Pacific-Basin Finance Journal 86 (2024) 102406

Contents lists available at ScienceDirect

Pacific-Basin Finance Journal

journal homepage: www.elsevier.com/locate/pacfin

Asymmetric connectedness and investment strategies between commodities and Islamic banks: Evidence from gulf cooperative council (GCC) markets

Mabruk Billah [a], Sinda Hadhri [b], Muneer Shaik [c], Faruk Balli [d,e,*]

[a] Department of Accounting and Finance, College of Business Administration, Prince Mohammad Bin Fahd University, Al Khobar, Saudi Arabia
[b] Institute of Sustainable Business and Organizations, Sciences and Humanities Confluence Research Center- UCLy, ESDES, Lyon, France
[c] School of Management, Mahindra University, Hyderabad, Telangana, India
[d] School of Economics and Finance, Massey University, Auckland, New Zealand
[e] Western Caspian University, Economic Research Center (WCERC), Baku, Azerbaijan

ARTICLE INFO

JEL classification:
F15
F36
G11
G21

Keywords:
Islamic banks
Commodities
GCC markets
Asymmetric connectedness
Crisis periods

ABSTRACT

The study uses the data of thirteen Islamic Banks (IB) in the GCC region and sixteen commodities that include soft agriculture, energy, industry, and precious metal commodities. Murabaha transactions makes up most of the revenues of the Islamic banks, whereas commodities set up the biggest portion of the assets among Murabaha transactions, therefore commodities and IB revenues are expected to comove. Interestingly, empirical findings suggest that most of the Islamic banks and commodities are not significantly affected by the shocks from other markets. We further observe that negative shocks have a higher impact on market connectedness among used assets compared to the positive returns and find a significant role of risk variables in explaining the magnitude of spillover between used assets. We perform robustness of our results in subsamples periods during Shale Oil Revolution, Global Financial Crisis, and the COVID-19. Additionally, the multivariate portfolio analysis shows some risk reduction properties of the majority of the used assets. The performance evaluation measures demonstrate that weights selected based on dynamic connectedness network presents diversification opportunities. These findings help investors and portfolio managers to remain alert to the movements of the risk factors and calibrate there hedging and portfolio management strategies by taking long and short positions as incorporation of Islamic banks and commodities in the GCC region in a portfolio could yield risk reduction benefits and profitability.

1. Introduction

Islamic banking (IB) is an economic system that runs according to Islamic law (Sharia) as well as is based on the principles of justice, justness, as well as the restriction of riba (rate of interest), speculation, gambling, cigarette, complicated derivatives, and also pornography (Ahmad and Hassan, 2007; Hassan et al., 2021; Zaman, 2009; Khan, 2010; El-sheikh, 2008; Abbasi et al., 1989). Islamic banks are financial institutions that offer a range of financial products and services that are compliant with Islamic law. In addition to traditional banking services, Islamic banks also offer a range of other financial products, such as murabaha (cost-plus financing), ijara

* Corresponding author at: School of Economics and Finance, Massey University, Auckland, New Zealand.
E-mail addresses: sbillah@pmu.edu.sa (M. Billah), shadhri@univ-catholyon.fr (S. Hadhri), F.Balli@massey.ac.nz (F. Balli).

https://doi.org/10.1016/j.pacfin.2024.102406
Received 28 September 2023; Received in revised form 13 March 2024; Accepted 26 May 2024
Available online 27 May 2024
0927-538X/© 2024 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

(leasing), and sukuk (Islamic bonds). These financial products are structured to comply with Islamic law and are intended to be more transparent and equitable than conventional financial products. It offers a unique approach to financial services that is based on ethical and socially responsible principles (Aliyu et al., 2017a, 2017b; Ahmed et al., 2015; Wajdi Dusuki, 2008).

Investors and investment advisors have extended their attention to unconventional forms of investments in alternative assets in recent years in an effort to diversify their portfolios. The spectacular rise of the Islamic finance sector over the past decade, especially after the financial crisis of 2008, is evidence that it is one of the "new havens" (Kenourgios et al., 2016; Mensi et al., 2017a, 2017b; Shahzad et al., 2018; Hassan et al., 2021). The Islamic banking movement is rising in Middle Eastern nations, particularly in the GCC states (Kapar et al., 2024). The six Arab nations of Qatar, Bahrain, Oman, Kuwait, UAE, and the Saudi Arabia make up the Gulf Cooperation Council, a regional association. Saudi Arabia, Bahrain, Kuwait, and Qatar make up a significant portion of the GCC's Islamic banking market by market share (Mensi et al., 2019). According to data from the Islamic Financial Services Board, as of the end of 2020, there were a total of 102 Islamic banks functioning in the Gulf region,[1] representing 37% of the total number of Islamic banks worldwide. In terms of assets, Islamic banks in this region has high liquidity and accounted for approximately 44% of the total assets of Islamic banks worldwide (Dusuki, 2012; Hussain et al., 2015; Aliyu et al., 2017a; Kammer et al., 2015).

IB and commodities are connected through the use of commodity murabaha financing, which is a type of Islamic financing that involves the purchase and resale of a commodity (Van Greuning and Iqbal, 2008; Aliyu et al., 2017b). In a commodity murabaha transaction, the Islamic bank acts as an intermediary between the seller and the buyer of a commodity, purchasing the commodity from the seller and then reselling it to the buyer at a profit (Minhat and Dzolkarnaini, 2016). Murabaha has been recognized as the most popular financing option in the interest-free financial system because it enables Islamic banks to make a profit on their investments without using interest, which is against Islamic law (Billah et al., 2024c). Based on the request of the customer, a bank purchases a commodity and resells it back to the customer at a markup price which is basically the profit earned by the bank in case of Murabaha transaction. The resale profit can be a fixed amount or a fixed percentage of the cost of commodity as per the agreement. Also, the bank takes ownership of the commodity and hence must carefully manage its risks to ensure that it is not exposed to undue risks associated with changes in commodity prices. If the price of the commodity which is purchased by the bank increases (decreases) between the time of purchase and resale, the bank's profit margin will increase (decrease), if the resale profit agreement is based on a fixed percentage of the cost of the commodity. Hence the movement in the price of a commodity will have a significant impact on the banks that engage in Murabaha financing. In the GCC countries, murabaha[2],[3] accounted for an average of >55% of all financing for Islamic banks in 2016 (Miah and Suzuki, 2020). Thus, the fluctuations in the commodity prices affect the revenues of the Islamic banks eventually, through the Murabaha transactions.

The GCC region is particularly well-known for its energy markets, which are some of the largest and most important in the world. The region is home to significant reserves of natural gas and oil, and these resources show a dominant role in the economy. According to data from the Organization of the Petroleum Exporting Countries (OPEC), in 2020, the GCC region was responsible for approximately 32% of global oil production and 20% of global natural gas production. In addition to energy markets, the GCC region also has significant metal and agricultural commodity markets. The region is a major producer of aluminium, and it is also home to a number of key agricultural commodities, such as wheat, barley, and dates. It is also observed that many IB's in the GCC region have investments in the metal and mining sector, particularly in precious metals such as gold and silver.

A recent stylized finding that has begun to draw the attention of academics and industry practitioners is the asymmetry in financial markets (Bekaert and Harvey, 2000; Bollerslev et al., 2006). Asymmetric correlations are crucial for investors since both positive and negative effects in one market might have varying effects on other markets (Xia and Yang, 2019). Furthermore, it is observed that there exists asymmetry in spillover in the total connectedness of financial assets between positive and negative returns system (Baruník et al., 2016; Deng et al., 2022; Gabauer, 2021; Adekoya et al., 2022). In the context of the GCC region, asymmetric connectedness between the commodity market and Islamic banks may refer to the extent to which changes in commodity prices, or the performance of the commodity market are transmitted to Islamic banks in the region. If Islamic banks in the region have a significant exposure to the commodity market through their investment portfolios, then changes in commodity prices or the performance of the commodity market could have a significant influence on the financial performance of these banks. It is worth noting that the degree of asymmetry in connectedness between the commodity market and Islamic banks in the GCC region may vary over time and may be influenced by a number of factors. As a result of Islamic banks' explicit position in the entire Islamic financial market, and its relations with commodities markets, this paper explores the asymmetry connectedness among the selected assets.

Motivated by the above reasons, we investigate the network connectedness as well as portfolio implications for thirteen GCC Islamic bank stocks and sixteen commodities (i.e., energy, metal, industrial and agriculture) for the period spanning 01/10/2005 to 30/09/2022. The significance of this paper is due to the scarcity of current literature on the connections between these two assets. Hence, we contribute to the literature on connectedness analysis by providing a detailed and policy-oriented study of the *spillovers* between commodities and stocks of GCC Islamic banks. Using new econometric estimation methods, we examine the network connectedness

[1] See Table A.3. in the appendix section for details on Islamic Banks in GCC region.

[2] According to a study by Miah et al. (2020), as of 2016, Murabaha financing income of Bank Al Bilad as a percentage of total financing income is 65.80%, Abu Dhabi Islamic Bank (58.99%), Bahrain Islamic Bank (58.32%), Kuwait International Bank (37.88%), and 72.96% for Qatar International Islamic Bank.

[3] As per Miah and Suzuki (2020), the lending structure of Bahrain Islamic Bank for Murabaha financing as a percentage of total financing is 60.71%, Al Salam Bank (34.62%), Kuwait International Bank (32.88%), Qatar International Islamic Bank (68.47%), Qatar Islamic Bank (62.46%), Al Rajhi Bank (25.84%), Al Bilad Bank (61.65%), Abu Dhabi Islamic Bank (57.45%), Ajman Bank (42.33%), and Sharjah Islamic Bank (29.79%).

among the selected indices by employing the time-varying parameter vector autoregression (TVP-VAR) technique of Balcilar et al. (2021) extended to an asymmetric framework (Antonakakis et al., 2020a) and implemented to daily data.

The research mainly contributes in the various ways. First, our study is different from the prior studies in the GCC region which have focused mostly on the connectedness between financial markets like stock indices, sectoral indices, and commodities (Hung, 2021; Yousuf and Zhai, 2022; Kapar et al., 2024). The present study focuses on the asymmetric connectedness, and hedging strategies over a comprehensive dataset, i.e., between thirteen Islamic Bank stocks in the GCC region (Saudi Arabia, Qatar, Bahrain, UAE, and Kuwait) and sixteen commodities (which include soft agriculture, energy, industry, and precious metal commodities) using an asymmetric TVP-VAR based connectedness technique of Antonakakis et al., 2020a, to uncover the total, negative, and positive return connectivity among the selected assets. Second, the empirical study spans from 2005 to 2023 which covers the major financial events like GFC (2008–2010), SOR (2014–2016), and the COVID-19 pandemic (2020−2022); and hence this paper conducts robust analysis during different subsample crisis periods. Third, unlike other studies on connectedness in the GCC region (like Mensi et al., 2019, Tabash et al., 2022), we investigate the determinants of the spillovers in the Islamic banks of GCC and commodities using global trade with global risk factor variables like economic policy uncertainty (EPU), volatility of the stock (VIX and EMV), oil (OVX), and gold (GVZ) markets, global financial stress (GFS), macroeconomic news surprises (GMNS) and climate change (CLMT) indices. Fourth, the study constructs the portfolio of Islamic bank stocks and commodities using Minimum Connectedness Portfolio (MCoP) approach that involves generating pairwise connectedness of selected indices (Broadstock et al., 2022), and evaluates the performance of the constructed portfolio using Sharpe Ratio (SR) and the Hedging Effectiveness (HE) criteria. In this regard our research diverges from prior empirical studies in the GCC region both in the selection of the assets and its methodological approach.

We have important findings in this paper. First, the static net pairwise spillover results suggest that all Islamic bank stocks are net transmitter of shocks except Saudi Arabian bank stocks and Abu Dhabi Islamic bank stock of UAE. It is observed that there exist weak spillovers between GCC Islamic bank stocks and commodities and negligible linkages among them demonstrates the risk mitigation properties for these markets for investors. The weak connectedness between Islamic banks is also observed in the work of Tabash et al., 2022, compared to the conventional banks in the GCC region. Second, based on the dynamic connectedness index, we observe that spillovers among the selected assets is time-varying and increases during crisis periods like GFC, SOR, and COVID-19, and drops immediately thereafter. Furthermore, it is observed that negative shocks have a higher impact on market connectedness compared to positive shocks, especially during crisis periods. This finding is in line with the prior studies like Mensi et al. (2019), Rabbani et al. (2023), inter alia. Third, the subsample analysis during different turmoil periods suggest that the connections established between some of the Islamic bank stocks and commodities do not seem to be affected by the risk transmitted from other markets. The results found to be robust for both expansionary and crisis periods. Fourth, we observe the effectiveness of the global risk factors like economic policy uncertainty (EPU), volatility of the stock (VIX and EMV), oil (OVX), and gold (GVZ) markets, global financial stress (GFS), macroeconomic news surprises (GMNS) and climate change (CLMT) indices in explaining the degree of spillovers between Islamic banks of GCC and commodities. The findings suggest that global risk factors have significant effect on spillover between commodities and GCC Islamic banks. Finally, multivariate portfolio analysis shows some risk reduction properties of the majority of used assets in the full sample period and during sub-samples. Using the hedge effectiveness indices and Sharpe ratios, we demonstrate that a pre–set portfolio technique in which weights of various assets are selected based on the dynamic connectedness network presents some diversification opportunities.

The intersection of commodities and Islamic banking in the Gulf Cooperative Council (GCC) markets presents a unique and underexplored area of study. The research question in this paper is formulated to address this gap by investigating the asymmetric connectedness between commodities and Islamic banks, shedding light on potential investment strategies that may emerge from these dynamics. The GCC region, known for its significant presence in both commodity markets and Islamic finance, serves as an ideal setting for such an investigation. The empirical analysis utilizes advanced econometric techniques that integrates relevant financial theories, such as the Efficient Market Hypothesis, Portfolio Theory, and Behavioral Finance, to elucidate the dynamics between commodities and Islamic banks in the GCC region. By understanding the connectedness between these markets, investors and market participants can better assess the potential risks and opportunities associated with investing in Islamic banks or commodities in the region. It is also essential for policymakers and regulators, as it can help them to identify potential risks or imbalances in the financial system and to take appropriate steps to address them.

This study paper's remaining sections are organized is follows: Earlier empirical studies are reviewed in Section 2, the methodology and data utilized are presented in Section 3, the outcomes are described in Section 4, and lastly the paper is concluded, and policy implications are provided in Section 5.

2. Review of literature

Efficient market theory holds that financial markets are efficient and that investors make rational decisions (Fama, 1991). Behavioral finance theorists contend, however, that human mistake and cognitive biases cause defects in markets and that investors' judgements are influenced by their emotions (Kahneman and Tversky, 1970). One significant human bias that is seen in a variety of financial markets is herding tendency. The herd mentality of investors causes a rise in market volatility, the emergence of bubbles, and a departure in prices from their underlying values. Similar to the literature on herd behaviour, a sizable corpus of empirical research has been done on financial market spillovers (Mensi et al., 2016; Tiwari et al., 2020, among others). How markets are linked and risks are dispersed is one of the main worries for investors. Previous studies on spillover effects based on connectedness approach predicted a symmetrical effect (Su, 2020; Umar et al., 2021). However, evidence suggests an asymmetric effect, according to which the volatility spillovers of assets react differentially to uptrends and downtrends (Alshater et al., 2023; Shah and Dar, 2022; Arfaoui et al., 2022).

According to the "spillover" effect, a single significant shock increases the correlation or volatility of returns across all markets and asset classes. The financial crisis episodes like Shale Oil Revolution, European debt crisis, Global Financial Crisis, and the recent COVID-19 has impacted the global markets (Hassan et al., 2021; Shaik and Maheswaran, 2017, Shaik and Maheswaran, 2018, Shaik and Padmakumari, 2022, Shaik et al., 2023a, 2023b; Billah et al., 2024b; Kanvinde and Shaik, 2020a, 2020b; Salisu and Shaik, 2022; Singh and Shaik, 2021; S. M.Billah and Adnan, 2024). The spillover effect could become more pronounced during financial crisis situations, increasing the possibility that volatility and correlation comove steadily over time (Silvennoinen and Thorp, 2013; Ewing and Malik, 2016; Sensoy et al., 2015).

After the sub-prime crisis, most of the academicians and practitioners have become attentive to Islamic markets as an investment vehicle (Billah et al., 2024a; Billah et al., 2024d; Rabbani et al., 2023; Adnan and Billah, 2023; Alam et al., 2022). A set of Islamic and conventional banks functioning in the GCC area were compared in the study by Benlagha and Mseddi (2019) to see how dependent they were on one another. They discovered that during times of high financial market volatility, there is a strong correlation between bank stock returns. The risk and performance characteristics of conventional and Islamic banks are frequently compared in the literature (Pappas et al., 2016; Salisu and Shaik, 2022; Johnes et al., 2014; Khediri et al., 2015; Sorwar et al., 2016; Abedifar et al., 2013; Abdelsalam et al., 2016). The fundamental finding of these empirical investigations is that Islamic banks are more effective and less vulnerable to risk than their traditional ones.

The Mensi et al. (2019) study illustrates supporting the claim that integrating gold and oil in a GCC portfolio provides banks in the GCC with superior but distinct diversification benefits and hedging efficacy. According to research done in 2022 by Tabash et al. on traditional and Islamic financial institutions in the GCC, market spillover is time-varying, asymmetrical, and crisis-sensitive. Additionally, long-oriented overflows develop most of the overall return overflows, whereas short-oriented overflows set the stage for long-oriented downpours. The total and immediate spillovers are strengthened more than long-term spillovers, according to subsample analyses of COVID-19 and GFC. The results of the study by Aydemir et al. (2022) by means of the multivariate quantile autoregression technique suggest that it doesn't really appear to be any discernible change in the stock price responses of Islamic and conventional banks both at the national and international levels. According to the research by Yoon et al. (2022), Islamic financial institutions are receiving a large quantity of danger spillover from various other financial institutions but are sending out much less threat to the different other banks from India and also China. Therefore, there is a significant one-directional risk contagion in the study sample that is geared towards Islamic banks. Using comparative research, Rizwan et al. (2022) found that Islamic banks share common systemic exposures to systematic and individual features throughout the externally generated real economic disruption of the COVID-19. However, Islamic banks have substantially less of an impact on other parties despite generating extraordinary returns than conventional banks.

In the literature, the spillover analysis using different versions of connectedness methodology is empirically applied extensively among assets like Sukuk Bonds (Naeem et al., 2021), Sukuk and Islamic stocks (Balli et al., 2022), sectoral returns (Billah et al., 2022a, 2022b; Balli et al., 2021), Environmental, Social, and Governance indices (Shaik and Rehman, 2022), Crude oil and Islamic sectoral stocks (Adekoya et al., 2022), global financial assets (Shaik et al., 2023a), among others. Furthermore, the connectedness between commodities is explored extensively in the literature such as the nexus between agricultural commodity and agri business (Cagli et al., 2023); energy market and carbon market (Liu et al., 2023); commodity and stock futures (Rehman et al., 2023); oil prices and financial assets (Antonakakis et al., 2023); clean energy stock markets and energy commodity markets (Qi et al., 2022); equity and commodity ETFs (Naeem et al., 2022); energy and stock markets (Billah et al., 2022a, 2022b); crude oil and precious metals (Ahmed et al., 2022); energy and agricultural commodities (Tiwari et al., 2022), energy and non-energy commodities (Anwer et al., 2022) and others. However, the connectedness among the Islamic banks and commodities in the GCC region, to the best of our knowledge is not investigated in the literature and hence our study examines the asymmetric connectedness and investment strategies in the GCC region.

