum and Bitcoin volatility indices are mostly low and around zero suggesting weak transmission of volatility from these two assets to MENA markets. Besides, sometimes platinum and Bitcoin seem to be a net receiver of volatility shocks. This feature is in line with some previous studies suggesting that some precious metals and cryptocurrencies can serve as hedging instruments and portfolio diversifier for international investments. Al-Yahyaee et al. (2019) point out that gold and palladium are a net receiver of information from GCC markets. They also conclude that precious metal markets provide stronger hedging effectiveness for all GCC markets for pre- and after Global financial crisis.

5.4. Portfolio design and hedging strategy

Table 5 reports the optimal portfolio weights, the hedge ratios and the hedging effectiveness index for both whole and COVID-19 periods. This allows to verify how portfolio diversification opportunities and hedging strategy choice differ across financial turmoils. We can also examine the ability of the three precious metals and Bitcoin to hedge risks on MENA stock markets during the recent coronavirus crisis.

Table 5 shows that the lower values of optimal weights are linked to the Bitcoin while the highest values are observed for platinum. Starting with the Bitcoin, the optimal weight varies between 0.0111 for the couple Bitcoin/Tunisia stocks and 0.0932 for the couple Bitcoin/Egypt stocks. This means that Tunisian investors should invest 1.11% of their wealth on the Bitcoin market while 98.89% should be allocated to equities. For Egyptian investors, the percentages are 9.32% and 90.68% for Bitcoin and stocks, respectively.

It should be noted that optimal weight of all the considered precious metals is higher than that of Bitcoin respecting the same stock market. It ranges between 0.0809 and 0.4757 for gold,

between 0.0585 and 0.3865 for palladium while it switches between 0.1039 and 0.5324 for platinum. This indicates that MENA investors need more precious metals than Bitcoin in order to reduce the risk of their portfolio without lowering the expected returns. For example, to achieve optimal portfolio diversification, Saudi investors should allocate 33.37%, 25.66% or 37.83% of their budget to gold, palladium or platinum, respectively while the rest of wealth should be invested on equity market. Nevertheless, Saudi investors can reach the same objective by devote only 6.01% of their wealth to Bitcoin market. This result is consistent with those of Chkili et al. (2021) who compare the ability of Bitcoin and gold to hedge Islamic stock markets before and during the COVID-19 outbreak. They find that for all considered Islamic markets the mean values of portfolio weight for gold are higher compared to Bitcoin.

The analysis of the COVID-19 period allows us to see that the average value of the optimal portfolio weight has increased for the period of crisis compared to whole period for gold while it has decreased for the other three assets. During the COVID-19 era, the average value of the portfolio weight for gold ranges between 0.1279 for Jordan stock market and 0.4946 for the Turkish stock market. This means that for one-dollar gold/ stock's portfolio, 12.79 cents should be allocated to gold while the remaining of 87.21 cents should be placed in the Jordan market index. For Turkish investors, the share allocated to gold increases to 49.46 cents against 50.54 cents should be devoted to buy Turkish equities. In the whole, to reduce the risk of their portfolios during the recent health crisis, investors in MENA region should involve more gold in their portfolios than during normal period. Therefore, they can achieve this objective with less of palladium, platinum or Bitcoin during the crisis compared to full period.

The statistics of the optimal weight values between Bitcoin and MENA stocks show that the highest value is observed for the Bitcoin/Turkish stocks pair which reaches 0.0889. However, Bitcoin/Jordan stock market index exhibits the lowest value which equal to 0.0094. This result points out that investors in MENA region can accomplish an optimal portfolio management by allocating between 0.94% and 8.89% of their wealth to the crypto-currency market while the rest should be invested in MENA equity markets. Urom et al. (2020) and Chkili et al. (2021) reveal that investors can achieve diversification benefits across portfolio involving Bitcoin and stocks.

