Analysis of the impact of COVID-19 on the dynamic volatility spillover network in the Saudi stock market

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🆔 **Nadia Belkhir**[1,2+]
🆔 **Mouna Boujelbène Abbes**[2]

[1]Department of Insurance and Risk Management, Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia.
Email: nabelkhir@imamu.edu.sa
[2]Faculty of Economics and Management of Sfax, University of Sfax, Tunisia.
Email: abbes.mouna@gmail.com

(+ Corresponding author)

ABSTRACT

This study investigates the risk spillover among the COVID-19-related news Panic Index, the insurance industry, the Tadawul All-Share Index, and sector indices in Saudi stock market. Volatility spillovers serve as an accurate indicator for the transmission of risk across various sectors. Our empirical findings show that, prior to the outbreak of COVID-19, the Tadawul All-Share stock market played a dominant role as a net transmitter of risk for sector indices, including insurance, media, pharma, retail, transport, and utilities. Furthermore, our analysis demonstrates that the COVID-19 Panic Index exerts significant influence on the net pairwise connectedness, particularly impacting the Tadawul All-Share Index, energy, banking, development, materials, real estate, transport, and utilities sectors. Additionally, our results indicate that the insurance sector acts as a net receiver of spillovers from the utilities, media, pharma, and retail sectors throughout the sample period, affirming the heightened impact of the pandemic on these sectors. The pandemic, being a health-related issue, led to a notable surge in the volatility of sectors associated with health, given their pivotal role in effectively addressing the crisis. These insights carry substantial implications for investors, portfolio managers, and policymakers, shedding light on the potential repercussions of the pandemic on the stock market.

Contribution/ Originality: This study constitutes the only examination to date that has delved into the interconnected relationships among insurance, the Tadawul All-Share, and sectoral indices, using the COVID-19 Panic Index as a proxy for stock market uncertainty. This index measures the degree of investor fear regarding the pandemic and has become an increasingly important tool for assessing risk in recent years.

1. INTRODUCTION

The COVID-19 outbreak, officially declared a pandemic on 11 March 2020 by the World Health Organization (WHO), has not only threatened the lives and well-being of individuals, but also triggered a global economic crisis. This crisis heightened the risk of spillovers among various sectors and markets, leading to a change in investor sentiment and market conditions.

This epidemic has emerged as a major threat to the global economy and financial markets, increasing global financial risks and giving rise to greater uncertainty. In this context, financial markets experienced significant shocks, characterized by sharp declines in their indicators. Therefore, the volatility induced by this shock mirrors that of the

"Black Monday" of 1987 and surpasses even the volatility witnessed in the stock market during the global financial crisis of 2007–2008.

Moreover, the COVID-19 pandemic has caused damage, resulting in negative returns, heightened uncertainty, and increased volatility in the equity markets (Cheng, Liu, Yao, & Zhao, 2022; Li, Zhuang, Wang, & Dong, 2021), commodity markets (Adekoya & Oliyide, 2021; Baker et al., 2020), and cryptocurrency markets (Conlon, Corbet, & McGee, 2020; Corbet, Goodell, & Günay, 2020; Garcia-Jorcano & Benito, 2020; Umar & Gubareva, 2021).

The American financial markets fell when the authorities ordered the cessation of most economic activities. The economies of European countries are closely linked to the Chinese economy, so the spread of the Coronavirus (Covid-19) pandemic prompted European countries to impose travel restrictions and close some factories, either to contain the virus or to interrupt supply chains coming from China, as a result European financial markets are among the most down by 40%. The transmission of instability from the Chinese stock market to the world's financial markets (Contessi & De Pace, 2021). European financial markets are no different from Arab markets, as these markets have been affected by the Coronavirus (COVID-19) pandemic, due to their connection with global markets and being affected by the same fears that other markets fear. However, the markets of these countries are linked to the extent to which their economies can generate revenues through oil prices, which have achieved declines during the spread of the Covid-19 virus. The market of the United Arab Emirates was the most affected Arab market, with a decrease in its prices 35.36%, Kuwait and Saudi Arabia followed in the second and third place, respectively, with a decrease of 31% and 26%. The continued low interest rates, capital market volatility, and weak growth prospects in all premiums are considered as factors affecting the financial stability of insurance companies.

The phenomenon of shock transmission in financial markets has long been an area of interest for economists and financial analysts (e.g., (Bekaert, Ehrmann, Fratzscher, & Mehl, 2014; Forbes & Rigobon, 2002)). However, the COVID-19 pandemic has brought this issue to the forefront of global economic discussions, as the outbreak has led to unprecedented levels of volatility and uncertainty across financial markets worldwide (Baker et al., 2020). The COVID-19 pandemic highlighted the interconnectedness of financial systems and the potential for shocks to spread rapidly across sectors and regions. The COVID-19 pandemic had a significant impact on financial markets around the world, with stock prices plummeting and volatility increasing dramatically in many cases. During the COVID-19 crisis, the transmission of shocks was particularly acute, affecting various sectors and asset classes in different ways (Auerbach, Gorodnichenko, & Murphy, 2020). One of the sectors most affected by the pandemic is the insurance industry, which is exposed to a wide range of risks associated with health, travel, and business interruptions (Cummins et al., 2020). As such, investors, policymakers, and other stakeholders have closely monitored the insurance sector for its potential implications for financial stability and economic recovery.