Table 1
List of Islamic banks.

Country	Islamic Banks	Abbreviation
Bahrain	BAHRAIN ISLAMIC BANK	BIB
	AL SALAM BANK	ASB
	AHLI UNITED BANK	AUB
Kuwait	KUWAIT FINANCE HOUSE	KFH
	KUWAIT INTERNATIONAL BANK	KIB
Qatar	QATAR INTERNATIONAL ISLAMIC BANK	QIIB
	QATAR ISLAMIC BANK	QIB
	AL RAJHI BANK	ARB
Saudi Arabia	AL BILAD BANK	BA
	BANK ALJAZIRA	BAL
	ABU DHABI ISLAMIC BANK	ADIB
United Arab Emirates	AJMAN BANK	AJB
	SHARJAH ISLAMIC BANK	SIB

Source: Authors own calculations.

3. Data and methodology

Given its objective, this study looks into how the prices of commodities and Islamic Bank stocks are impacted by one another. We look at the time frame from October 1, 2005, and September 30, 2022, that comprises significant turmoil events, like the US subprime event (2007), the GFC (2008–2010), the European Debt turmoil (2010−2012), the sharp decline in oil prices (2014), SOR (2014–2016), and the ongoing COVID-19 (2020–2022). We have chosen 13 Islamic banks in the GCC region because 2005 was the latest year for which information for all the variables were available to conduct the analysis. Table 1 lists the stock prices of all 13 Islamic banks in the GCC, with Kuwait, UAE, and the Saudi Arabia having the maximum number of banks (three), while Bahrain and Qatar have the lowest number (two).

Additionally, our research study evaluates the dynamic connectivity among Islamic banks and commodities using the daily spot log returns. The study uses sixteen commodities generated through the Dow Jones Commodity (DJC) Index for the 01 October 2005 to 30 September 2022 timeframe. Spot returns in commodities are the major causes of volatility in short time frames, while rolling returns are significant features that lead to excess returns in longer time frames (Nagayev et al., 2016). S&P GSCI, is the significant commodity index that represents well-known production-weighted, and broad-based benchmarks. The benchmarks comprise the industrial metals commodities index (zinc, copper, and aluminium), the soft agriculture commodity index (wheat, soybeans, corn, grains, sugar, cotton, cocoa, coffee, corn, and cattle), the precious metals index (silver and gold), and the energy commodity index (natural gas and crude oil). The variety of commodities employed in this study may provide information on how sectors are exposed when calculating the risk and return of Islamic bank indexes. The daily data of 16 commodities and 13 Islamic banks in the GCC region are sourced from the Bloomberg. The formula for calculating the daily spot return is: $r_{i,t} = ln\left(p_{i,t}\right) - ln\left(p_{i,t-1}\right)$. Here, $r_{i,t}$ signifies the log return and $p_{i,t}$ means the price the asset i at time t.

Tables 2 reports the descriptive statistics for the daily commodity markets' returns. The average daily returns are positive for all series except Cocoa market. For energy markets, the daily average return ranges from 0.018 for Silver to 0.073 for Natural gas during the sample period. For agriculture commodities, the average return ranges from −0.014 for Cocoa to 0.037 for Corn. This increase in prices of the majority of used commodities could be attributed to the thriving demand at the international level and is consistent with evidence that investing in commodities has been more and more common, in spite of its significant impacts, due to its positive returns (e.g., Lombardi and Ravazzolo, 2016). Particularly, in times of recession, the supply of commodities is limited and can maintain their value due to high demand in response to their scarcity. In the case of all commodities, the unconditional volatility, as measured by the standard deviations, is similarly moderate among markets, except for crude oil (0.034) and natural gas (0.032) with gold being the less volatile market (0.009). These statistics are in congruence with the dynamics of the change in prices of these energy markets over the sample period that encompasses a number of turmoil episodes that have caused lows and highs of supply and demand. The skewness coefficients are negative for the majority of commodities' return series (except for Coffee, Sugar, and Wheat). The kurtosis coefficients show non-normal distributions for all return series. We utilize the ADF test and the Jarque-Bera (JB) examination to examine the stationarity procedure. The outcomes deny the null hypothesis of non-stationarity at the 1% level of importance, suggesting that all products under consideration are level stationary.

The summary statistics of the Islamic bank stock returns in Table 3 show mixed results regarding the sign of stock returns over the sample period. The daily average return ranges from −0.015 for Kuwait International Bank (KIB) to 0.025 for Kuwait Finance House (KFH). Among the GCC Islamic bank stock indices, Al Salam Bank of Bahrain (ASB) displays the highest volatility over the sample

Table 2
Descriptive statistics and unit-root test for commodity markets.

	ABR	Mean	Max	Min	SD	Skew	Kurt	JB	ADF
Energy, Precious & Industrial metals									
GOLD	GOLD	0.025	0.056	−0.051	0.009	−0.148	5.226	11,679.15***	−15.159***
SILVER	SILV	0.018	0.089	−0.123	0.018	−0.650	7.361	44,808.10***	−19.932***
CRUDE OIL	COIL	0.049	0.438	−0.569	0.034	−2.103	71.193	72,754.07***	−18.730***
NATURAL GAS	NGAS	0.073	0.166	−0.192	0.032	−0.254	4.008	1,787,605.00***	−19.783***
ALUMINIUM	ALUM	0.026	0.054	−0.077	0.012	−0.251	2.975	4325.94***	−15.345***
COPPER	COPP	0.029	0.046	−0.081	0.013	−0.268	1.949	4392.08***	−16.870***
ZINC	ZINC	0.041	0.074	−0.072	0.015	−0.091	1.489	570,085.30***	−15.364***
Soft Agriculture Commodities									
COCOA	COCO	−0.014	0.064	−0.065	0.017	−0.028	0.469	190,889.20***	−15.841***
COFFEE	COFF	0.032	0.096	−0.090	0.019	0.175	1.573	1249.35***	−19.785***
COTTON	COTT	0.029	0.058	−0.058	0.015	−0.120	1.523	36,223.68***	−18.592***
SUGAR	SUG	0.012	0.086	−0.058	0.017	0.122	1.005	72,754.07***	−17.873***
GRAINS	GRAIN	0.035	0.062	−0.063	0.013	−0.080	2.340	14,762.65***	−18.675***
LIVESTOCK	LIVE	0.010	0.053	−0.062	0.011	−0.339	2.593	13,457.86***	−17.78***
CORN	CORN	0.037	0.069	−0.070	0.015	−0.249	2.774	1438.44***	−16.439***
SOYBEANS	SOYB	0.030	0.064	−0.070	0.012	−0.255	3.295	1919.39***	−15.657***
WHEAT	WHEA	0.036	0.078	−0.085	0.018	0.150	1.706	6843.45***	−15.847***

Note: This table gives the definitive stats for the sixteen commodities under research study. ABR, Max, Min, SD, Skew, Kurt, JB, and ADF represents Abbreviation, Maximum, Minimum, Standard Deviation, Skewness, Kurtosis, Jarque-Bera, and Augmented Dicky-Fuller test, respectively. *** Indicates significance at 1%.

Table 3
Descriptive statistics of Islamic bank returns of GCC countries.

Country	Abbreviation	Mean	Max	Min	SD	Skew	Kurt	JB	ADF
Bahrain	BIB	−0.022	0.2729	−0.2167	0.0175	−0.0947	35.5182	1.88E+05***	−16.178***
	ASB	−0.014	2.3031	−2.3031	0.0557	0.0134	1379.3630	3.36E+08***	−16.740***
	AUB	0.017	0.0931	−0.0965	0.0167	0.2035	7.8663	4.23E+03***	−15.678***
Kuwait	KFH	0.025	0.0952	−0.1054	0.0163	−0.2430	8.6781	5.77E+03***	−18.639***
	KIB	−0.015	0.0953	−0.1040	0.0177	−0.1109	7.9389	4.34E+03***	−17.429***
Qatar	QIIB	0.003	0.6020	−0.5875	0.0214	0.2580	287.1986	1.43E+07***	−19.683***
	QIB	0.004	0.4132	−0.4054	0.0200	0.0157	89.2738	1.32E+06***	−17.896***
	ARB	0.019	0.0954	−0.1513	0.0187	−0.3069	11.7703	1.37E+04***	−18.780***
Saudi Arabia	BA	−0.001	0.1044	−0.1561	0.0213	−0.1709	9.9950	8.71E+03***	−17.845***
	BAL	−0.005	0.2401	−0.1809	0.0221	−0.0607	12.7068	1.67E+04***	−18.847***
	ADIB	0.006	0.1588	−0.1632	0.0200	−0.1846	12.4396	1.58E+04***	−16.780***
United Arab Emirates	AJB	−0.012	0.1401	−0.1621	0.0230	0.3659	12.7841	1.71E+04***	−17.382***
	SIB	−0.007	0.3311	−0.3490	0.0244	−0.1667	52.2536	4.31E+05***	−18.739***

Note: This table gives the definitive stats for the thirteen Islamic banks under research study. ABR, Max, Min, SD, Skew, Kurt, JB, and ADF represents Abbreviation, Maximum, Minimum, Standard Deviation, Skewness, Kurtosis, Jarque-Bera, and Augmented Dicky-Fuller test, respectively. *** Indicates significance at 1%.

period (0.0557). The lowest volatilities are displayed by Kuwaiti banks, which is in line with the claims of the fundamentally sound banking system in this country. The minimum and maximum values indicate moderate variability for all stock return series. The skewness and kurtosis values indicate that all return distributions are heavy-fatter-tailed. The kurtosis coefficients reject normality for all return series, and are similar to JB test outcome. Furthermore, the outcome of the ADF test shows that all series are level-stationary.

The series were divided into positive and negative daily return. The benefit of dividing the data into three forms can determine the three systems of spillovers: standard, positive and negative. This allows for the assessment of multivariate portfolios and the diversification benefits of Islamic banks and commodities.

$$S_t = \begin{cases} 0, & \underline{if\ z_t < 0} \\ 1, & if\ z_t \geq 0 \end{cases} \tag{1}$$

$$z_t^+ = S_t \cdot z_t \tag{2}$$

$$z_t^- = (1 - S_t) \cdot z_t \tag{3}$$

where z_t^+, and z_t^- positions for the daily percentage movements in positive and negative direction.

3.1. Asymmetric TVP-VAR connectedness methodology

Diebold and Yılmaz's connectedness approach, initially proposed in 2009, 2012, has gained immense popularity in recent years. The approach involves using a widely used VAR toolkit, namely IRFs and FEVDs, to summarize the complex nonlinear transmission mechanism of large networks. The connectedness table presents a simplified overview of the propagation mechanism by incorporating feedback loops of the entire network. It helps us compare the relative impacts of a shock in one variable on another variable's forecast error variance. This technique enables us to analyze different impact scenarios more effectively and is especially useful in studying the interconnections between different economic variables.

The proposed approach is aimed at observing and evaluating the potential negative effects that may arise in a specific network due to an economic shock. This helps in developing economic and political strategies to mitigate any adverse impacts on the national or global economy. In order to accurately assess spillovers and the strength of shocks, the rolling-window size used to determine dynamic connectedness should be optimized. Antonakakis et al. (2020a) have proposed using a TVP-VAR approach instead of a rolling-window VAR to determine the optimal window size, as well as multivariate Kalman Filters to improve sensitivity to outliers (Koop and Korobilis, 2013, 2014). Monte Carlo simulations have shown that the total connectedness index cannot exceed 100% (Chatziantoniou et al., 2019). Additionally, Caloia et al. (2019) has demonstrated that the normalization of the original connectedness approach is suboptimal and dependent on the technique used. Therefore, we follow an asymmetric TVP-VAR connectedness analysis Adekoya et al. (2022) to analyze time-varying total and directional connectedness at the three systems of spillovers: standard, positive, and negative.

To uncover asymmetric return connectivity among Islamic banks and commodity markets, we use a negative and positive returns based on the modern connectivity approach derived from a TVP-VAR method put forth by Antonakakis et al., 2020a, which is built on the Generalized Forecast Error Variance Decomposition (GFEVD) technique. The TVP-VAR (1) approach hinted by the BIC is represented as:

$$Y_t = \beta_t Y_{t-1} + \varepsilon_t; \varepsilon_t \mid F_{t-1} \sim N(0, S_t) \tag{4}$$

$$vec(\beta_t) = vec(\beta_{t-1}) + \nu_t; \nu_t \mid F_{t-1} \sim N(0, \Xi_t) \tag{5}$$

where Y_t and Y_{t-1} are $N \times 1$ matrix size of vectors with endogenous variables; ε_t is the $N \times 1$ matrix size of the error terms with an $N \times N$ size time-varying variance-covariance matrix, S_t; β_t is the $N \times N$ size VAR coefficient matrix; ν_t is an $N^2 \times 1$ error vector with an $N^2 \times N^2$ size of time-varying variance-covariance matrix, Ξ_t; $vec(\beta_t)$ is the vectorization of β_t.

The TVP-VAR is converted into a VMA form (Vector Moving Average) in order to obtain the GFEVD as

$$Y_t = \sum_{j=0}^{\infty} A_{jt}\varepsilon_{t-j} \tag{6}$$

Where A_{jt} is an $N \times N$ matrix size designed by the usual Wold Representation Theorem.

The unscaled GFEVD ($\theta^g_{ij,t}(H)$) is represented as:

$$\theta^g_{ij,t}(H) = \frac{S^{-1}_{ii,t}\sum_{t=1}^{H-1}\left(e_i' A_t S_t e_j\right)^2}{\sum_{j=1}^{k}\sum_{t=1}^{H-1}\left(e_i A_t S_t A_t' e_i\right)} \tag{7}$$

We calculate the normalized GFEVD ($\widetilde{\theta}^g_{ij,t}(H)$) as follows to ensure that sum of each row equals one, meaning that chosen quantities describe 100% of the quantity i's forecast error variance (FEV).

$$\widetilde{\theta}^g_{ij,t}(H) = \frac{\theta^g_{ij,t}(H)}{\sum_{j=1}^{N}\theta^g_{ij,t}(H)} \tag{8}$$

where, $\sum_{j=1}^{k}\theta^g_{ij,t}(H) = 1, \sum_{i,j=1}^{k}\widetilde{\theta}^g_{ij,t}(H) = k$, and e_i is a vector that takes the value 1 in the i^{th} component and 0 otherwise; $\widetilde{\theta}^g_{ij,t}(\text{H})$ signifies a degree of the bidirectional connectedness from index j to index i at limit H.

In the context of Diebold and Yılmaz (2014), the following connected measures can be calculated using the GFEVD:

Total directional connectivity from index i to all indexes:

$$C_{\blacksquare\leftarrow i,t}(H) = \frac{\sum_{j=1, j\neq i}^{N}\widetilde{\theta}^g_{ji,t}(H)}{\sum_{i,j=1}^{N}\widetilde{\theta}^g_{ji,t}(H)} \times 100 \tag{9}$$

Total directional connectivity from all indexes to index i

$$C_{i\leftarrow\blacksquare,t}(H) = \frac{\sum_{j=1, i\neq j}^{N}\widetilde{\theta}^g_{ij,t}(H)}{\sum_{i,j=1}^{N}\widetilde{\theta}^g_{ij,t}(H)} \times 100 \tag{10}$$

The net total of directional connectivity

$$C_{i,t}(H) = C_{\blacksquare\leftarrow i,t}(H) - C_{i\leftarrow\blacksquare,t}(H) \tag{11}$$

The net bidirectional connectedness

$$C_{ij,t} = C_{i\leftarrow j,t}(H) - C_{j\leftarrow i,t}(H) \tag{12}$$

If $C_{ij,t} > 0$ ($C_{ij,t} < 0$), index i directs (is directed by) index j suggesting that index i impacts (is impacted by) index j more than being impacted by (impacting) it.

Another useful indicator that illustrates the degree of system interconnection and hence market risk is the total connectedness index (TCI). The average sum of the index's transmitted (received) overflow over all other indexes, as determined by TCI, which can be defined as the average total directional connectivity to (from) the others. As the own variance shares are by construct usually greater than or equal to all cross-variance shares, Gabauer (2021) and Chatziantoniou and Gabauer (2021) have demonstrated that the TCI is contained inside [0, (K-1)/K]. The adjusted TCI is used to create a TCI that is between [0,1]:

$$C_t^g(H) = \frac{\sum\limits_{\substack{i,j=1 \\ i \neq j}}^{K} \tilde{\theta}_{ij,t}^g(H)}{\sum\limits_{i,j=1}^{K} \tilde{\theta}_{ij,t}^g(H)} = \frac{\sum\limits_{\substack{i,j=1 \\ i \neq j}}^{K} \tilde{\theta}_{ij,t}^g(H)}{K} \tag{13}$$

$$C_t^g(H) = \left(\frac{K}{K-1}\right) \frac{\sum\limits_{\substack{i,j=1 \\ i \neq j}}^{K} \tilde{\theta}_{ij,t}^g(H)}{K} \tag{14}$$

$$C_t^g(H) = \frac{\sum\limits_{\substack{i,j=1 \\ i \neq j}}^{K} \tilde{\theta}_{ij,t}^g(H)}{K-1} \quad 0 \leq C_t^g(H) \leq 1. \tag{15}$$

Finally, Gabauer (2021) has demonstrated that the pairwise connectedness index (PCI), which assesses the interconnectedness amid two quantities i and j can be used to deconstruct the TCI:

$$PCI_{ijt}(H) = 2\left(\frac{\tilde{\theta}_{ij,t}^g(H) + \tilde{\theta}_{ji,t}^g(H)}{\tilde{\theta}_{ii,t}^g(H) + \tilde{\theta}_{ij,t}^g(H) + \tilde{\theta}_{ji,t}^g(H) + \tilde{\theta}_{jj,t}^g(H)}\right) \tag{16}$$

Where $0 \leq PCI_{ijt}(H) \leq 1$.

3.2. Determinants of the asymmetric return spillovers

After determining the amount of variability utilising total, positive, and negative return spillovers (Figs. 2 and 3), a second-level analysis was carried out to ascertain the causes of spillovers. We utilize a pooled OLS model for global trade—asset market returns. In larger marketplaces, spillover may be minimal, according to our predictions. Global influences are also taken into consideration as additional gravitational factors.