Table 5
Optimal portfolio weights, hedge ratios and hedging effectiveness

	Optimal weight		Hedge ratio		Hedging effectiveness	
	Whole period	COVID-19 period	Whole period	COVID-19 period	Whole period	COVID-19 period
Gold/Egypt	0.4337	0.4386	-0.0268	-0.0235	40.692	51.737
Gold/Morocco	0.1334	0.1728	0.0069	0.0086	11.766	18.853
Gold/Tunisia	0.0809	0.0887	0.0012	0.0017	7.106	10.760
Gold/Jordan	0.1022	0.1279	-0.0039	-0.0013	7.186	11.737
Gold/Turkey	04757	0.4916	0.0306	0.0329	39.378	53.146
Gold/Bahrain	0.1187	0.1427	-0.0092	-0.0116	9.635	20.596
Gold/KSA	0.3337	0.3479	-0.0193	-0.0261	32.763	46.594
Gold/Oman	0.1356	0.1449	0.0215	0.0193	11.248	16.159
Gold/Qatar	0.3128	0.2862	0.0175	0.0165	27.106	38.113
Gold/UAE	0.2881	0.3152	-0.0013	-0.0047	28.467	42.794
Palladium/Egypt	0.3575	0.2607	-0.0074	-0.0005	29.790	4.647
Palladium/Morocco	0.1001	0.0819	0.0031	0.0071	4.265	2.438
Palladium/Tunisia	0.0585	0.0416	0.0028	0.0027	1.087	8.085
Palladium/Jordan	0.0742	0.0668	0.0008	0.0032	2.247	5.151
Palladium/Turkey	0.3865	0.2887	0.0897	0.0736	25.691	6.396
Palladium/Bahrain	0.0762	0.0587	0.0108	0.0106	1.681	2.938
Palladium/KSA	0.2566	0.1829	0.0262	0.0185	20.256	6.866
Palladium/Oman	0.1089	0.0730	0.0074	0.0051	6.087	10.428
Palladium/Qatar	0.2478	0.1454	0.0244	0.0173	17.593	11.105
Palladium/UAE	0.2180	0.1618	000274	0.0227	12.969	5.161
Platinum/ Egypt	0.4882	0.2593	0.0035	0.0127	40.768	1.097
Platinum/Morocco	0.1718	0.0935	-0.0028	0.0004	8.941	2.243
Platinum/Tunisia	0.1039	0.0399	0.0015	0.0027	4.428	14.517
Platinum/Jordan	0.1247	0.0603	0.0040	0.0079	3.721	13.213
Platinum/Turkey	0.5324	0.2853	0.1042	0.0761	39.013	13.698
Platinum/Bahrain	0.1436	0.0638	0.0015	0.0064	5.080	4.487
Platinum/KSA	0.3783	0.1913	0.0311	0.0253	30.936	1.852
Platinum/Oman	0.1769	0.0723	0.0122	0.0124	10.663	27.030
Platinum/Qatar	0.3701	01494	0.0324	0.0217	28.267	18.776
Platinum/UAE	0.3361	0.1744	0.0210	0.0221	27.280	16.067
Bitcoin/Egypt	0.0932	0.0843	-0.0055	-0.0007	3.5175	3.3458
Bitcoin/Morocco	0.0208	0.0231	-0.0020	0.0002	9.5609	9.8952
Bitcoin/Tunisia	0.0111	0.0112	-0.0003	-0.0007	0.9923	0.5082
Bitcoin/Jordan	0.0103	0.0094	0.0019	0.0047	1.0641	1.8966
Bitcoin/Turkey	0.0945	0.0889	0.0066	0.0124	4.3439	6.6446
Bitcoin/Bahrain	0.0159	0.0158	-0.0012	0.0017	1.7033	2.5397
Bitcoin/KSA	0.0688	0.0601	0.0008	0.0038	5.2086	2.3535
Bitcoin/Oman	0.0238	0.0166	-0.0001	0.0031	2.1865	4.4235
Bitcoin/Qatar	0.0633	0.0468	-0.0072	-0.0014	4.7828	7.4106
Bitcoin/UAE	0.0590	0.0587	-0.0101	-0.0043	6.4801	9.5962