It is theorized that a number of variables will inevitably influence the impact of shocks on GCC Islamic banks as well as commodities at the total, positive and negative return spillovers, including (1) CLMT, (2) OVX, (3) VIX, (4) GFS, (5) EMV, (6) GVZ, (7) GMNS, and (8) EPU.[4] Recent research papers, including Balli et al. (2019) and Balli et al. (2021), have defined a recognized regression model for Islamic banks and commodity markets. The pooled OLS regression model is used in this case is constructed on the fundamental gravity model, but it has been modified to include variables related to global indices, taking the following into consideration as gravity factors:

$$TSI_{ij,t} = \alpha_0 + a^* X_t + \varepsilon_{it} \tag{17}$$

Where the dependent variable $TSI_{ij,t}$ is created within three ways, which are total, positive and negative return spillovers between Islamic banks i and commodities j (Tables 4–6). The data is sourced from DataStream. The term X_t is a matrix includes the determinants of return and volatility connectedness including $EPU\ VIX, OVX, GVZ, GFS, EMV, GMNS, CLMT$. Since the dependent variable is different for every combination of the I and j, the independent variables are same but enlarged the dimensions to performed the pooled OLS. EPU stands for the economic policy uncertainty index, and VIX is real market index. OVX is the expected 30-day crude oil volatility estimate. GVZ is an estimation regarding the anticipated 30-day volatility of returns on the SPDR Gold Shares ETF. Equity Market Volatility (EMV) tis the market volatility tracker. The details of these variables and others are presented at Appendix Table. Along with the autocorrelation corrected standard errors (HAC), we have identified heteroskedasticity in the evaluations. In our calculations, we test for the normality of the error terms and model misspecification (RESET).

3.3. Portfolio implications

3.3.1. Minimum connectedness portfolio (MCoP)

Then, using the Minimum Connectedness Portfolio (MCoP) technique, we build a portfolio by creating pairwise connectedness of indices (Broadstock et al., 2022). The weights of assets within a portfolio are decided based on how much an asset influences and is

[4] The variables that we have used in this study, is being used in previous studies, (such as, Batten et al., 2021; Lundgren et al., 2018; Ji et al., 2019; Kocaarslan and Soytas, 2019; Bouri et al., 2021; Saeed et al., 2020, 2021), and these variables are daily basis. Understanding the economic and financial factors that affect the interconnection between Islamic banks and commodities is crucial in making informed investment and risk management decisions. This knowledge enhances investors' awareness and helps them make better decisions. Moreover, to understand the variables further, we have provided the explanations for each variables in the Appendix A.1.

Table 4
Determinants of dynamic total return spillovers for Commodity and Islamic bank of GCC returns.

Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
EPU	−0.025***								0.068***
	(0.004)								(0.004)
VIX		0.271***							0.189***
		(0.044)							(0.066)
OVX			−0.123***						−0.075***
			(0.023)						(0.026)
GVZ				−0.377***					0.526***
				(0.058)					(0.078)
GFS					−6.589***				−2.288***
					(0.244)				(0.303)
EMV						0.418***			0.264***
						(0.033)			(0.027)
GMNS							0.099		0.066
							(0.093)		(0.077)
CLMT								0.025***	0.010***
								(0.003)	(0.002)
R^2(%)	18.54	20.20	28.00	29.3	27.07	28.80	27.00	26.29	46.69
N	4432	4432	4432	4432	4432	4432	4432	4432	4432

Note: Standard errors are printed in parenthesis. *, ** and *** show that the relevant coefficient is significant at the 10%, 5% and 1% level respectively. The estimated model is The estimated model is $TSI_{ij,t} = \alpha_0 + AX_t + \varepsilon_{it}$ Where the dependent variable $TSI_{ij,t}$ is the total return spillovers between Islamic banks *i* and commodities *j*. X_t stands for the explanatory variables, EPU, VIX, OVX, GVX, GFS, EMV, GMNS, CLMT, definitions are explained in the Appendix.

Table 5
Determinants of dynamic total positive return spillovers for Commodity and Islamic bank of GCC returns.

Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
EPU	−0.047***								−0.078***
	(0.003)								(0.006)
VIX		−0.444***							−0.324***
		(0.023)							(0.033)
OVX			−0.099***						−0.098***
			(0.010)						(0.011)
GVZ				−1.010***					−1.342***
				(0.047)					(0.067)
GFS					4.399***				1.902***
					(0.362)				(0.376)
EMV						0.069***			0.077***
						(0.018)			(0.024)
GMNS							−0.133*		−0.099**
							(0.072)		(0.056)
CLMT								−0.007***	−0.008***
								(0.009)	(0.002)
R^2(%)	19.07	27.68	31.00	30.23	28.07	29.80	25.23	29.50	59.00
N	4432	4432	4432	4432	4432	4432	4432	4432	4432

Note: Standard errors are printed in parenthesis. *, ** and *** show that the relevant coefficient is significant at the 10%, 5% and 1% level respectively. The estimated model is $TSI_{ij,t} = \alpha_0 + AX_t + \varepsilon_{it}$ Where the dependent variable $TSI_{ij,t}$ is the positive return spillovers between Islamic banks *i* and commodities *j*. X_t stands for the explanatory variables, EPU, VIX, OVX, GVX, GFS, EMV, GMNS, CLMT, definitions are explained in the Appendix.

influenced by other assets, with the goal of obtaining a portfolio with a minimum amount of bilateral interconnectivity. The assets that do not affect other assets and do not get affected by other assets will have a higher weight in that portfolio, which will be least affected by network shocks. The weights will be calculated as follows:

$$\omega_{Ct} = \frac{PCI_t^{-1} I}{IPCI_t^{-1} I} \tag{18}$$

where, ω_{Ct} is the weight of the asset in the portfolio with minimum interconnectedness, PCI_t represents the pairwise connectedness index matrix during time t and I signifies the identity matrix.

3.3.2. Portfolio evaluation

The portfolio's performance is evaluated using two criteria, the Sharpe Ratio (SR) and the Hedging effectiveness (HE). The SR as

Table 6
Determinants of dynamic total negative return spillovers for Commodity and Islamic bank of GCC returns.

Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
EPU	−0.033***								0.067***
	(0.004)								(0.005)
VIX		0.371***							0.190***
		(0.044)							(0.044)
OVX			−0.223***						−0.076***
			(0.023)						(0.018)
GVZ				−0.587***					0.456***
				(0.057)					(0.090)
GFS					−6.346***				−3.189***
					(0.466)				(0.504)
EMV						0.402***			0.176***
						(0.033)			(0.020)
GMNS							0.099		0.066
							(0.087)		(0.077)
CLMT								0.024***	0.010***
								(0.004)	(0.003)
R^2(%)	22.34	29.20	28.00	29.3	27.07	28.80	27.00	26.29	46.69
N	4432	4432	4432	4432	4432	4432	4432	4432	4432

Note: Standard errors are printed in parenthesis. *, ** and *** show that the relevant coefficient is significant at the 10%, 5% and 1% level respectively. The estimated model is $TSI_{ij,t} = \alpha_0 + AX_t + \varepsilon_{it}$ Where the dependent variable $TSI_{ij,t}$ is the negative return spillovers between Islamic banks *i* and commodities *j*. X_t stands for the explanatory variables, EPU, VIX, OVX, GVX, GFS, EMV, GMNS, CLMT, definitions are explained in the Appendix.

given by Sharpe (1994) compares the return against the risk of the portfolio. Sharpe ratio is defined as:

$$SR = \frac{\overline{r}_p}{\sqrt{var(r_p)}} \tag{19}$$

where, r_p signifies return of the portfolio, $var(r_p)$ represents the variance of the portfolio.

Sharpe ratio provides a metric for return of the portfolio given the risk involved. It helps in comparing various portfolios and the best portfolio will be the one with highest SR value i.e., highest return with the same level of risk.

The second criteria used for evaluating portfolio's performance is Hedging Effectiveness (HE). It tells the percentage of risk that is getting reduced by investing in a particular portfolio as compared to investing in a single asset. The significance of the reduction percentage is investigated using HE test statistics as given by Antonakakis et al. (2020b), as shown below:

$$HE_i = 1 - \frac{var(r_p)}{var(r_i)} \tag{20}$$

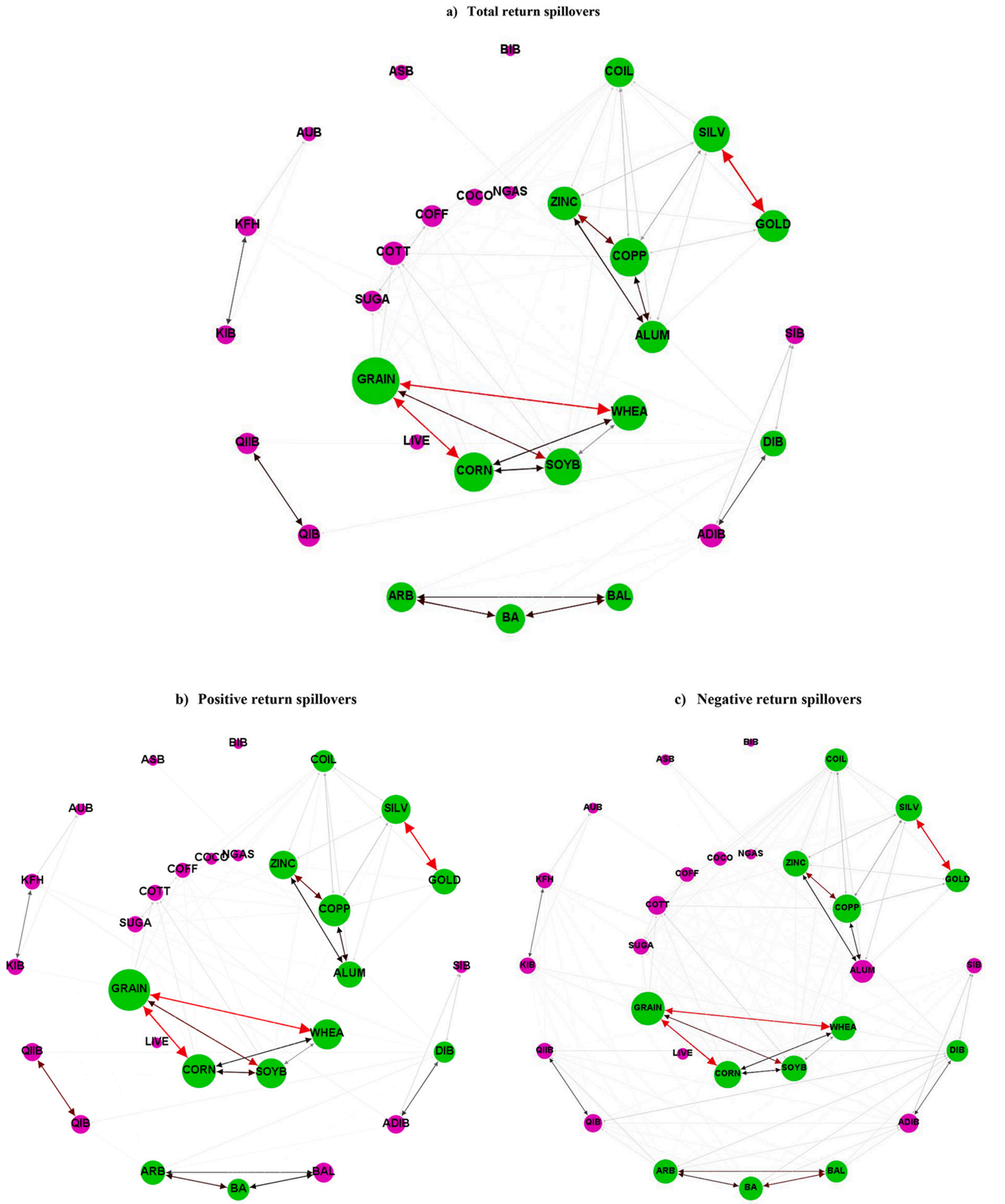
where, HE_i denotes the hedging effectiveness i.e., the reduction in risk by adopting portfolio *p* against investing in asset *i*, the portfolio variance is $var(r_p)$, and $var(r_i)$ is the variance of the unhedged position i.e., variance of asset *i*.

4. Empirical results

In this section, we present the results of both averaged and dynamic connectedness analysis. First, we present the results of the Net Pairwise directional Connectedness in total, negative and positive returns between Islamic bank stocks and commodities. Second, we discuss the results of the dynamic evolution of the TCI across time to examine the time-varying spillover between used markets. Third, we illustrate the results of the net pairwise spillover between used assets during episodes of economic turmoil (i.e., Global financial crisis, Shale Oil revolution, and Covid-19). Fourth, we discuss the results of the different basic gravity models to study the determinants of return connectedness. Finally, we interpret the results of the multivariate portfolio analysis.

4.1. Results of the static net pairwise spillover

We examine the direction and intensity of *spillover* between Islamic bank stocks and commodities as depicted by Fig. 1. The figure shows the network of directional relationships between stocks and commodities used for total returns (graph a), positive returns (graph b) and negative returns (graph c). The direction of the arrow from one stock or commodity to another indicates the average *spillover* interaction between the pair. In particular, the arrow from *x to y* indicates that y is the shock recipient of *x*. The width of the arrows indicates the strength of the pairwise overflows, with the red and black colors indicating the strongest and weakest overflow directions, correspondingly. The size of nodes shows the magnitude of each stock or commodity's contribution to the system connectedness, and colors green and pink define net shocks transmitters and receivers, respectively.



(caption on next page)

Fig. 1. Full-sample Return connectedness networks between Sixteen Commodities and Thirteen Islamic Banks of GCC markets. System-wide total dynamic connectedness index is based on a 1st-order TVP-VAR with a 1st-order delay length and a 28-level GFEVD.
Note: This network graph illustrates the degree of total connectedness in a system that consists of Sixteen Commodities and Thirteen Islamic Bank returns over the full sample period. The size of the node shows the magnitude of contribution of each variable to system connectedness, while the color indicates the origin of connectedness. Node size signifies the extent of spillovers effect and color specifies whether a market is a net transmitter (green) or recipient (pink) of spillovers. The forced directed layout algorithm set node location where the sum of the vectors set the node route. Arrow width signifies the strength of the pairwise spillovers and color specifies strongest (red) to weakest (black) directions of spillovers. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Some interesting results can be drawn from the graphs. Graph (a) shows that all Islamic bank stocks, except ARB, BA, BAL, and ADIB are net receivers of shocks. This result for Saudi Arabian banks is consistent with the government's lifeline support for Islamic banks in this country making it an international financial centre for Islamic banking in the region. For energy and commodity markets, except for natural gas, Cocoa, Coffee, Cotton, Sugar, and Livestocks, all markets appear to be net transmitters of shocks in the network system. We notice that the strongest pairwise *spillovers*, with respect to total returns (panel a), are between Grain and Wheat, Grain and Corn and Silver and Gold. A lower but material connection is also established between Zinc and Copper, and from Grain to Soybeans. Apart from these relationships, the graph shows some weak and/or inexistent linkages among used Islamic bank stocks and commodities indicating some potential interesting diversification and reduced risk for investors when combining Islamic banks and commodities in a single portfolio.

Graphs (b) and (c) of figure 1illustrate the connectedness system with respect to positive and negative returns, respectively. The results complement those of graph (a) and show that the spillovers are rather symmetric. Specifically, the results on the strongest and weakest linkages confirm those derived for total returns. The only changes discernible are that Bank Aljazira (Aluminium) becomes net receivers of shocks in the connectedness network of positive (negative) returns. The results also imply that most stocks and commodities are not significantly affected by shocks from other markets, both in bearish and bullish market conditions. This finding seems to be inconsistent with previous empirical findings about strong return reciprocity between Islamic countries (Bley and Chen, 2006; Sclip et al., 2016; Akhtar et al., 2017). Interestingly, while GCC countries are net exporters of oil, results show that crude oil contributes marginally to the risk spillover to GCC Islamic banking. While gold tends to be net contributor of risk to the remaining markets, its marginal contribution to risk is in accordance with its properly known role as a good hedge asset for stock markets in general and GCC bank markets, in particular (Mensi et al., 2019). Furthermore, the weak spillovers between GCC Islamic banking stock indices could be explained by the domestically isolated nature of these banks due to the close supervision by their respective central banks.

In short, Fig. 1 shows an important aspect of stability in multi-commodity linkages with respect to both positive and negative returns. Investors' acknowledgement of these relationships helps diversify the risk of their portfolios. While a large portion of institutional investors in GCC banks come from other GCC countries, the negligible linkages among them demonstrates some important risk mitigation properties of these markets for investors. The stability feature observed in connections between some commodities and GCC Islamic banks is in line with the theory of morally-based decisions. Islamic banks operate based on Shariah principles, which prohibit activities such as interest-based transactions and speculative trading. As a result, Islamic bank stocks and commodities may exhibit stability and resilience to shocks from other markets due to adherence to ethical and risk-sharing principles.

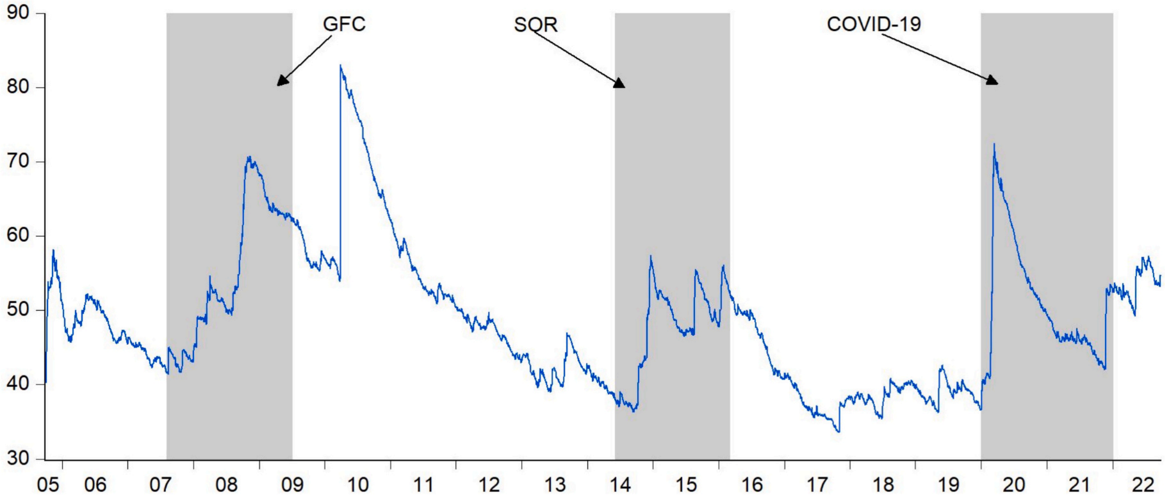


Fig. 2. Total time-varying Return connectedness between Sixteen Commodities and Thirteen Islamic Banks of GCC markets.
Notes: System-wide total dynamic connectedness index is based on a 1st-order TVP-VAR with a 1st-order delay length and a 28-level GFEVD.

4.2. Time-varying spillover analysis

To further boost our analysis, we examine the time-varying behaviour of the return connectedness. More specifically, since our studied period includes several significant events that may influence the magnitude of the spillover among markets, we use a dynamic connectedness index to provide information about the dynamics of the spillover among markets. In doing this, and as explained in the methodology section, we use a spillover index based on a first order TVP-VAR with one-day delay length and a 28-level GFEVD.