Table 5 also displays the optimal hedge ratios. Regarding the gold results, the hedge ratio is negative for Egypt, Jordan, Bahrain, KSA and UAE and positive for others. It varies between -0.0268 for Egypt stock index and 0.0306 for Turkey stock index. This indicates that investors on the markets with negative hedge ratio should take either short or long position for both considered assets (gold and stocks) in order to achieve beneficial hedging strategy. For example, a USD 1000 long position in the Egyptian equity market should be hedged by also a long position of USD 2.68 in the gold market. Therefore, investors of Morocco, Tunisia,

Turkey, Oman and Qatar should take two inverse positions. A USD 1000 short position in the stock market of Oman can be hedged by taking a long position of USD 2.15 in gold market. Note that the hedge ratio has increased in absolute values for some countries during the COVID-10 crisis suggesting that hedging strategy becomes more expensive.

Looking to the palladium and platinum results, we see that the hedge ratios are positive in all cases suggesting that hedging strategy can be accomplished by implementing two inverse positions in stock and precious metal markets. For example, a USD 1000 short position in the Saudi stock market should be hedged by accomplishing a long position of USD 2.62 in the palladium market or USD 3.11 in the platinum market, respectively. The results also show that the hedge ratios of these two precious metals are lower than those of gold for all countries. In effect, these two metals offer for MENA investors a hedging strategy with lower costs than the yellow metal.

With regards to the results of the major cryptocurrency, the hedge ratios in absolute values are lower compared to those of all the precious metals. More precisely, investors in MENA region can use Bitcoin in order to accomplish an efficacious hedging strategy for their stock investments with lower cost. This result is consistent with the growing interest of international investors to the Bitcoin market. Chkili et al. (2021) reveal that Bitcoin presents a high ability to hedge Islamic market risks. Furthermore, investors need much smaller budget in Bitcoin than in gold to hedge equity investment uncertainty. Note that Table 5 reports only the average values the hedge ratios. However, these ratios are not stable over the period study and are somewhat volatile as shown in Figs A1-A4.

To evaluate the performance of hedging strategy, we calculate in the two last columns in Table 5 the Hedging effectiveness index. High index values correspond to a hedging efficiency with a better risk reduction. The main conclusion is that the hedging efficiency varies across markets and periods. More precisely, none of the potential hedge assets can be considered as the best one for all markets. In addition, such asset does not exhibit similar effect for all periods. From the results reported in the table, we can see that gold have the higher values of hedging effectiveness index compared to the other precious metals and Bitcoin. In other words, portfolio involving gold and stocks leads to greater reductions of risk. The risk reduction varies between 40.692% for Egypt and 7.106% for Tunisia. This result is consistent with those of some previous studies (Chemkha et al., 2021; Shahzad et al, 2020). These studies conclude that gold outperforms other assets in terms of hedging efficiency. More interestingly, the values of hedging index increase significantly during the COVID-19 crisis for all countries indicating greater risk minimization during the pandemic. Example for Turkish context, HE skips from

39.378 for the full sample to 53.146% during the recent health crisis. This reveals that gold continues to play his traditional role as a hedge and safe haven for extreme market conditions. Turning to the two other precious metals, results show that HE is weaker than that of gold in all cases. For example, the HE for Turkey decreases to 39.013% and 25.601% for platinum and palladium, respectively. This result confirms the superiority of gold as effective hedging instrument for stocks (Chemkha et al., 2021). However, unlike gold, the ability of these two metals to reduce portfolio risk in the MENA region has lowered substantially during the COVID-19 pandemic. Thereby, the HE index for the two assets has decreased during the crisis for most cases. This indicates that palladium and platinum failed to compete gold as effective hedge.

Finally, Bitcoin produces the lowest risk reduction compared to precious metals. Practically, the variance of the hedged portfolio involving stocks and Bitcoin is reduced between 1.0641% for Jordan and 9.5609% for Morocco. This result is consistent with those of Chemkha et al. (2021) for major word stock markets, Shahzad et al. (2020) for G7 stock markets and Charfeddine et al. (2020) for S&P 500 index. Shahzad et al. (2020) find that gold exhibits higher HE values than Bitcoin for all the G7 countries suggesting that gold is a more effective hedge for stocks than Bitcoin. Rubbaniy et al. (2021) reveal that the portfolios including commodities are less risky and efficient compared to the portfolio containing stocks only. Besides, their results firmly support the safe haven properties of soft commodities during COVID-19.

5.5. Safe haven effect

We report in Table 6 the estimation results of Eq. (16). As regards the gold results, the coefficient δ_2 is negative and statistically significant for Egypt, Bahrain, KSA, Qatar and UAE. This prove that gold plays a strong safe haven during extreme market conditions of GCC countries. In addition, for the other countries the coefficient is statistically not different from zero suggesting that gold can act as a weak safe haven for these countries. In the whole, results show that gold maintains its traditional propriety as safe haven asset during the crisis of the COVID-19 pandemic. This result is consistent with those of several previous studies (Akhtaruzzaman et al., 2021a; Salisu et al., 2921; Ji et al., 2020; Syuhada et al., 2021). Akhtaruzzaman et al. (2021a) use the DCC-GARCH model to investigate the role of gold as a hedge or safe-haven asset during the COVID-19 era. They find that gold has served as an effective safe haven for stock markets during the first wave of the pandemic. Syuhada et al. (2021) suggest that the addition of gold in international portfolio substantially reduces the downside risk indicating its safe-haven ability.

For the palladium, the estimated coefficient relying COVID-19 period and DCC is statistically not significant in all cases except for Egypt and Morocco. This suggest that palladium can be regarded as a weak safe haven in the MENA region except for the two north African countries. Turning to the platinum, this coefficient is significant and positive for Egypt, Jordan and Turkey and not significant for the other MENA stock markets. Thus, we can conclude that these two precious metals exhibit low safe haven qualities against MENA stock market movements. Salisu et al., 2921 find quite similar results for the US stocks. They point out that gold consistently offers better safe haven properties than other precious metals like silver, palladium and platinum during the COVID-19 outbreak.

Finally, for the Bitcoin the coefficient δ_2 is positive and statistically significant for all cases except Egypt and Tunisia. The positive sign of the coefficient indicates that the two assets vary in the same direction. Consequently, this cryptocurrency cannot act as a safe haven for MENA stock markets during the COVID-19 crisis. This result is in line with those of Conlon et al. (2020), Raheem (2021), Hasan et al. (2021) and Chemkha et al. (2021). Conlon et al. (2020) test the safe haven properties of three cryptocurrencies from the perspective of international equity investors during the COVID-19 pandemic. They conclude that Bitcoin and Ethereum fail securing the majority of international equity markets during the health crisis. Raheem (2021) examine the safe haven prowess of Bitcoin against VIX, EPU and oil shock as proxy of uncertainty for pre-and post-COVID-19 period. His results reveal that prior to COVID-19 Bitcoin has maintain its characteristics as a shelter. However, the post COVID-19 shows that the safe haven proprieties of Bitcoin have fizzled out. Chemkha et al. (2021) share the same view for major world stock market indices and currencies. They conclude that Bitcoin variability has increased significantly and consequently this cryptocurrency cannot provide haven during the recent crisis. Kakinuma (2021) points out that bitcoin does not provide protection for investors in Southeast Asia during the turbulent period of COVID-19.