Fig. 2 displays the dynamics of the total return spillover index over time. It shows that the total return connectedness oscillates in both up and down directions meaning that the magnitude of spillover has often changed over the studied period. It is worth noting that the magnitude of spillover increases in crisis episodes, as depicted by the Fig. 2. The index reaches up to 84 in the period of the global financial crisis (GFC) and afterwards, up to 58 in the period of the U.S. Shale oil revolution (SOR) and Saudi Arabia changing oil policies, and up to 70 during the global Covid-19 crisis period. These results reveal that the shocks induced by macroeconomic and energy factors impact the relationship among Islamic banks and commodities. Historically, global macroeconomic and energy shocks have been the main cause of commodity price volatility. Specifically, commodities' demand in key emerging and developed countries is mainly driven by business cycles and long–run structural factors (Radetzki, 2006). Since 2000, global demand shocks have been the main source for variability in global commodity price growth with a contribution of 50% to the price variance against 20% for supply shocks (Baumeister and Hamilton, 2019; Ha et al., 2021). On the demand side, during the global financial crisis and the Covid-19 period, the deceleration of the demand for commodities reflects the dire state of the global economy that has simply slow down the growth performance of emerging and developed economies. On the supply-side, these periods of crisis have been linked with unexpected disruptions of commodity production triggered by drought and wildfires in Russia and Ukraine and floods in Asia in 2010 and the border restrictions that have constrained labour supply during Covid-19. U.S. SOR has also reshaped the world energy market. Supply response to increased demand, driven by the population boom and industrial growth, has led many Middle Eastern countries and especially Saudi Arabia to start to invest in Shale gas exploration. All of these demand- and supply-side shocks have rapidly impacted the relationship among commodities and Islamic banks in GCC countries where the economy relies heavily on commodities. Nevertheless, our results suggest also that these periods of GFC, SOR and Covid-19 have not fundamentally changed the spillover picture among Islamic banks and commodity markets given the drop in the spillover index immediately after.

In Fig. 3, we separate between positive and negative return spillovers. The dynamic negative return spillover index has recorded higher results than its dynamic positive return spillover counterpart during the whole sample period. This result suggests that total return spillovers between used markets are mainly driven by negative returns. Specifically, during the GFC and the Covid-19 pandemic periods, the negative return spillover index reached up to 80 (against 64 and 75 for the positive return spillover index during these two periods, respectively). These findings suggest that negative shocks have a higher impact on market connectedness, especially during crisis episodes.

Figs. 4, 5 and 6 show the connections of the rolling spillovers for total, positive and negative returns, respectively, and hence, depict the appropriate input of each stock or commodity to the overall connectivity system as drawn from the total directional overflow, and its changes from collaborators from shock-to-shock recipient over time and vice versa.

Considering total returns (Fig. 4), results for both Islamic banks and commodities appear to be mixed. For Islamic banks, BIB, AUB, KFH, KIB, QIB, QIIB, and ADIB, they appear to, mostly, be net recipients of shocks during the sample period with a relatively low

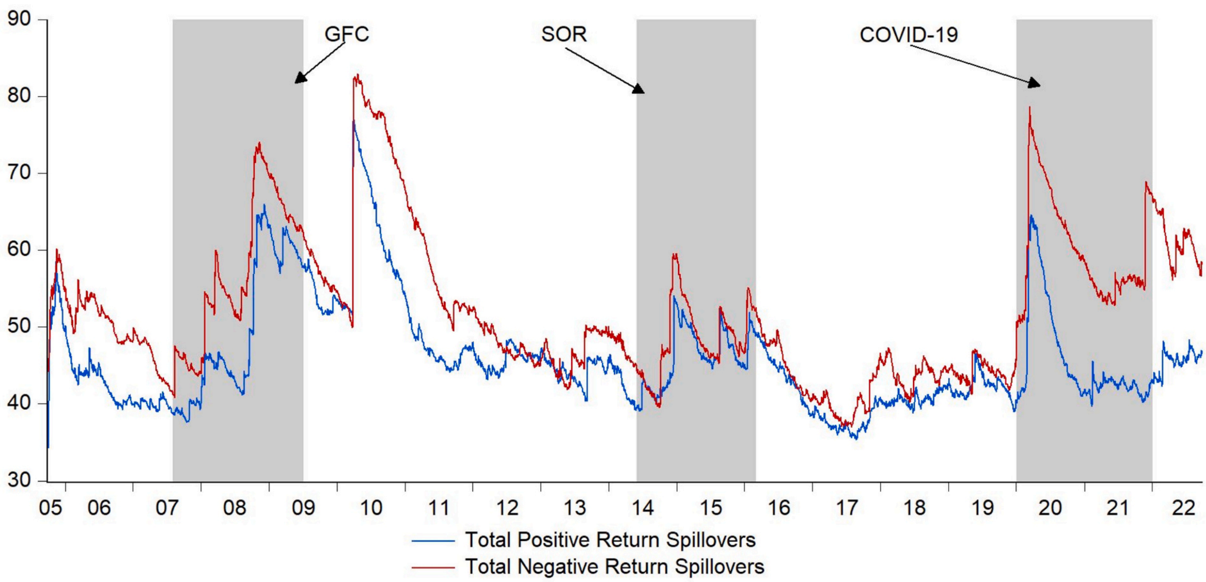


Fig. 3. Total time-varying Postive and Negative Return connectedness between Sixteen Commodities and Thirteen Islamic Banks of GCC markets. *Notes*: System-wide total dynamic connectedness index is based on a 1st-order TVP-VAR with a 1st-order delay length and a 28-level GFEVD.

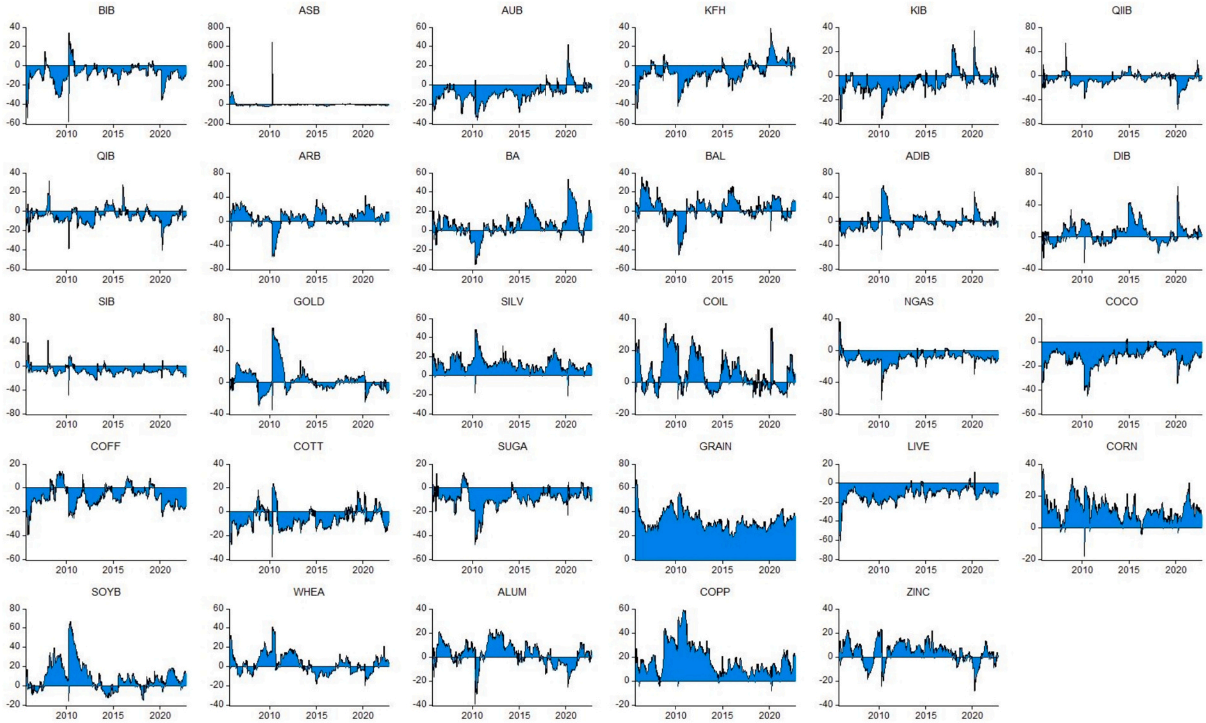


Fig. 4. Net total return spillovers.
Notes: See Fig. 2.

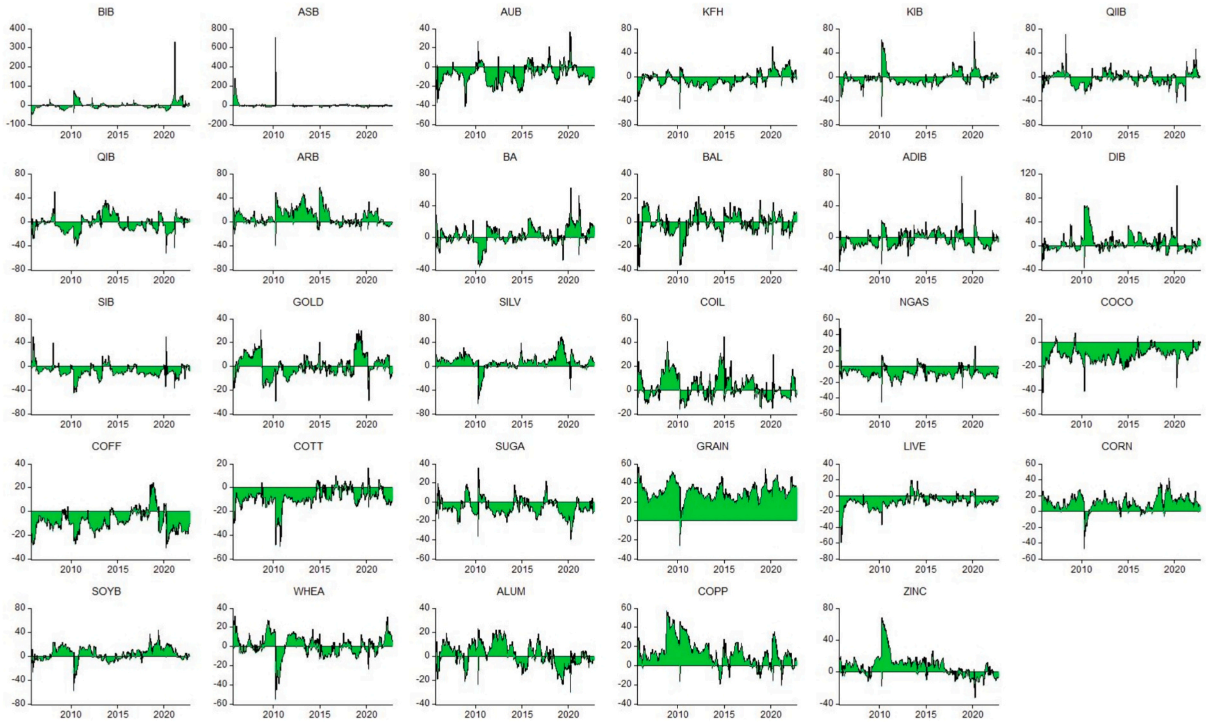


Fig. 5. Net total positive return spillovers.
Notes: See Fig. 2.

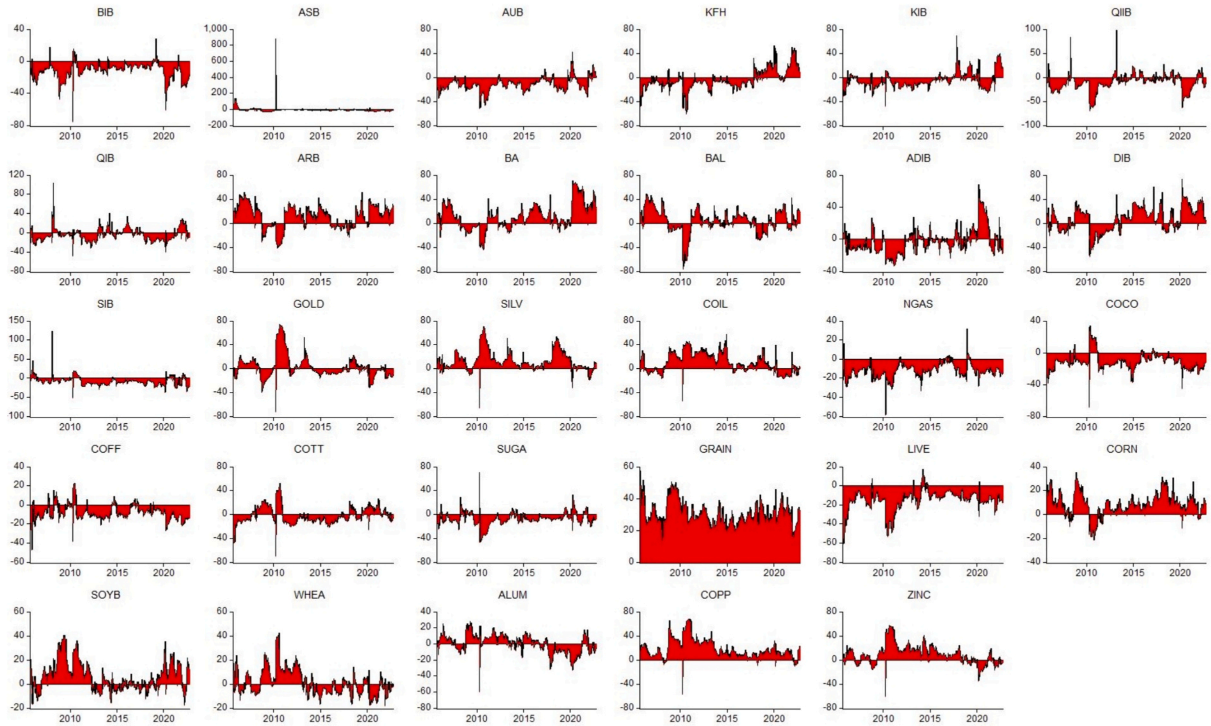


Fig. 6. Net total negative return spillovers.
Notes: See Fig. 2.

degree of spillover that of no more than −40, in general. Results show the opposite for ARB, BA, BAL and AJB which tend to be net contributors to risk spillover in most the sample period with a moderate spillover index not exceeding 50. For ASB and SIB, a neutral trend in spillover patterns is noticed indicating a neutral position for these two Islamic banks in most the sample period. The only exception for ASB is during 2010 when the bank exhibited a very high spillover index that reached up to 600. This result could be attributed to the Bahraini market openness to foreign investors. During the late sample period that coincides with the pandemic period, some Kuwaiti, Emirati and Saudi Islamic banks (AUB, KFH, KIB, BA, and DIB) exhibit a relatively high level of risk source as compared to the rest of the sampled period. This result could indicate these banks have become integrated with regional and commodity markets. Overall, due to their smaller universe as compared to the conventional model that does not allow for all financial instruments, Islamic banks needed some product innovations that could be optimally utilized for risk hedging and liquidity management purposes. Sharia commodities or as commonly known commodity murabaha were set as a solution for Islamic banking industry whose procurement is carried out through the commodity exchange. The low exposure of GCC Islamic banks to spillover risk reflects the relatively good systemic risk management of these banks that seem to be well surveilled by regulators against extreme events.

For commodities, results show that silver, crude oil, grain, corn, soybeans, copper and zinc are net transmitters of risk while gold, natural gas, cocoa, coffee, cotton, sugar, livestock, wheat and aluminium are net recipients of shocks in most the study period. The time-varying spillover is moderate, not exceeding ±50 for most commodities. The position of gold could be considered as relatively neutral, except in 2010 where it appears to be a net contributor to shocks with an index of >70, which confirms again its safe-haven features. For crude oil, we note that it appears to be a net recipient of spillover shocks in light of the shocks from GFC, SOR, and Covid-19 that is primarily due to the significant plunge in its price.

The pattern of estimated total spillovers for positive and negative returns is shown in Figs. 5 and 6 correspondingly. In general, the pattern of net spillover does not appear to change over the period for all markets, although the pattern of net spillover does change relative to total returns. However, we notice higher spillover indices for negative returns as compared to positive returns which indicates the tighter linkages between markets in bearish market conditions. The tighter linkages observed during bearish market conditions, may be influenced by behavioral finance theories. Behavioral biases, such as herding behaviour and risk aversion, can amplify market movements and lead to contagion effects, where negative sentiment spreads across asset classes, resulting in higher spillover levels during bear markets.

4.3. Results of the pairwise spillover in sub-samples

We focus, in this section, on the episodes of the global financial crisis (Fig. 7), the Shale Oil Revolution (Fig. 8), and the Covid-19 pandemic (Fig. 9) and we examine the connectedness between commodities and Islamic bank stocks. The figures show the network connectedness between our underlying assets.

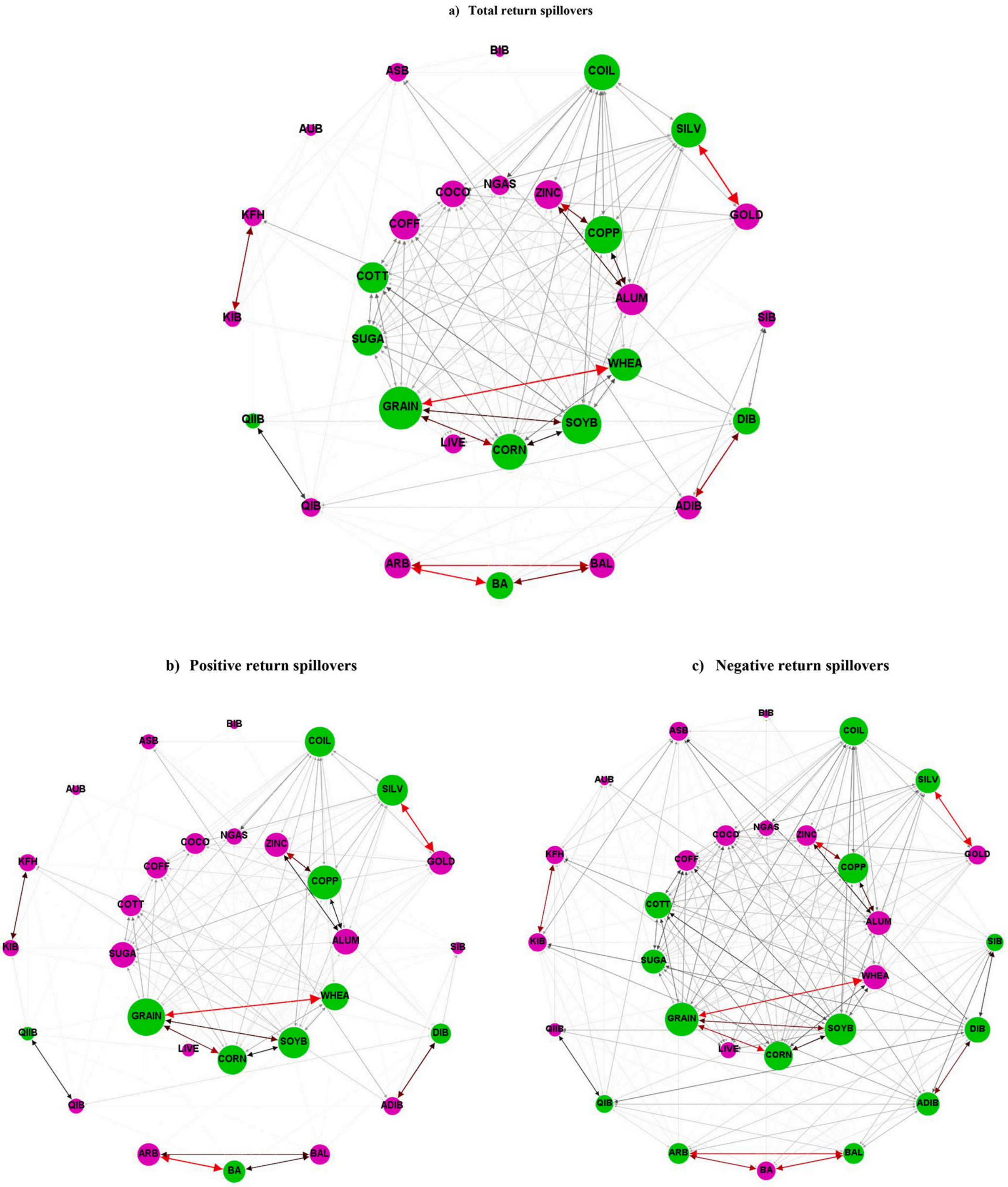


Fig. 7. Return connectedness networks during Global Financial Crisis (GFC) between Sixteen Commodities and *Thirteen* Islamic Banks of GCC markets. System-wide total dynamic connectedness index is based on a 1st-order TVP-VAR with a 1st-order delay length and a 28-level GFEVD. Notes: See Fig. 1.