Table 6
Safe haven effects

	EGY	MOR	TUN	JOR	TUR	BAH	KSA	OMA	QAT	UAE
Panel A: Gold										
δ_0	-0.0002*	0.0002	0.0001	-0.0001*	0.0004**	-0.0001	0.0004	0.0014***	0.0001	0.0001
δ_1 (DCC (-1))	0.991***	0.991***	0.983***	0.986***	0.982***	0.992***	0.973***	0.935***	0.996***	0.996***
δ_2 (COVID-19)	-0.0007**	0.0006	0.0002	0.0002	-0.0003	-0.0004*	-0.0002***	-0.0001	-0.0008***	-0.0002*
Panel B: Palladium										
δ_0	-0.0002	0.0001	0.0002***	0.0005**	0.0028***	0.0002	0.0010***	0.0012***	0.0011***	0.0023***
δ_1 (DCC (-1))	0.986***	0.993***	0.988***	0.981***	0.982***	0.997***	0.988***	0.976***	0.983***	0.977***
δ_2 (COVID-19)	0.0003**	0.0002**	0.0002	0.0006	0.0003	-0.0002	-0.0003	-0.0005	0.0008	-0.0007
Panel C: Platinum										
δ_0	0.0003*	-0.0002	0.0002	0.0003	0.0018***	0.0008	0.0007**	0.0010***	0.0008***	0.0006**
δ_1 (DCC (-1))	0.984***	0.984***	0.981***	0.984***	0.983***	0.994***	0.988***	0.983***	0.986***	0.989***
δ_2 (COVID-19)	0.0014***	0.0004	0.0005	0.0014**	0.0018***	0.0004	0.0006	0.0005	0.0004	0.0003
Panel D: Bitcoin										
δ_0	-0.0005	-0.0004**	0.0001	0.0002	0.0004	0.0003	-0.0002	0.0001	-0.0001	-0.0005**
δ_1 (DCC (-1))	0.988***	0.985***	0.987***	0.989***	0.986***	0.982***	0.985***	0.984***	0.085***	0.984***
δ_2 (COVID-19)	0.0004	0.0013***	-0.0002	0.0010*	0.0017***	0.0013**	0.0003*	0.0014***	0.0013**	0.0015***

6. Conclusion and discussion

This paper investigates the safe haven properties of three precious metals (gold, palladium, platinum) and Bitcoin against uncertainties associated with the COVID-19 pandemic. We apply two types of models namely the DCC-GARCH and the Diebold-Yilmaz spillover index for twenty MENA stock markets. The empirical results show that COVID-19 uncertainty has swiftly transmitted to MENA countries. This is followed by high volatility of stock markets and substantial risk. However, the conditional correlation between precious metals/Bitcoin and each MENA stock market is highly volatile during the period under investigation and switch between low positive and negative values indicating the existence of some diversification opportunities between them.

The results of hedging ability show that gold performed relatively better than all other considered assets for both the full period and the COVID-19 period. However, adding gold in portfolio of stocks leads to a substantial reduction of portfolio risk. More interestingly, this result is observed for both importer and exporter MENA countries. This suggests that gold maintains its traditional role as a strong hedge for equity markets.

Our results for COVID-19 period reveal that gold preserve its propriety of effective safe haven during turmoil periods. More precisely, gold acts as a strong safe haven for major GCC countries and Egypt while it serves as a weak safe haven for the other countries of the MENA region. However, Bitcoin that considered as a new virtual gold fails to exhibit this property for all markets.

These findings have several empirical implications for risk managers, financial analysts, policy makers and international investors. Indeed, the exploration of the extent and magnitude of volatility spillover between markets is an essential task in the area of finance. In addition, understanding the nexus between financial, commodity and crypto-currency markets becomes increasingly important for all market participants during the COVID-19 outbreak. Such analysis can help on the one hand investors to evaluate the risk of their investments in the MENA stock markets during the crisis period. On the other hand, it allows confronting various potential safe haven assets in order to achieve an optimal diversification strategy. This is due, to the fact, that the COVID-19 pandemic has caused severe distress to financial and commodity markets which incites investors searching investment strategy involving the better safe haven to protect themselves from the drawbacks of this pandemic. More interestingly, Investors in the MENA region should more head to gold market given the yellow metal can act as a strong hedge and safe haven against MENA stock equity movements. In other words, investors in the MENA region should involve gold in their portfolio of stocks to shelter their investments.