We report some similarities compared to the full sample. However, some changes are discernible. We begin with the GFC period, for total returns, we find that the strongest pairwise relationships are between grain and wheat, silver and gold, from grain to corn, and from copper to zinc. For Islamic banks, strong connections are also established among Saudi Arabian banks (ARB, BA, and BAL), between two Emirati banks (DIB and ADIB), and between Kuwaiti banks (KFH and KIB). Apart from these connections, the weak and/ or inexistent connections between the other markets are a sign of potential diversification benefits from investment in them. These

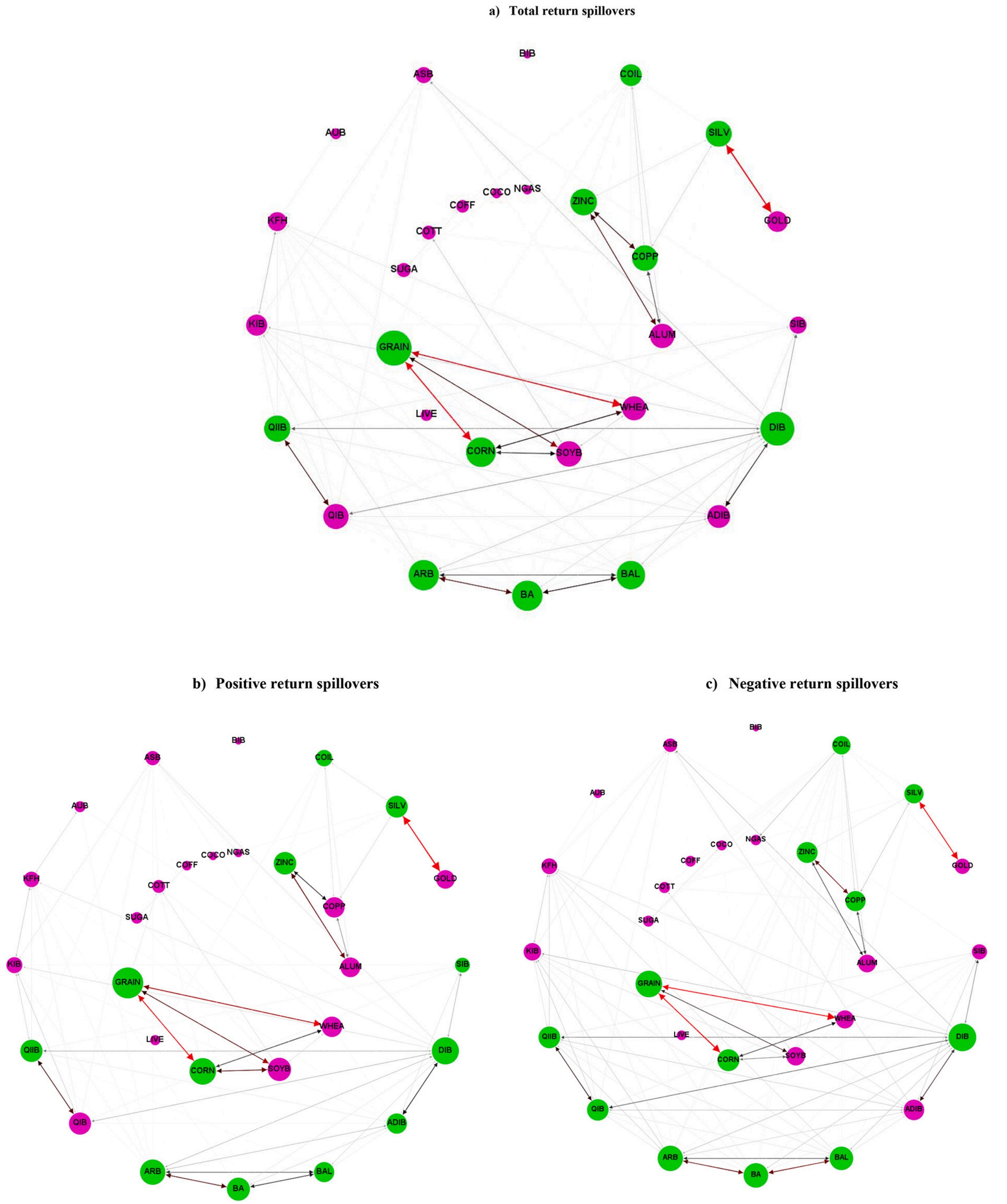


Fig. 8. Return connectedness networks during Shale Oil Revolution (SOR) between Sixteen Commodities and *Thirteen* Islamic Banks of GCC markets. System-wide total dynamic connectedness index is based on a 1st-order TVP-VAR with a 1st-order delay length and a 28-level GFEVD. Notes: See Fig. 1.

results are qualitatively stable with respect to both positive and negative returns. The only changes are that the connections between Islamic bank stocks become lower albeit material when using positive returns.

For the SOR period, intense connections in total returns are only established between some commodities (grain and wheat, grain

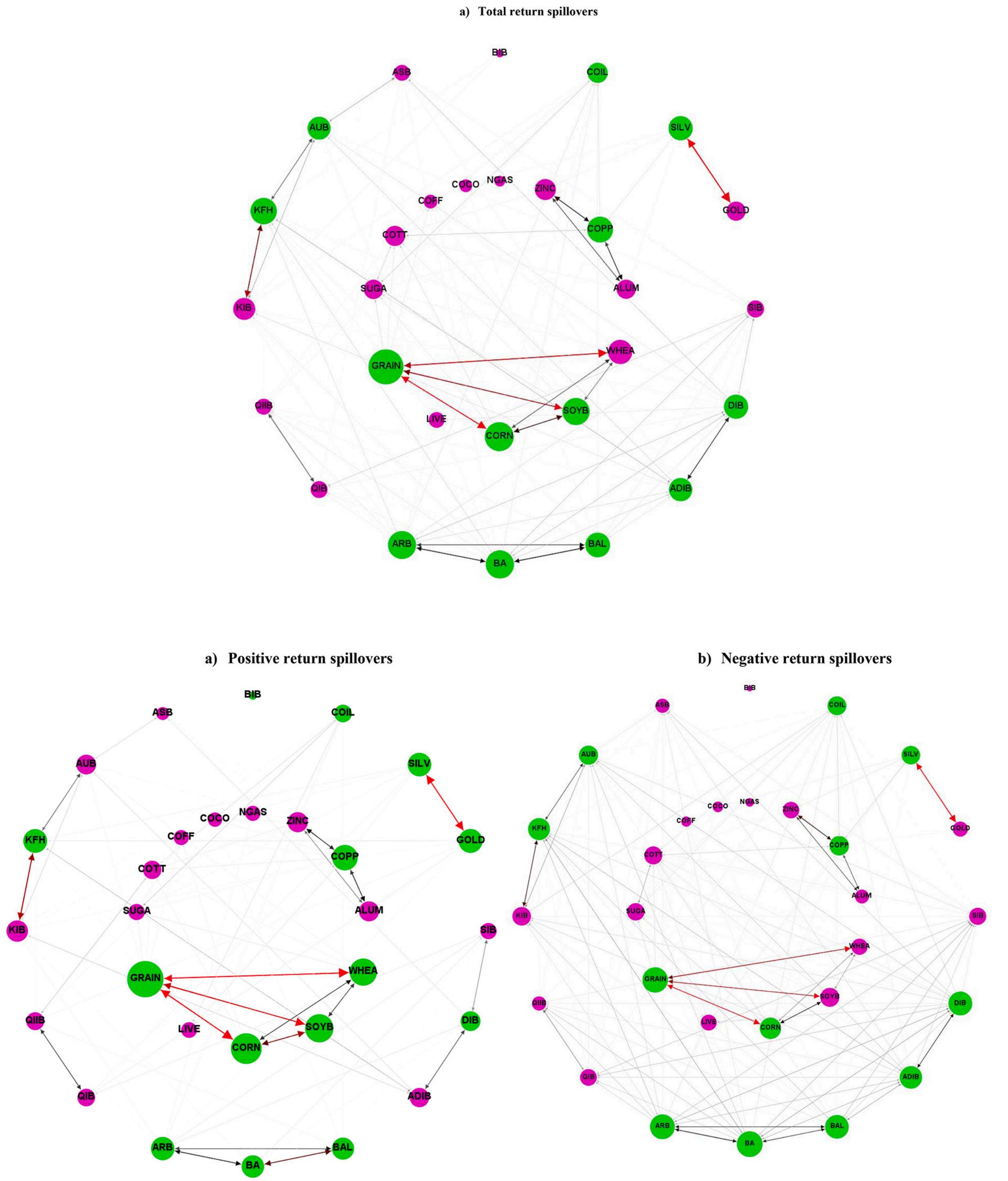


Fig. 9. Return connectedness networks during COVID-19 between Sixteen Commodities and *Thirteen* Islamic Banks of GCC markets. System-wide total dynamic connectedness index is based on a 1st-order TVP-VAR with a 1st-order delay length and a 28-level GFEVD.
Notes: See Fig. 1.

and corn, silver and gold, and from grain to soybeans). A lower but significant connection is also found between two Qatari (QIB and QIIB) and Saudi (ARB and BA) banks. For the other markets, connections are either weak or inexistent. These findings are also confirmed with respect to connections in both positive and negative returns. However, when using negative returns, the connections between BA and BAL, and Zinc and Copper (QIB and QIIB) become more (less) significant.

Finally, for the period of the pandemic, the magnitude of the established connections is not very different from that reported for the full sample with respect to total returns. The only difference is the connection between Kuwaiti banks, KFH and KIB, (zinc and copper) that becomes stronger (weaker) during the Covid-19 period. The results with respect to positive (negative) returns are qualitatively the same as for total returns with stronger (weaker) connections between BA and BAL, and corn and soybeans (KFH and KIB).

Overall, the sub-sample analysis confirms the findings of the initial testing about the interesting diversification opportunities for investors in commodities and Islamic bank stocks and suggests that the results found are robust to both expansionary and crisis episodes. Apart from the connections that have been made between some of the assets, the two assets appear to be unaffected by risks transferred from other markets.

4.4. Determinants of the connectedness

In this section, we focus on testing the significance power of some risk variables as determinants of return spillover between used commodities and Islamic bank stocks. The connectedness is explained on the base on the asset pricing theories like CAPM or bond pricing. The variables used to explain the connectedness include the economic policy uncertainty (EPU), volatility of the stock (VIX and EMV), oil (OVX), and gold (GVZ) markets, global financial stress (GFS), macroeconomic news surprises (GMNS) and climate change (CLMT) indices. All risk variables used are described in Table A.1. in the appendix. The pairwise correlation between these explanatory variables is, typically, moderate ranging between −0.32 and 0.57 rules out the multicollinearity issue. The pairwise correlation coefficients are reported in Table A.2. in the appendix. Tables 4, 5 and 6 report the results for determinants of the total, positive and negative return connectedness, respectively. Columns (1–8) give the results for risk variables used in the pooled OLS estimations separately. The estimates for the complete model that uses all the variables are reported in column (9).

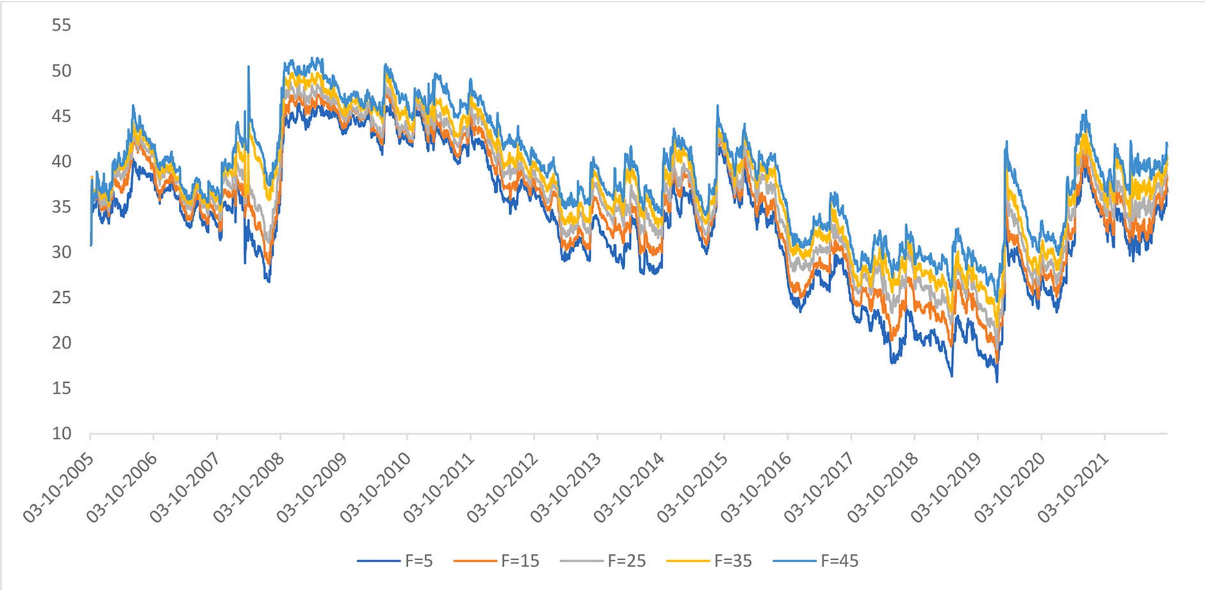
Results in Table 4 indicate that all variables, except GMNS have significant impact on total return spillovers between used markets, with a significance level of 1%. The same results are found for negative return spillovers (Table 6). These findings suggest a strong explanatory power of risk factors on the dynamic total and negative return connectedness between Islamic bank stocks and commodities. Specifically, the relation is statistically significant for EPU, OVX, GVZ and GFS (VIX, EMV and CLMT) variables. For example, in Model 3, the results indicate that an increase in the volatility of oil market is associated to a decrease in the degree of total and negative returns *spillover* among used markets. The same reasoning holds for the other variables. For positive returns, results of the individual testing show a significant relation between GFS and EMV (EPU, VIX, OVX, GVZ, GMNS and CLMT. Specifically, results suggest that a 1% increase in global financial stress is associated to around 6.5% decrease in the magnitude of total return connectedness between commodities and Islamic bank stocks. For positive (negative) return spillovers, a general increase in global financial stress would significantly increase (decrease) *spillovers* between markets of about 4.399 (6.346) percent. When using all risk factors

Table 7
GMM estimation.

Coefficient	Total	Positive	Negative
$Total_{i(t-1)}$	0.643***		
$Total\ Positive_{I,(t-1)}$		0.654***	
		(0.002)	
$Total\ Negative_{(t-1)}$			0.831***
			(0.002)
EPU	1.321***	−1.561***	1.211***
	(0.005)	(0.004)	(0.004)
VIX	0.207	0.157	0.006
	(0.003)	(0.002)	(0.002)
OVX	−0.184**	−0.207**	−0.213**
	(0.001)	(0.001)	(0.112)
GVZ	0.660*	0.447	1.020**
	(0.004)	(0.004)	(0.442)
GFS	0.879	2.179	−1.750
	(0.030)	(0.023)	(2.402)
EMV	−0.044	0.048	0.146**
	(0.001)	(0.001)	(0.073)
GMNS	0.246	0.129	0.528**
	(0.003)	(0.002)	(0.265)
CLMT	0.009**	−0.004	0.012***
	(0.005)	(0.001)	(0.005)
R^2(%)	99.62	98.90	99.54
N	4432	4432	4432
AB(1) test *p*-value	(0.11)	(0.06)	(0.03)
AB(2) test *p*-value	(0.13)	(0.32)	(0.31)
Sargan statistic *p*-value	(0.44) (0.	(0.35)	(0.21)

Note: Standard errors are printed in parenthesis. *, ** and *** show that the relevant coefficient is significant at the 10%, 5% and 1% level respectively. Estimated model is $\Delta TSI_{ij,t} = \beta_0 + \beta \Delta X_t + \varepsilon_{it}$. Definition of the dependent and independent variables are listed in Table4–6.

Panel A: Forecast Horizon Sensitivity Analysis



Panel B: Decay Factor Sensitivity Analysis

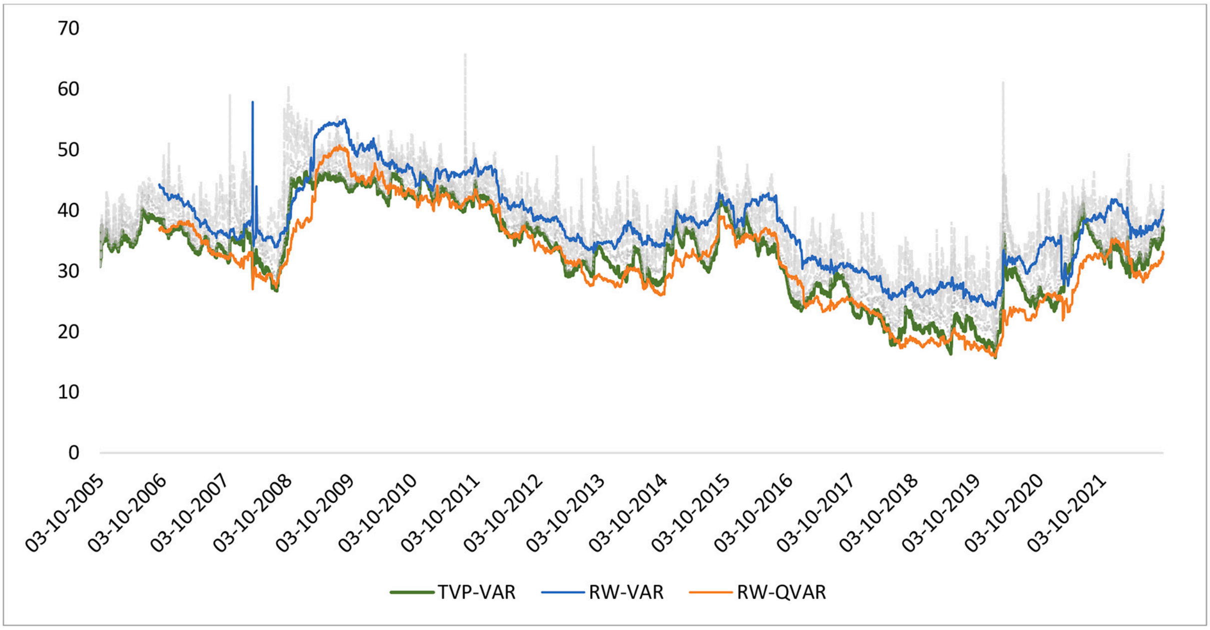


Fig. 10. Sensitivity analyses.
Note: Panel A: Different forecast horizons are used [5, 15, 25, 35, 45].
Panel B: $\kappa_1 = [0.95, 0.96, 0.97, 0.98, 0.99]$ and $\kappa_2 = 0.99$.

together (Model 9), we note some differences in the sign of the relation between used risk variables and return connections as compared to the individual testing results. Specifically, for total and negative return models, the results become significantly positive for EPU and GVZ. The sign of the coefficients holds for the other factors. Risk factors show no difference in sign and significance with respect to the results of the individual models (1–8) for positive returns.