Portfolio manager can use the findings to search potential safe havens and to propose optimal portfolio allocation to individual and institutional investors during the crisis. Policy makers in MENA region can rely on the findings in order to develop their stock exchange through the diversification of the investment opportunity and the attracting of international investors. Such decision should stimulate economic growth in these countries.

Appendices

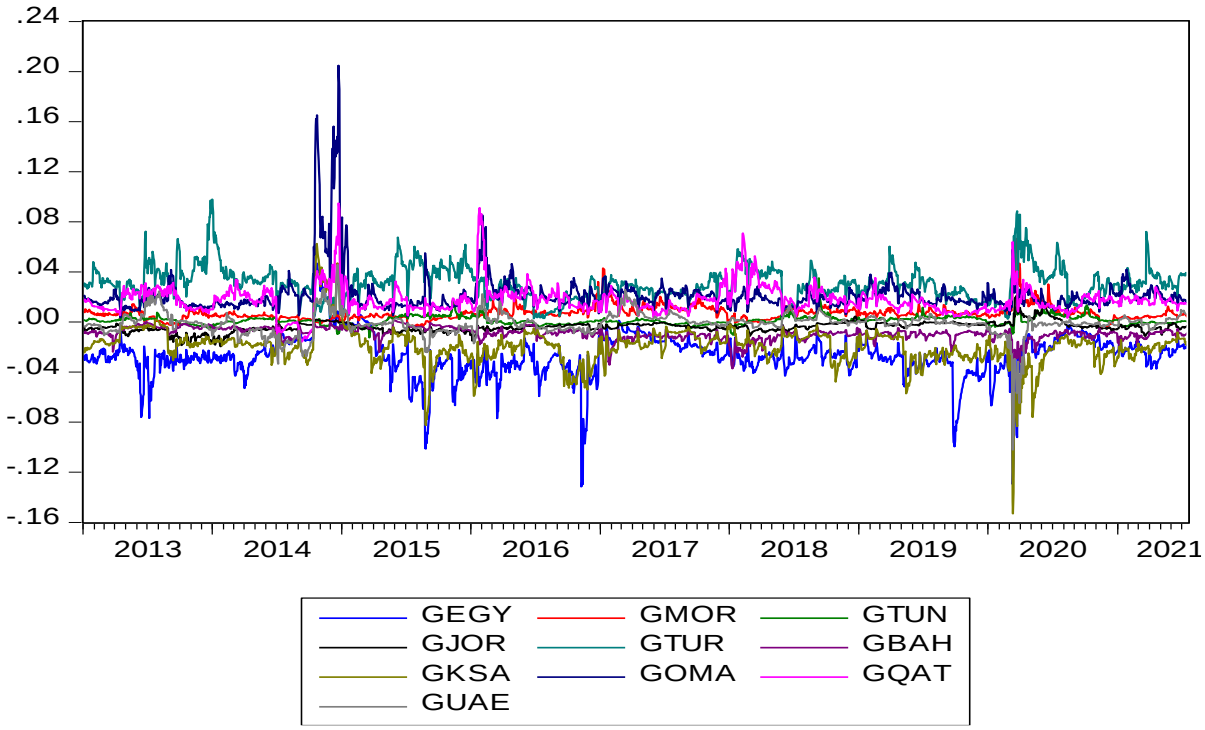

Fig. A1. Optimal hedge ratios for gold

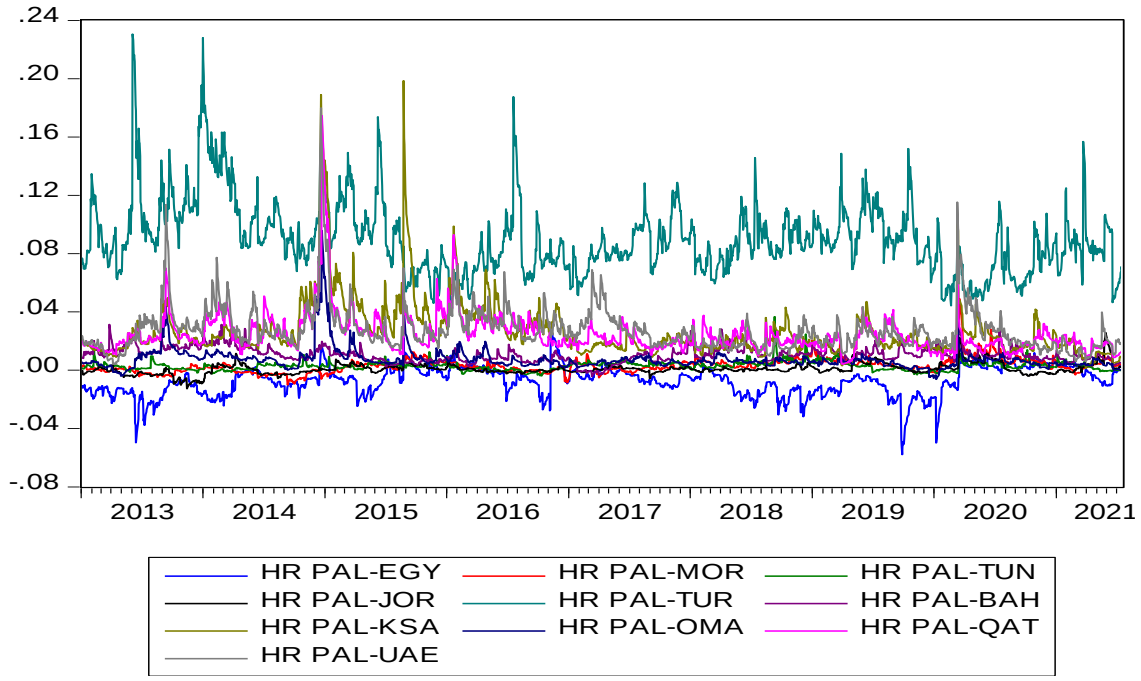

Fig. A2. Optimal hedge ratios for Palladium

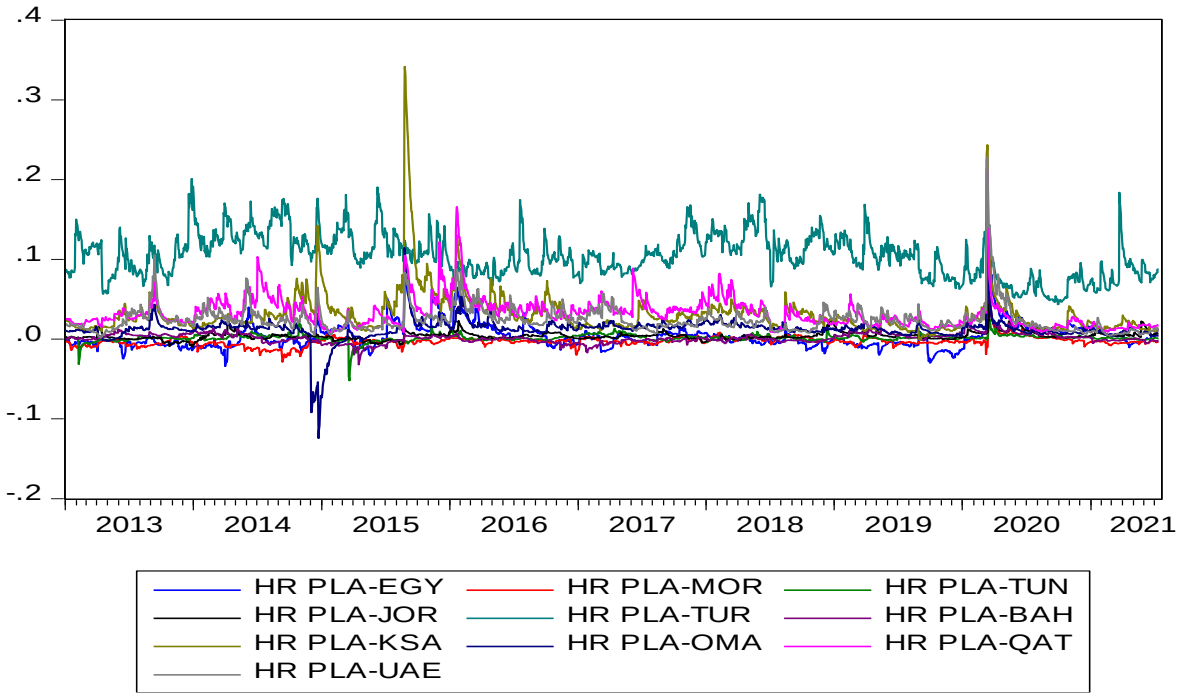

Fig. A3. Optimal hedge ratios for Platinum

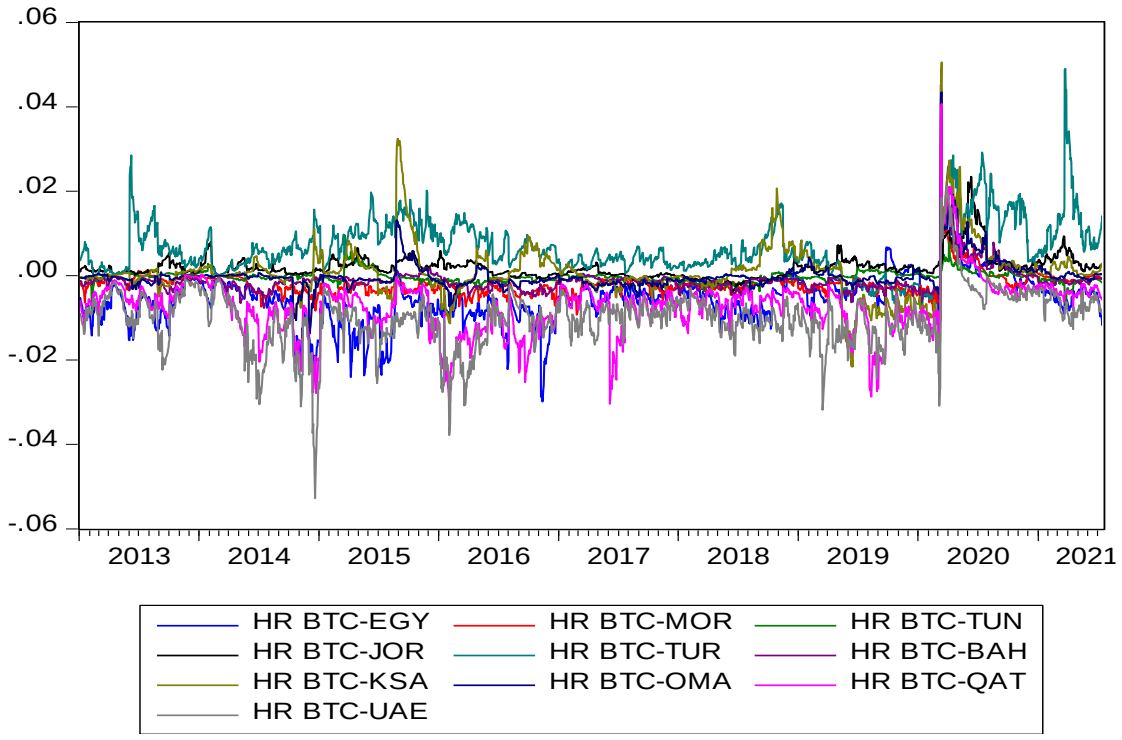

Fig. A4. Optimal hedge ratios for Bitcoin

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