Overall, our empirical findings suggest the effectiveness of global risk factors in explaining the extent of *spillover* between commodities and GCC Islamic bank stocks.

Table 8
Dynamic multivariate portfolio weights.

Minimum Connectedness Portfolio (MCoP) based on TVP-VAR model

Panel A: FULL SAMPLE

	MEAN	*STD-D*	*5%*	*95%*	*HE*	*P-VALUE*	*SHARPE RATIO*
BIB	0.04	0.01	0.03	0.06	0.74	0.00	1.242
ASB	0.04	0.01	0.02	0.05	0.97	0.00	0.325
AUB	0.04	0.01	0.01	0.05	0.72	0.00	1.520
KFH	0.03	0.01	0	0.05	0.7	0.00	1.532
KIB	0.03	0.01	0.01	0.05	0.75	0.00	−0.933
QIIB	0.03	0.01	0.01	0.04	0.83	0.00	0.204
QIB	0.03	0.01	0.01	0.04	0.8	0.00	0.416
ARB	0.02	0.01	0	0.03	0.78	0.00	0.791
BA	0.02	0.01	0	0.03	0.84	0.00	−0.271
BAL	0.02	0.01	0.01	0.04	0.83	0.00	0.066
ADIB	0.03	0.01	0	0.04	0.81	0.00	0.588
DIB	0.02	0.01	0	0.04	0.82	0.00	−0.504
SIB	0.03	0.01	0.02	0.04	0.86	0.00	−0.270
GOLD	0.03	0.02	0	0.07	0.39	0.00	2.528
SILV	0.01	0.02	0	0.03	0.82	0.00	1.012
COIL	0.02	0.01	0	0.04	0.9	0.00	0.187
NGAS	0.04	0.01	0.02	0.05	0.91	0.00	−0.525
COCO	0.04	0.01	0.02	0.05	0.73	0.00	0.649
COFF	0.03	0.01	0.01	0.05	0.79	0.00	1.056
COTT	0.03	0.01	0.01	0.04	0.7	0.00	0.679
SUGA	0.03	0.01	0.01	0.04	0.79	0.00	0.501
GRAIN	0.28	0.09	0.1	0.43	0.66	0.00	1.488
LIVE	0.04	0.01	0.02	0.05	0.17	0.00	0.859
CORN	0.01	0.05	0	0	0.74	0.00	1.510
SOYB	0.01	0.04	0	0	0.62	0.00	1.390
WHEA	0.01	0.05	0	0	0.8	0.00	1.094
ALUM	0.02	0.01	0	0.04	0.6	0.00	0.211
COPP	0.01	0.01	0	0.03	0.72	0.00	0.875
ZINC	0.02	0.01	0	0.04	0.79	0.00	0.833

Panel B: Global Financial Crisis (GFC)

	MEAN	*STD-D*	*5%*	*95%*	*HE*	*P-VALUE*	*SHARPE RATIO*
BIB	0.04	0.02	0	0.06	0.7	0.00	2.534
ASB	0.03	0.02	0	0.05	0.79	0.00	1.336
AUB	0.03	0.02	0	0.07	0.71	0.00	8.089
KFH	0.03	0.02	0	0.04	0.75	0.00	4.261
KIB	0.03	0.02	0	0.05	0.76	0.00	−5.903
QIIB	0.03	0.02	0.01	0.05	0.92	0.00	−0.992
QIB	0.03	0.02	0	0.05	0.88	0.00	−0.146
ARB	0.03	0.02	0	0.06	0.76	0.00	0.458
BA	0.01	0.02	0	0.02	0.79	0.00	4.198
BAL	0.03	0.02	0	0.05	0.74	0.00	−0.921
ADIB	0.02	0.02	0	0.04	0.76	0.00	−4.854
DIB	0.01	0.01	0	0.04	0.85	0.00	−7.251
SIB	0.03	0.02	0	0.05	0.92	0.00	−2.785
GOLD	0.05	0.02	0	0.08	0.37	0.00	3.763
SILV	0.01	0.03	0	0.08	0.77	0.00	0.347
COIL	0.01	0.02	0	0.05	0.83	0.00	−0.557
NGAS	0.03	0.02	0	0.04	0.82	0.00	−3.234
COCO	0.02	0.02	0	0.04	0.65	0.00	2.379
COFF	0.02	0.03	0	0.07	0.52	0.00	0.606
COTT	0.02	0.01	0	0.05	0.61	0.00	−1.035
SUGA	0.02	0.02	0	0.05	0.67	0.00	4.757
GRAIN	0.24	0.14	0	0.39	0.62	0.00	−0.030
LIVE	0.04	0.02	0	0.07	−0.77	0.00	−3.280
CORN	0.04	0.09	0	0.25	0.68	0.00	0.894
SOYB	0.04	0.09	0	0.25	0.62	0.00	1.331
WHEA	0.04	0.09	0	0.25	0.76	0.00	−0.932
ALUM	0.01	0.02	0	0.05	0.45	0.00	5.743
COPP	0.02	0.03	0	0.07	0.76	0.00	−3.435
ZINC	0.04	0.02	0	0.07	0.79	0.00	−5.647

Panel C: Shale Oil Revolution (SOR)							
	MEAN	*STD·D*	*5%*	*95%*	*HE*	*P-VALUE*	*SHARPE RATIO*
BIB	0.05	0.01	0.02	0.07	0.83	0.00	5.586
ASB	0.04	0.02	0.01	0.06	0.94	0.00	−7.344
AUB	0.03	0.02	0	0.05	0.55	0.00	4.208
KFH	0.03	0.01	0.01	0.05	0.85	0.00	5.724
KIB	0.03	0.02	0.01	0.06	0.79	0.00	−7.778
QIIB	0.03	0.02	0	0.06	0.87	0.00	−2.745
QIB	0.02	0.02	0	0.03	0.91	0.00	0.768
ARB	0.02	0.03	0	0.06	0.88	0.00	−2.910
BA	0.01	0.01	0	0.02	0.92	0.00	−9.477
BAL	0.03	0.02	0.01	0.05	0.94	0.00	−4.184
ADIB	0.03	0.02	0	0.06	0.92	0.00	−6.384
DIB	0	0.02	0	0.02	0.93	0.00	1.531
SIB	0.04	0.02	0	0.06	0.94	0.00	−2.528
GOLD	0.04	0.02	0	0.06	0.6	0.00	0.179
SILV	0.01	0.03	0	0.03	0.87	0.00	3.038
COIL	0.03	0.02	0.01	0.07	0.95	0.00	−9.110
NGAS	0.05	0.01	0.02	0.07	0.95	0.00	8.387
COCO	0.04	0.01	0.03	0.05	0.74	0.00	0.697
COFF	0.04	0.01	0.02	0.05	0.92	0.00	4.156
COTT	0.03	0.02	0	0.05	0.73	0.00	8.034
SUGA	0.03	0.02	0	0.05	0.88	0.00	−2.272
GRAIN	0.25	0.08	0.04	0.33	0.77	0.00	6.560
LIVE	0.04	0.01	0	0.05	0.63	0.00	4.814
CORN	0	0.02	0	0	0.82	0.00	4.143
SOYB	0	0.02	0	0	0.78	0.00	9.390
WHEA	0	0.01	0	0.01	0.87	0.00	4.557
ALUM	0.02	0.02	0	0.03	0.69	0.00	−3.106
COPP	0.03	0.02	0.01	0.05	0.77	0.00	6.857
ZINC	0.02	0.02	0	0.04	0.82	0.00	−2.550

Panel D: COVID-19							
	MEAN	*STD·D*	*5%*	*95%*	*HE*	*P-VALUE*	*SHARPE RATIO*
BIB	0.06	0.01	0.05	0.08	0.36	0.00	7.916
ASB	0.03	0.02	0.01	0.05	0.81	0.00	0.882
AUB	0.02	0.02	0	0.05	0.79	0.00	0.270
KFH	0	0.01	0	0.01	0.73	0.00	2.920
KIB	0.04	0.02	0.01	0.07	0.76	0.00	−2.282
QIIB	0.03	0.01	0	0.04	0.62	0.00	−0.796
QIB	0.04	0.02	0	0.05	0.62	0.00	2.859
ARB	0.01	0.02	0	0.03	0.74	0.00	10.197
BA	0.02	0.03	0	0.05	0.77	0.00	3.091
BAL	0.02	0.01	0	0.05	0.82	0.00	5.930
ADIB	0.02	0.02	0	0.04	0.8	0.00	2.790
DIB	0.01	0.02	0	0.02	0.78	0.00	−0.288
SIB	0.04	0.01	0	0.05	0.71	0.00	7.167
GOLD	0.05	0.03	0	0.11	0.59	0.00	3.052
SILV	0.01	0.02	0	0.03	0.91	0.00	2.071
COIL	0.03	0.02	0	0.06	0.98	0.00	0.781
NGAS	0.05	0.01	0.03	0.06	0.95	0.00	2.986
COCO	0.04	0.01	0.01	0.05	0.79	0.00	−0.093
COFF	0.04	0.02	0.02	0.07	0.89	0.00	4.794
COTT	0.03	0.01	0.01	0.04	0.77	0.00	6.059
SUGA	0.02	0.01	0	0.03	0.82	0.00	3.768
GRAIN	0.27	0.08	0.08	0.35	0.7	0.00	5.497
LIVE	0.04	0.01	0	0.05	0.66	0.00	1.845
CORN	0	0.01	0	0	0.79	0.00	4.993
SOYB	0	0.01	0	0	0.66	0.00	5.096
WHEA	0	0.02	0	0	0.8	0.00	4.355
ALUM	0.04	0.02	0	0.07	0.64	0.00	6.864
COPP	0.01	0.02	0	0.05	0.72	0.00	6.233
ZINC	0.03	0.02	0	0.04	0.74	0.00	5.933

Notes: This table illustrate the hedge ratios, among sixteen commodities and twenty Islamic Bank of GCC markets in full sample, GFC, SOR and during Covid-19.

4.5. The GMM estimations

From the previous section, we postulate that the impact of the global risk factors on commodities and Islamic bank stocks, might cause delays in the announcement information to be recognized by the market as this paper has the high frequency of daily data. Moreover, due to the time difference between the geographic areas, it might take longer for the news to spill over (Balli et al., 2020). We take this issue into consideration by generalized method of moments (GMM) that incorporates the lag of the dependent variable, along with other variables' lags, as explanatory variables.

The dilemma with the inclusion of lagged dependent variables as regressors is that ordinary least squares no longer produce unbiased estimates due to the so-called endogeneity problem. One solution is to estimate the model differently, with lags of the dependent variable as instruments using the generalized method of moments (GMM) of Arellano and Bond (1991), which yields consistent and efficient estimates of the parameters. The GMM model for the total, positive, and negative return spillovers can be represented as follows

$$\Delta TSI_{ij,t} = \beta_0 + \beta\Delta X_t + \varepsilon_{it} \tag{21}$$

Where the dependent variable $\Delta TSI_{ij,t}$ is created within three ways, which are total, positive and negative return spillovers between Islamic banks i and commodities j (Table 7). The data is sourced from DataStream. The term ΔX_t includes the determinants of return and volatility connectedness including $\Delta EPU_t, \Delta VIX_t, \Delta OVX_{t,} \Delta GVZ_t, \Delta GFS_t, \Delta EMV_t, \Delta GMNS_t, \Delta CLMT_t$.

Table 7 contains the GMM estimations for the Eq. (21). In all three models the first- and second-order correlation A tests have p-values bigger than 10%, support the idea error terms are not correlated for the first and second orders. This gives us the green light that lagged endogenous variables are appropriate to use as instruments. Additionally, the p-values of the Sargan test of over-identifying restrictions fails to reject the null hypothesis that the instruments are exogenous in any specification. The findings are not different much from previous tables. However, the persistency of the connectedness is revealed. However even after controlling for lagged dependent variables, in all 3 models (total, positive and negative connectedness, respectively) shocks controlled with variables such as EPU, GVZ, OVX and CLMT have significant coefficients, in line with Tables 4–6.

4.6. Robustness checks

Moving forward, we must conduct a thorough and rigorous set of robustness analyses explicitly focusing on the TVP-VAR-based connectedness outcomes. Furthermore, we will present the findings of our 250-day rolling-window VAR and Quantile VAR (QVAR) analyses. After careful examination, we have determined that the 250-observations rolling window yields results highly correlated with the TVP-VAR outcomes. Therefore, we have chosen it as our benchmark model following Diebold and Yılmaz's research (Diebold and Yilmaz, 2009; Diebold and Yilmaz, 2012). The VAR model, determined through the equation-by-equation Ordinary Least Squares (OLS) style, is highly vulnerable to outliers due to its provisional mean-based method. However, to combat this issue, we must consider opting for quantile regression or the slightest absolute deviation (LAD) regression to choose each formula. By doing so, we can prioritize the conditional median-based computation and effectively eliminate the outlier sensitivity problem of the VAR model. It is essential to act against this issue to ensure accurate and reliable results. Upon closer analysis, it is evident that the TVP-VAR model has a distinct advantage over the other two models due to its quicker adjustments, as highlighted by Antonakakis et al. (2020a) and Korobilis and Yilmaz (2018). This is critical when accurately forecasting interconnectedness and risk within the analyzed system. On the other hand, the VAR model's sensitivity to outliers can result in misleading outcomes, particularly during times of crisis such as the GFC, SOR, and COVID-19. Despite this shortcoming, the time delay is not a significant concern when tracking the system's evolution during crises.

Fig. 10 presents two sensitivity analyses. Panel A illustrates the changes in total connectedness over time by adjusting the forecast horizon. Notably, significant improvements in measurement were observed at the end of 2008, 2015, and the beginning of 2020. This can be attributed to the network's increased consistency during the Global Financial Crisis, Sovereign Debt Crisis, and COVID-19, resulting in increased efficiency. Moreover, the dynamics appear to even out towards the end of the period, leading to a return to standard time in the sample markets.

Panel B displays the varying dynamic connectedness with different values of the variance-covariance decay factor. We keep the VAR coefficient decay factor constant at 0.99 since the connection between variables is unlikely to change by >1% daily. Surprisingly, the grey area, which shows the dynamic connectedness of TVP-VAR models with various requirements, doesn't include the VAR and QVAR values. This highlights the time delay issue of rolling-window models. Interestingly, the VAR model behaves differently from the other two models towards the end of 2008, 2015, and the beginning of 2020, while the QVAR and TVP-VAR models exhibit comparable movements.

4.7. Multivariate portfolio analysis

In this section, we examine the implications for portfolio diversification and risk hedging. We use the Minimum Connectedness Portfolio (MCoP) approach that minimizes pairwise connections among markets. Specifically, we focus on examining the hedging effectiveness (HE) and Sharpe ratios to study risk hedging and profitability for the different used stocks and commodities. The results are reported in Table 8 for the full-sample period (Panel A), the period of the global financial crisis (Panel B), the period of the Shale oil revolution (Panel C), and the Covid-19 pandemic (Panel D).

Before considering hedge effectiveness and Sharpe ratios, we begin with the average portfolio allocations in the full sample (Panel A). The mean portfolio weights for GCC Islamic bank stocks range between 2% and 4%, with a combined time averaged weight of 38%. For commodities, average portfolio weights, typically, range between 1% and 4%. The highest weight is recorded for Grain (28%) giving commodities a combined time averaged weight of 62%. For the period of the GFC (Panel B), the combined time averaged weight is 65% for commodities and 35% for Islamic bank stocks. In the period of the SOR (Panel B), the combined time averaged weight is of about 63% for commodities and 36% for Islamic bank stocks, against 66% for commodities and 34% for Islamic banks during the Covid-19 period (Panel D). It is noteworthy that some agriculture commodities (i.e., corn, soybeans and wheat) have a mean weight of 0% during both SOR and Covid-19 periods. This result might indicate that excluding these commodities from the multivariate portfolios provide some benefits for investors. Grain market has the largest single weight in the four sample periods among all markets, which suggests its important contribution in a fixed-income investment portfolio.

Moving to the hedge effectiveness scores (*HE*), results in the full sample show that, based on the mean portfolio weights, an investor could statistically and significantly lower the volatility of each asset in her portfolio by >60% with respect to an investment of the corresponding average weight, for most of the markets. The only exceptions are live stocks and gold that are associated to a *HE* of 17% and 39%, respectively, against >60% for all the other markets. For example, an investor that attributes a weight of 3% to gold could decrease the risk of her portfolio by 39%. The same reasoning holds for all the other markets. The highest *HE* is associated to Bahraini Islamic bank ASB. Specifically, when investing 4% of her portfolio in ASB, an investor could hedge about 97% of its risk. For Islamic banks in general, *HE* ranges between 70% and 97% which means that investing in GCC Islamic banking present some non-trivial hedging properties when combined with commodities. These same conclusions of financially meaningful volatility reductions are also valid for all markets in three sample periods (Panel B – D). the only exception is live stocks in the period of GFC whose result of negative *HE* suggests that it is associated with increased portfolio volatility during this period. For the periods of SOR and Covid-19, the hedging effectiveness of commodities seems to be more pronounced than that of the full-sample period. The hedging effectiveness of GCC Islamic banks seems to be important in all samples, which confirms their stability in risk reduction properties. In sum, these findings tend to validate the hypothesis of presence of diversification opportunities among used markets.

Finally, considering the results of the Sharpe ratios, we find that all commodities, except natural gas, seem to be highly performant during the full sample period. Gold exhibits the strongest performance with 2.528, and corn appears to display the strongest combined risk reduction and diversification properties with a *HE* of 74% and a Sharp ratio of 1.510. For Islamic banks, we find that the highest Sharpe ratio is for Kuwaiti bank KFH (1.532). The risk-adjusted performance of the majority of Islamic banks is positive except for KIB, BA, DIB and SIB, suggesting a high remuneration of returns to risk in the full sample. Turning to the results of the GFC and SOR period, we find that more banks and commodities exhibit negative Sharpe ratios. The most highly performant commodities (banks) during these two periods are Sugar with 4.757 (AUB with 8.089) and natural gas with 8.034 (BIB with 5.586) during GFC and SOR, respectively. For the period of the pandemic (Panel D), all commodities and Islamic banks (except for KIB, QIIB, and DIB) exhibit uniformly positive Sharpe ratios suggesting that the inclusion of these assets in a portfolio is likely to lead to substantially higher returns and/or lower risks.

To give a more concrete understanding of this dynamic portfolio with minimum interconnectedness, Fig. 11 illustrates the time varying MCoP. Under a closer inspection, we find a growth in MCoP in 2007 that precedes a decline until the end of 2009. This period corresponds to the GFC and suggests increased bilateral spillovers across assets in this period. The weight then appreciates again between 2010 and 2015 before declining by 2015. It remains constant between 2015 and 2019 and then increases during the period of the pandemic.

5. Conclusion and policy implications

In this paper, we investigate the network connectedness as well as portfolio implications for thirteen GCC Islamic bank stocks and sixteen commodities (i.e., energy, metal, industrial and agriculture) for the period spanning 01/10/2005 to 30/09/2022. The importance of this work is set against the absence of existing literature on the connections between these two assets. Hence, we contribute to the literature on connectedness analysis by providing a detailed and policy-oriented study of the *spillovers* between commodities and stocks of GCC Islamic banks. Using recent advances in econometric estimation procedures, we analyze the network connectedness between the indices by employing the time-varying parameter vector autoregression (TVP-VAR) based connectedness approach of Balcilar et al. (2021) extended to an asymmetric framework and applied to daily data.

We find some interesting results that can be summarized as follows. First, the static total return *spillover* analysis shows strong pairwise connections between grain and wheat, grain and corn, and silver and gold. Some other substantial linkages are also found between zinc and copper and from grain to soybeans. The linkages are inexistent or weak between the other markets. Second, we find an important stability feature in the connections between some commodities and GCC Islamic banks with respect to both positive and negative returns. Specifically, results indicate that the majority of Islamic bank stocks and commodities are not significantly affected by shocks from other markets. Third, the time-varying analysis shows that shocks induced by demand – and supply – side (i.e., GFC, SOR, and Covid-19) significantly increase the magnitude of spillover among used assets. However, these periods do not seem to fundamentally change the spillover picture in the long – run. Fourth, we find that the patterns of the net spillover positions of used markets fluctuate in the full sample period and that connections of negative returns recorded higher levels as compared to positive returns which indicates tighter linkages between markets in bearish market conditions. Fifth, we test the robustness of our results in sub-samples, and we find that during the GFC, the SOR, and the Covid-19 pandemic, the majority of used assets do not seem to be largely affected by shocks transmitted from other markets. Sixth, we find a significant role of risk variables in determining the magnitude of the spillover among commodities and GCC Islamic bank stocks. Finally, multivariate portfolio analysis shows some risk

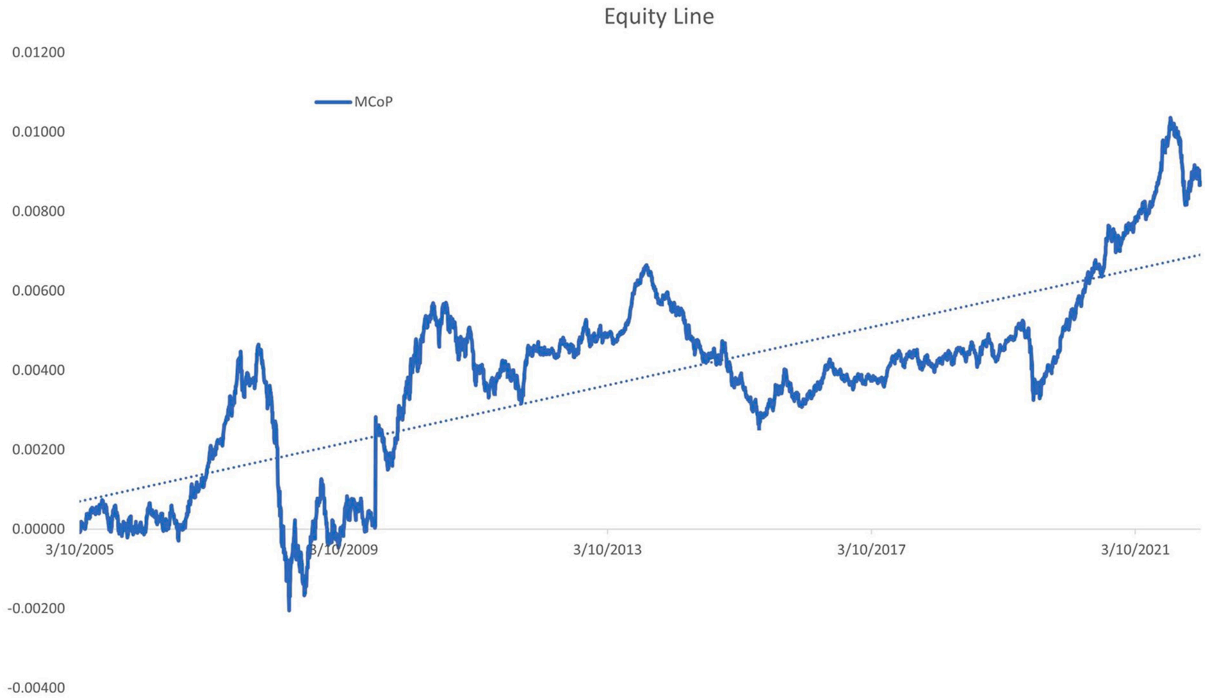


Fig. 11. Equity line.
Note: The series illustrate the cumulative sum of portfolio returns. MCoP denotes the minimum connectedness portfolio (Broadstock et al., 2022).

reduction properties of the majority of used assets in the full sample period and during sub-samples. Using the hedge effectiveness indices and Sharpe ratios, we demonstrate that a pre–set portfolio technique in which weights of various assets are selected based on the dynamic connectedness network presents some diversification opportunities.

The findings outlined have significant implications for policy, regulatory bodies, and the generalizability of research in the context of global applicability. First, strong pairwise connections between certain commodities, such as grain and wheat, grain and corn, and silver and gold, suggest the need for policies that address potential spillover effects and market interdependencies. Regulatory frameworks may need to consider these connections to mitigate systemic risks. Second, the stability feature observed in connections between commodities and GCC Islamic banks highlights the resilience of Islamic banking systems to shocks from other markets. Policymakers could explore the factors contributing to this stability and potentially leverage them to enhance overall financial stability. Third, tighter linkages between markets during bearish conditions underscore the importance of regulatory oversight during periods of market stress. Regulators may need to implement measures to enhance market resilience and prevent the amplification of negative shocks. Fourth, the significant role of risk variables in determining spillover magnitudes emphasizes the importance of incorporating risk management strategies into regulatory frameworks and investment decision-making processes. Regulators and investors can use these insights to develop more effective risk mitigation strategies. Fifth, the robustness of findings across different sub-samples, including the GFC, SOR, and Covid-19 pandemic periods, suggests that the observed spillover dynamics may hold true across various market conditions. This enhances the generalizability of the research findings and underscores their relevance for policymakers and market participants globally. Finally, multivariate portfolio analysis highlights the potential benefits of diversification strategies in mitigating risk. Policymakers, investors, and financial institutions can leverage these findings to design more resilient portfolios that offer improved risk-adjusted returns. The demonstration of risk reduction properties and diversification opportunities through dynamic connectedness networks suggests potential benefits from adopting sophisticated portfolio management techniques.

Our study also provides important insights for investors. Specifically, our findings show some sizeable risk mitigation and diversification opportunities between used markets, which suggests that including GCC Islamic banks and commodities in a portfolio could yield some risk reduction benefits and profitability. Second, while we find that return connections between used assets become more pronounced during episodes of demand – and supply – side shocks, the general spillover picture does not seem to be fundamentally reshaped as the spillover extent is likely to decrease immediately after. Specifically, the predictable connection between Islamic banks and commodities due to commodities murabaha is shown to be well monitored in the context of GCC as connectedness between these two assets does not seem to be largely affected by systemic risk of extreme events, which could, indirectly, suggest the good risk management ability of GCC Islamic banks. Finally, as risk factors as shown to be significant determinants of the connectedness patterns across markets, rational investors should remain alert to the movements of these factors and take long and short positions accordingly.

CRediT authorship contribution statement

Mabruk Billah: Data curation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Sinda Hadhri:** Data curation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Muneer Shaik:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Faruk Balli:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Appendix section

Table A.1
Variables to determine the spillovers.

Variable	Description
EPU	EPU index shows the relevant consistency of own-country newspaper information in which consist of a threesome of conditions referring to the economy (E), policy (P) and uncertainty (U). Former investigations indicate an inverted connection among transformations in EPU and Sukuk returns (Balli et al., 2020). Therefore, the negative sign will be expecting from EPU.
VIX	The VIX is a real-time market index that meets market assumptions for volatility over the next 30 days. Considering the bond attributes of Sukuk and green bonds, rises in the degree of the VIX possess an adverse effect on (Sukuk and green) bonds, which decreases the TSI. As a result, we anticipate. an adverse indication for the VIX.
OVX	OVX is the expected 30-day crude oil volatility estimate since the US Oil Fund (USO) set the price. Rises in the degree of the OVX come with a negative effect on green bond prices (Saeed et al., 2021), which results in a decrease in the degree of the TSI. Therefore, the negative sign will be expecting from OVX.
GVZ	GVZ is an estimation regarding the anticipated 30-day volatility of returns on the SPDR Gold Shares ETF (GLD).
GFS	Anticipated through Bank of America Merrill Lynch, the Global Financial Stress Index is a method regarding cross-market risk, demand protection, and financial investment flows in the worldwide financial process.
EMV	Baker et al. (2019) developed an index which is called Equity Market Volatility (EMV) tracker, and it is being based on the eleven major U.S. newspapers. Moreover, this index closely moves with the VIX and with realized volatility on the S&P 500.
GMNS	We have another interesting variable that we have taken, which is called global macroeconomic news surprises and has been developed by Scotti (2016). As we know the aggregate demand and supply conditions may have higher uncertainty through macroeconomic news surprises. Therefore, considered that sukuk and commodity prices, are strongly sensitive to demand and supply conditions, a rise in the uncertainty encompassing the macroeconomy may cause a higher volatility in sukuk and commodity prices.
CLMT	The MSCI World Climate Change Index (CLMT) is accorded to the MSCI World Index, it is relative index, and consists of substantial and mid-cap securities across 23 Developed regions. The index aims to represent the efficiency of an investment strategy that re-weights securities based upon the opportunities and risks connected with the transition to a lower carbon economy, although looking for to reduce exemptions from the relative index.

Table A.2
Correlation coefficients of explanatory variables.

Explanatory variables	EPU	VIX	OVX	GVZ	GFS	EMV	GMNS	CLMT
EPU	1.00							
VIX	0.17	1.00						
OVX	0.13	0.48	1.00					
GVZ	0.11	0.45	0.27	1.00				
GFS	−0.18	0.05	0.31	0.13	1.00			
EMV	0.23	−0.06	0.27	−0.26	−0.13	1.00		
GMNS	0.10	0.13	−0.07	0.11	−0.32	0.14	1.00	
CLMT	0.03	0.57	0.22	0.25	0.40	−0.05	−0.14	1.00

Table A.3
Details of Islamic banks in the GCC region.

Country	Number of Islamic Banks	Total Assets (in USD billion)	Total Financing (in USD billion)	Share of Murabaha Financing
Bahrain	26	67.7	48.6	61.30%
Kuwait	11	59.4	39.9	52.50%
Oman	6	4.8	2.2	53.80%
Qatar	11	78.7	57.3	65.90%
Saudi Arabia	34	419.2	325.1	65.40%
United Arab Emirates	14	102.3	73.1	58.20%
Total	102	732.1	546.2	63.50%

Note that the share of Murabaha financing reported in this table represents the percentage of total financing that is provided through the Murabaha financing mode. Source: Islamic Financial Services Board (IFSB) (2021). Islamic Financial Services Industry Stability Report 2021. Retrieved from https://www.ifsb.org/ifsbindonesia/images/IFSB-IFSI-Stability-Report-2021.pdf.

References

Abbasi, S.M., Hollman, K.W., Murrey, J.H., 1989. Islamic economics: foundations and practices. Int. J. Soc. Econ. 16, 5–17. https://doi.org/10.1108/03068298910367215.

Abdelsalam, O., Dimitropoulos, P., Elnahass, M., Leventis, S., 2016. Earnings management behaviors under different monitoring mechanisms: the case of Islamic and conventional banks. J. Econ. Behav. Organ. 132, 155–173.

Abedifar, P., Molyneux, P., Tarazi, A., 2013. Risk in Islamic banking. Rev. Financ. 17 (6), 2035–2096. https://doi.org/10.1093/rof/rfs041.

Adekoya, O.B., Akinseye, A.B., Antonakakis, N., Chatziantoniou, I., Gabauer, D., Oliyide, J., 2022. Crude oil and Islamic sectoral stocks: asymmetric TVP-VAR connectedness and investment strategies. Res. Policy 78, 102877.

Adnan, N., Billah, S.M., 2023. Assessing the symmetric and asymmetric impact of technological innovations environmental quality in Qatar. Environ. Develop. Sustain. https://doi.org/10.1007/s10668-023-03909-3.

Ahmad, A.U.F., Hassan, M.K., 2007. Riba and Islamic banking. J. Islam. Econ. Bank. Financ. 3, 1–33.

Ahmed, H., Mohieldin, M., Verbeek, J., Aboulmagd, F., 2015. On the sustainable development goals and the role of Islamic finance, policy research working papers. World Bank. https://doi.org/10.1596/1813-9450-7266.

Ahmed, R., Chaudhry, S.M., Kumpamool, C., Benjasak, C., 2022. Tail risk, systemic risk and spillover risk of crude oil and precious metals. Energy Econ. 112, 106063 https://doi.org/10.1016/j.eneco.2022.106063.

Akhtar, S.F., Jaromi, M., John, K., 2017. Impact of interest rate surprises on Islamic and conventional stocks and bonds. J. Int. Money Financ. 79, 218–231.

Alam, M.K., Tabash, M.I., Billah, M., Kumar, S., Anagreh, S., 2022. The Impacts of the Russia–Ukraine Invasion on Global Markets and Commodities: A Dynamic Connectedness among G7 and BRIC Markets. J. Risk Financ. Manage. 15 (8), 352.

Aliyu, S., Hassan, M.K., Mohd Yusof, R., Naiimi, N., 2017a. Islamic banking sustainability: a review of literature and directions for future research. Emerg. Mark. Financ. Trade 1–31. https://doi.org/10.1080/1540496X.2016.1262761 forthcomin.

Aliyu, S., Yusof, R.M., Naiimi, N., 2017b. The role of moral transaction mode for sustainability of banking business. Int. J. Soc. Econ. 44, 2238–2256. https://doi.org/10.1108/IJSE-07-2016-0205.

Alshater, M.M., Alqaralleh, H., El Khoury, R., 2023. Dynamic asymmetric connectedness in technological sectors. J. Econ. Asymmet. 27, e00287.

Antonakakis, N., Chatziantoniou, I., Gabauer, D., 2020a. Refined measures of dynamic connectedness based on time-varying parameter vector autoregressions. J. Risk Financ. Manage. 13 (4), 84.

Antonakakis, N., Cunado, J., Filis, G., Gabauer, D., de Gracia, F.P., 2020b. Oil and asset classes implied volatilities: investment strategies and hedging effectiveness. Energy Econ. 91, 104762.

Antonakakis, N., Cunado, J., Filis, G., Gabauer, D., de Gracia, F.P., 2023. Dynamic connectedness among the implied volatilities of oil prices and financial assets: new evidence of the COVID-19 pandemic. Int. Rev. Econ. Financ. 83, 114–123. https://doi.org/10.1016/j.iref.2022.08.009.

Anwer, Z., Khan, A., Naeem, M.A., Tiwari, A.K., 2022. Modelling systemic risk of energy and non-energy commodity markets during the COVID-19 pandemic. Ann. Oper. Res. 1–35.

Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. The Rev. Econ. Stud. 58 (2), 277–297.

Arfaoui, M., Chkili, W., Rejeb, A.B., 2022. Asymmetric and dynamic links in GCC Sukuk-stocks: implications for portfolio management before and during the COVID-19 pandemic. J. Econ. Asymmet. 25, e00244.

Aydemir, R., Atan, H.Z., Guloglu, B., 2022. How do the global equity and bond markets affect Islamic and conventional banks? A comparative cross-country analysis using multivariate regression quantiles. Eur. Econ. Rev. 12 (1), 95–114. https://doi.org/10.1007/s40822-022-00198-5.

Balli, F., de Bruin, A., Chowdhury, M.I.H., 2019. Spillovers and the determinants in Islamic equity markets. North Am. J. Econ. Financ. 50, 101040.

Balli, F., Billah, M., Balli, H.O., Gregory-Allen, R., 2020. Economic uncertainties, macroeconomic announcements and sukuk spreads. Appl. Econ. 52 (35), 3748–3769.

Baker, S.R., Bloom, N., Davis, S.J., Kost, K.J., 2019. *Policy news and stock market volatility* (No. w25720). National Bureau of Economic Research.

Balcilar, M., Gabauer, D., Umar, Z., 2021. Crude Oil futures contracts and commodity markets: New evidence from a TVP-VAR extended joint connectedness approach. Resourc. Policy 73, 102219.

Balli, F., Billah, M., Balli, H.O., De Bruin, A., 2021. Spillovers to sectoral equity returns: do liquidity and financial positions matter? Appl. Econ. 53 (27), 3097–3130. https://doi.org/10.1080/00036846.2021.1875120.

Balli, F., Billah, M., Balli, H.O., De Bruin, A., 2022. Spillovers between Sukuks and Shariah-compliant equity markets. Pac. Basin Financ. J. 72, 101725.

Baruník, J., Kočenda, E., Vácha, L., 2016. Asymmetric connectedness on the US stock market: bad and good volatility spillovers. J. Financ. Markets 27, 55–78.

Batten, J.A., Kinateder, H., Szilagyi, P.G., Wagner, N.F., 2021. Hedging stocks with oil. Energy Econ. 93, 104422.

Baumeister, C., Hamilton, J.D., 2019. Structural interpretation of vector autoregressions with incomplete identification: revisiting the role of oil supply and demand shocks. Am. Econ. Rev. 109 (5), 1873–1910.

Bekaert, G., Harvey, C.R., 2000. Foreign speculators and emerging equity markets. The J. Financ. 55 (2), 565–613.

Benlagha, N., Mseddi, S., 2019. Return and volatility spillovers in the presence of structural breaks: evidence from GCC Islamic and conventional banks. J. Asset Manage. 20, 72–90.

Billah, S.M., Adnan, N., 2024. Navigating environmental concerns and geopolitical risks: A study on green sukuk and Islamic equities amid climate crisis and the Russia-Ukraine conflict. Energy Strategy Revi. 53, 101372. https://doi.org/10.1016/j.esr.2024.101372.

Billah, M., Alam, M.R., Hoque, M.E., 2024a. Global uncertainty and the spillover of tail risk between green and Islamic markets: a time-frequency domain approach with portfolio implications. Int. Rev. Econ. Financ. 92, 1416–1433. https://doi.org/10.1016/j.iref.2024.02.081.

Billah, M., Balli, F., Balli, H.O., 2022a. Spillovers on sectoral sukuk returns: evidence from country level analysis. Appl. Econ. 1–31.

Billah, M., Hadhri, S., Balli, F., Sahabuddin, M., 2024b. Exploring the dynamic links, implications for hedging and investment strategies between sukuk and commodity market volatility: evidence from country level analysis. Int. Rev. Econ. Financ. 93, 350–371. https://doi.org/10.1016/j.iref.2024.03.011.

Billah, M., Hadhri, S., Hoque, M.E., Balli, F., 2024c. A multi-dimensional connectedness and spillover between green bond and Islamic banking equity: Evidence from country level analysis. Pacific-basin Finance Journal 83, 102258. https://doi.org/10.1016/j.pacfin.2024.102258.

Billah, M., Hoque, M.E., Balli, F., Kaur, J., Kumar, S., 2024d. Downside risk connectedness between Islamic sectors and green bond markets: implications for hedging and investment strategies. Appl. Econ. 1–34. https://doi.org/10.1080/00036846.2023.2295305.

Billah, M., Karim, S., Naeem, M.A., Vigne, S.A., 2022b. Return and volatility spillovers between energy and BRIC markets: evidence from quantile connectedness. Res. Int. Bus. Financ. 62, 101680 https://doi.org/10.1016/j.ribaf.2022.101680.

Bley, J., Chen, K.H., 2006. Gulf cooperation council (GCC) stock markets: the dawn of a new era. Glob. Financ. J. 17 (1), 75–91.

Bollerslev, T., Litvinova, J., Tauchen, G., 2006. Leverage and volatility feedback effects in high-frequency data. J. Financial Econ. 4 (3), 353–384.

Bouri, E., Lei, X., Jalkh, N., Xu, Y., Zhang, H., 2021. Spillovers in higher moments and jumps across US stock and strategic commodity markets. Res. Policy 72, 102060. https://doi.org/10.1016/j.resourpol.2021.102060.

Broadstock, D.C., Chatziantoniou, I., Gabauer, D., 2022. Minimum connectedness portfolios and the market for green bonds: Advocating socially responsible investment (SRI) activity. In: Applications in Energy Finance. Palgrave Macmillan, Cham, pp. 217–253.

Cagli, E.C., Mandaci, P.E., Taskin, D., 2023. The volatility connectedness between agricultural commodity and Agri businesses: evidence from time-varying extended joint approach. Financ. Res. Lett. 52, 103555 https://doi.org/10.1016/j.frl.2022.103555.

Caloia, F.G., Cipollini, A., Muzzioli, S., 2019. How do normalization schemes affect net spillovers? A replication of the Diebold and Yilmaz (2012) study. Energy Econ. 84, 104536.

Chatziantoniou, I., Degiannakis, S., Filis, G., 2019. Futures-based forecasts: how useful are they for oil price volatility forecasting? Energy Econ. 81, 639–649.

Chatziantoniou, I., Gabauer, D., 2021. EMU risk-synchronisation and financial fragility through the prism of dynamic connectedness. Q. Rev. Econ. Financ. 79, 1–14. https://doi.org/10.1016/j.qref.2020.12.003.

Deng, W., Zhang, X., Zhou, Y., Liu, Y., Zhou, X., Chen, H., Zhao, H., 2022. An enhanced fast non-dominated solution sorting genetic algorithm for multi-objective problems. Inform. Sci. 585, 441–453. https://doi.org/10.1016/j.ins.2021.11.052.
Diebold, F.X., Yilmaz, K., 2009. Measuring financial asset return and volatility spillovers, with application to global equity markets. Econ. J. 119 (534), 158–171.
Diebold, F.X., Yilmaz, K., 2012. Better to give than to receive: predictive directional measurement of volatility spillovers. Int. J. Forecast. 28 (1), 57–66.
Diebold, F.X., Yılmaz, K., 2014. On the network topology of variance decompositions: measuring the connectedness of financial firms. J. Econ. 182 (1), 119–134.
Dusuki, A.W., 2012. Islamic financial system : Principles & operations. In: International Shari'ah Research Academy for Islamic Finance (ISRA), 1st ed. Kuala Lumpur, Malaysia.
El-sheikh, S., 2008. The moral economy of classical Islam: a FiqhiConomic model. Muslim World 116–144. https://doi.org/10.1111/j.1478-1913.2008.00213.
Ewing, B.T., Malik, F., 2016. Volatility spillovers between oil prices and the stock market under structural breaks. Glob. Financ. J. 29, 12–23. https://doi.org/10.1016/j.gfj.2015.04.008.
Fama, E.F., 1991. Efficient capital markets: II. J. Financ. 46 (5), 1575–1617.
Gabauer, D., 2021. Dynamic measures of asymmetric & pairwise connectedness within an optimal currency area: evidence from the ERM I system. J. Multinatl. Financ. Manag. 60, 100680 https://doi.org/10.1016/j.mulfin.2021.100680.
Ha, J., Kose, M.A., Ohnsorge, F., 2021. One-Stop Source: A Global Database of Inflation. Policy Research Working paper 9737. World Bank.
Hassan, M.K., Djajadikerta, H.G., Choudhury, T., Kamran, M., 2021. Safe havens in Islamic financial markets: COVID-19 versus GFC. Glob. Financ. J. https://doi.org/10.1016/j.gfj.2021.100643.
Hung, N.T., 2021. Financial connectedness of GCC emerging stock markets. Eur. Econ. Rev. 11 (4), 753–773.
Hussain, M., Shahmoradi, A., Turk, R., 2015. An Overview of Islamic Finance (No. WP/15/120). IMF Working Papers, IMF Working Paper Series, Washington, D.C. USA.
Ji, Q., Zhang, D., Geng, J.B., 2019. Information linkage, dynamic spillovers in prices and volatility between the carbon and energy markets. J. Clean. Prod. 198, 972–978.
Johnes, J., Izzeldin, M., Pappas, V., 2014. A comparison of performance of Islamic and conventional banks 2004–2009. J. Econ. Behav. Organ. 103, S93–S107. https://doi.org/10.1016/j.jebo.2013.07.016.
Kahneman, D., Tversky, A., 1970. Prospect theory: an analysis under risk. Econometria 47 (2), 263–290.
Kammer, A., Norat, M., Piñón, M., Prasad, A., Towe, C., 2015. Islamic Finance: Opportunities, Challenges, and Policy Options (No. SDN/15/05), Islamic Finance, IMF Staff Discussion Note. Washington, D.C. USA.
Kanvinde, M., Shaik, M., 2020a. Are BRICS stock market indices mean reverting? Evidence based on expected lifetime range ratio. Int. J. Bus. Econ. 19 (2), 189–206.
Kanvinde, M., Shaik, M., 2020b. Testing asymmetry in mean reversion based on high and low prices: evidence from BRICS countries. J. Public Aff. e2443 https://doi.org/10.1002/pa.2443.
Kapar, B., Billah, S.M., Rana, F., Balli, F., 2024. An investigation of the frequency dynamics of spillovers and connectedness among GCC sectoral indices. Int. Rev. Econ. Financ. 89, 1442–1467. https://doi.org/10.1016/j.iref.2023.09.004.
Kenourgios, D., Naifar, N., Dimitriou, D., 2016. Islamic financial markets and global crises: contagion or decoupling? Econ. Model. 57, 36–46.
Khan, F., 2010. How "Islamic" is Islamic banking? J. Econ. Behav. Organ. 76, 805–820. https://doi.org/10.1016/j.jebo.2010.09.015.
Khediri, K.B., Charfeddine, L., Ben Youssef, S., 2015. Islamic versus conventional banks in the GCC countries: a comparative study using classification techniques. Res. Int. Bus. Financ. 33, 75–98. https://doi.org/10.1016/j.ribaf.2014.07.002.
Kocaarslan, B., Soytas, U., 2019. Dynamic correlations between oil prices and the stock prices of clean energy and technology firms: the role of reserve currency (US dollar). Energy Econ. 84, 104502.
Koop, G., Korobilis, D., 2013. Large time-varying parameter VARs. J. Economet. 177 (2), 185–198.
Koop, G., Korobilis, D., 2014. A new index of financial conditions. European Econ. Rev. 71, 101–116.
Korobilis, D., Yilmaz, K., 2018. Measuring dynamic connectedness with large Bayesian VAR models. Available at SSRN 3099725.
Liu, J., Man, Y., Dong, X., 2023. Tail dependence and risk spillover effects between China's carbon market and energy markets. Int. Rev. Econ. Financ. 84, 553–567. https://doi.org/10.1016/j.iref.2022.11.013.
Lombardi, M.J., Ravazzolo, F., 2016. On the correlation between commodity and equity returns: implications for portfolio allocation. J. Commod. Mark. 2 (1), 45–57.
Lundgren, A.I., Milicevic, A., Uddin, G.S., Kang, S.H., 2018. Connectedness network and dependence structure mechanism in green investments. Energy Econ. 72, 145–153. https://doi.org/10.1016/j.eneco.2018.04.015.
Mensi, W., Hammoudeh, S., Nguyen, D.K., Kang, S.H., 2016. Global financial crisis and spillover effects among the U.S. and BRICS stock markets. Int. Rev. Econ. Financ. 42 C, 257–276.
Mensi, W., Hammoudeh, S., Al-Jarrah, I.M.W., Sensoy, A., Kang, S.H., 2017a. Dynamic risk spillovers between gold, oil prices and conventional, sustainability and Islamic equity aggregate and sectors with portfolio implications. Energy Econ. 67, 454–475.
Mensi, W., Tiwari, A.K., Yoon, S.M., 2017b. Global financial crisis and weak-form efficiency of Islamic sectoral stock markets: an MF-DFA analysis. Physics A 471, 135–146. https://doi.org/10.1016/j.physa.2016.12.034.
Mensi, W., Hammoudeh, S., Al-Jarrah, I.M.W., Al-Yahyaee, K.H., Kang, S.H., 2019. Risk spillovers and hedging effectiveness between major commodities, and Islamic and conventional GCC banks. J. Int. Financ. Mark. Inst. Money 60, 68–88. https://doi.org/10.1016/j.intfin.2018.12.011.
Miah, M.D., Suzuki, Y., 2020. Murabaha syndrome of Islamic banks: a paradox or product of the system? J. Islamic Account. Busin. Res. 11 (7), 1363–1378.
Minhat, M., Dzolkarnaini, N., 2016. Islamic corporate financing: does it promote profit and loss sharing? Bus. Ethics A Eur. Rev. 25, 482–497. https://doi.org/10.1111/beer.12120.
Naeem, M.A., Billah, M., Marei, M., Balli, F., 2021. Quantile connectedness between Sukuk bonds and the impact of COVID-19. Appl. Econ. Lett. 1–10.
Naeem, M.A., Peng, Z., Bouri, E., Hussain Shahzad, S.J., Karim, S., 2022. Examining the asymmetries between equity and commodity ETFs during COVID-19. Res. Policy 79, 103048. https://doi.org/10.1016/j.resourpol.2022.103048.
Nagayev, Ruslan, Disli, Mustafa, Inghelbrecht, Koen, Ng, Adam, 2016. On the dynamic links between commodities and Islamic equity. Energy Econ. 58, 125–140.
Pappas, V., Ongena, S., Izzeldin, M., Fuertes, A.M., 2016. A survival analysis of Islamic and conventional banks. J. Financ. Serv. Res. 51 (2), 221–256. https://doi.org/10.1007/s1069 3-016-0239-0.
Qi, H., Ma, L., Peng, P., Chen, H., Li, K., 2022. Dynamic connectedness between clean energy stock markets and energy commodity markets during times of COVID-19: empirical evidence from China. Res. Policy 79, 103094. https://doi.org/10.1016/j.resourpol.2022.103094.
Rabbani, M.R., Billah, S.M., Shaik, M., Rahman, M., Boujlil, R., 2023. Dynamic connectedness, spillover, and optimal hedging strategy among FinTech, Sukuk, and Islamic equity markets. Glob. Financ. J. 58, 100901 https://doi.org/10.1016/j.gfj.2023.100901.
Radetzki, M., 2006. The anatomy of commodity booms. Res. Policy 31, 56–64.
Rehman, M.U., Vo, X.V., Ko, H.-U., Ahmad, N., Kang, S.H., 2023. Quantile connectedness between Chinese stock and commodity futures markets. Res. Int. Bus. Financ. 64, 101810 https://doi.org/10.1016/j.ribaf.2022.101810.
Rizwan, M.S., Ahmad, G., Ashraf, D., 2022. Systemic risk, Islamic banks, and the COVID-19 pandemic: an empirical investigation. Emerg. Mark. Rev. 51, 100890 https://doi.org/10.1016/j.ememar.2022.100890.
Saeed, T., Bouri, E., Tran, D.K., 2020. Hedging strategies of green assets against dirty energy assets. Energies 13 (12), 3141. https://doi.org/10.3390/en13123141.
Saeed, T., Bouri, E., Alsulami, H., 2021. Extreme return connectedness and its determinants between clean/green and dirty energy investments. Energy Econ. 96, 105017 https://doi.org/10.1016/j.eneco.2020.105017.
Salisu, A.A., Shaik, M., 2022. Islamic stock indices and COVID-19 pandemic. Int. Rev. Econ. Financ. 80, 282–293.
Sclip, A., Dreassi, A., Miani, S., Paltrinieri, A., 2016. Dynamic correlations and volatility linkages between stocks and sukuk: evidence from international markets. Rev. Financ. Econ. 31, 34–44.
Scotti, C., 2016. Surprise and uncertainty indexes: Real-time aggregation of real-activity macro-surprises. J. Monetary Econ. 82, 1–19.

Sensoy, A., Aras, G., Hacihasanoglu, E., 2015. Predictability dynamics of Islamic and conventional equity markets. N. Am. J. Econ. Financ. 31, 222–248. https://doi.org/10.1016/j.najef.2014.12.001. Simon, H. A. 1961. Administrative Behavior.
Shah, A.A., Dar, A.B., 2022. Asymmetric, time and frequency-based spillover transmission in financial and commodity markets. J. Econ. Asymmet. 25, e00241.
Shahzad, S.J.H., Arreola-Hernandez, J., Bekiros, S., Shahbaz, M., Kayani, G.M., 2018. A systemic risk analysis of Islamic equity markets using vine copula and delta CoVaR modelling. J. Int. Finan. Markets. Inst. Money 56, 104–127.
Shaik, M., Maheswaran, S., 2017. Random walk in emerging Asian stock markets. Int. J. Econ. Financ. 9 (1), 20–31. https://doi.org/10.5539/ijef. v9n1p20.
Shaik, M., Maheswaran, S., 2018. Expected lifetime range ratio to find mean reversion: evidence from Indian stock market. Cogent. Econ. Financ. 6 (1), 1–23. https://doi.org/10.1080/23322039.2018.1475926.
Shaik, M., Padmakumari, L., 2022. Value-at-risk (VAR) estimation and backtesting during COVID-19: empirical analysis based on BRICS and US stock markets. Invest. Manage. Financ. Innov. 19 (1), 51–63. https://doi.org/10.21511/imfi.19(1). 2022.04.
Shaik, M., Rehman, M.Z., 2022. The dynamic volatility connectedness of major environmental, social, and governance (ESG) stock indices: evidence based on DCC-GARCH model. Asia-Pacific Finan. Markets. 1–16.
Shaik, M., Varghese, G., Madhavan, V., 2023a. The dynamic volatility connectedness of global financial assets during the Ebola & MERS epidemic and the COVID-19 pandemic. Appl. Econ. 1-21 https://doi.org/10.1080/00036846.2023.2174499.
Shaik, M., Jamil, S.A., Hawaldar, I.T., Sahabuddin, M., Rabbani, M.R., Atif, M., 2023b. Impact of geo-political risk on stocks, oil, and gold returns during GFC, COVID-19, and Russian–Ukraine War. Cogent. Econ. Financ. 11 (1), 2190213.
Sharpe, S.A., 1994. Financial market imperfections, firm leverage, and the cyclicality of employment. Am. Econ. Rev. 84 (4), 1060–1074.
Silvennoinen, A., Thorp, S., 2013. Financialization, crisis and commodity correlation dynamics. J. Int. Financ. Mark. Inst. Money 24, 42–65.
Singh, G., Shaik, M., 2021. The short-term impact of COVID-19 on global stock market indices. Contemp. Econ. 15 (1), 1–18.
Sorwar, G., Pappas, V., Pereira, J., Nurullah, M., 2016. To debt or not to debt: are Islamic banks less risky than conventional banks? J. Econ. Behav. Organ. 132, 113–126. https://doi.org/10.1016/j.jebo.2016.10.012.
Su, X., 2020. Measuring extreme risk spillovers across international stock markets: a quantile variance decomposition analysis. North Am. J. Econ. Financ. 51, 101098.
Tabash, M.I., Billah, M., Kumar, S., Alam, M.K., Balli, F., 2022. Analysis of the frequency dynamics of spillovers and connectedness among Islamic and conventional banks and their determinants: evidence from gulf cooperative council (GCC) markets. Appl. Econ. https://doi.org/10.1080/00036846.2022.2140771.
Tiwari, A.K., Nasreen, S., Ullah, S., Shahbaz, M., 2020. Analysing spillover between returns and volatility series of oil across major stock markets. Int. J. Financ. Econ. 26 (2), 2458–2490.
Tiwari, A.K., Abakah, E.J.A., Adewuyi, A.O., Lee, C.C., 2022. Quantile risk spillovers between energy and agricultural commodity markets: evidence from pre and during COVID-19 outbreak. Energy Econ. 113, 106235.
Umar, Z., Trabelsi, N., Alqahtani, F., 2021. Connectedness between cryptocurrency and technology sectors: international evidence. Int. Rev. Econ. Financ. 71, 910–922.
Van Greuning, H., Iqbal, Z., 2008. *Risk analysis for Islamic banks*. World Bank Publications.
Wajdi Dusuki, A., 2008. Understanding the objectives of Islamic banking: a survey of stakeholders' perspectives. Int. J. Islam. Middle East. Financ. Manag. 1, 132–148. https://doi.org/10.1108/17538390810880982.
Xia, Q., Yang, J.J., 2019. Memristive crossbar arrays for brain-inspired computing. Nature Materials 18 (4), 309–323.
Yoon, D.-E., Choudhury, T., Saha, A.K., Rashid, M., 2022. Contagion risk: cases of Islamic and emerging market banks. Int. J. Islam. Middle East. Financ. Manag. 15 (3), 481–505. https://doi.org/10.1108/IMEFM-11-2020-0555.
Yousuf, M., Zhai, J., 2022. The financial interconnectedness between global equity markets and crude oil: evidence from the GCC. J. Chin. Econ. Bus. Stud. 20 (2), 183–206.
Zaman, A., 2009. Islamic Economics: A Survey of the Literature, 48, pp. 525–566.