This study examines the dynamic volatility spillovers between the insurance sector, the Tadawul All-Share Index and other sector indices in Saudi Arabia before and during the COVID-19 crisis. Moreover, this study is unique in that it is the first to investigate the spillover effects on stock and sector indices using the COVID-19 Panic Index. This index measures the degree of investor fear regarding the pandemic and its impact on financial markets and has become an increasingly important tool for assessing risk in recent years. By analyzing the information spillover from the pandemic to these indices, we seek to provide insights into the interdependence and transmission of shocks between the insurance sector and other economic sectors in Saudi Arabia during this crisis.

Our paper contributes significantly to the existing literature in several ways. Firstly, it analyzes the impact of the pandemic on the Saudi stock market, shedding light not only on the Tadawul All-Share Index but also sectoral indices. This comprehensive approach allows for the identification of the effects across various sectors.

During the pandemic, we explore the impact of COVID-19-related media coverage on the insurance sector, the Tadawul All Share Index, and other sectoral indices. This investigation offers fresh insights into analyzing the global influence of COVID-19 on financial markets. Specifically, to examine the effects of stock market uncertainty spillovers

on the volatility of stock and sector indices, we employ a novel panic index based on COVID-19, developed by Subrahmanyam (2019), Ding, Zhou, and Li (2020) and Rognone, Hyde, and Zhang (2020). This index measures the extent of stress, panic, fear, or hysteria in media coverage related to the COVID-19 pandemic, drawing from hundreds of news sources, and utilizing neutral stock market-related Google search terms. This study constitutes the only examination to date that has delved into the interconnected relationships among insurance, the Tadawul All-Share, and sectoral indices, using the COVID-19 Panic Index as a proxy for stock market uncertainty.

Secondly, we use the approach proposed by Diebold and Yilmaz (2012) to examine the magnitude and direction of spillover effects between the insurance sector, the Tadawul All Share Index, and other sector indices both before and during the COVID-19 crisis. This analysis is of considerable importance for investors and policymakers amid the pandemic. We also look to the net spillover index, identifying the receiver or transmitter of volatility shocks between the insurance sector and other sectors before and during the pandemic, a novel aspect not previously explored. Hence, this study is the first examination of bidirectional dynamic connectedness between the insurance sector and other sectors during the COVID-19 pandemic, potentially offering crucial insights for investors. In summary, our paper introduces a new perspective to examine the influence of COVID-19 on insurance and other sector indices within the Saudi stock market. The pandemic's impact on the insurance industry could be substantial, driven by heightened demand for health and life insurance products as individuals prioritize protection for themselves and their families.

In summary, our paper introduces a fresh perspective for scrutinizing the influence of COVID-19 on insurance and other sector indices within the Saudi stock market. The pandemic's impact on the insurance industry could be substantial, driven by heightened demand for health and life insurance products as individuals prioritize protection for themselves and their families.

However, the virus may also lead to an increase in claims, which could put a strain on insurance companies' finances. The Saudi Tadawul All Share Index and sector indices have also been affected by the epidemic, with fluctuations and volatility in response to the pandemic and the resulting economic uncertainty. Identifying which sector is driving market movements and how shocks are transmitted across sectors during the coronavirus pandemic is essential for risk management and portfolio diversification. Our findings can inform investors, policymakers, and other stakeholders of the potential implications of the COVID-19 epidemic for the insurance and other economic sectors in Saudi Arabia.

The remainder of this paper is organized as follows: Section 2 reviews the related literature. The methodologies are developed in section 3. Section 4 describes the data. Section 5 presents and discusses the empirical results. Finally, we conclude in section 6.

2. LITERATURE REVIEW

Two primary theoretical arguments regarding volatility spillovers are extensively discussed in the literature. The contagion hypothesis posits that the strength of volatility spillovers across markets increases during crises, limiting the benefits of portfolio diversification. Conversely, the decoupling hypothesis suggests that the performance in emerging economies is detached from modifications in developed economies.

Recent literature extensively investigates the impact of the COVID-19 pandemic on financial markets from diverse perspectives. Some empirical studies have delved into the volatility connectedness network of global stock markets (Ashraf, 2020; Cheng et al., 2022; Heyden & Heyden, 2021; Li et al., 2021), while others have specifically explored volatility spillovers across sectors (Choi, 2020, 2021; Costa, Matos, & Da Silva, 2022; Dong, Li, Zhuang, & Wang, 2022; Laborda & Olmo, 2021; Shahzad, Bouri, Kristoufek, & Saeed, 2021).

Ashraf (2020) explored the response of stock markets to COVID-19, noting their swift reaction to the pandemic, with responses varying over time depending on the outbreak's stage. Heyden and Heyden (2021) employed an event-study approach to analyze cross-country stock market reactions at the onset of the COVID-19 pandemic, assessing

short-term responses. The findings revealed diverse reactions among stock markets to the announcement of the first death in a country. Furthermore, other studies have elucidated the implications of the pandemic on market dynamics and connectedness.

For example, Cheng et al. (2022) explored the impact of the COVID-19 pandemic on the volatility connectedness network among 19 stock markets spanning from January 4, 2016, to December 1, 2020. Their findings indicated that European, American, and Australian stock markets exhibited a closer connection during the COVID-19 epidemic compared to other markets. Conversely, China appeared disconnected from the global network of stock market volatility spillover. Furthermore, Li et al. (2021) investigated the impact of COVID-19 on G20 stock markets by analyzing the dynamic evolution of risk transmission relations and channels. They observed a significant increase in total volatility connectedness among G20 stock markets during the pandemic. Additionally, they noted that developed markets primarily acted as spillover transmitters, while emerging markets were the primary receivers of spillovers. Moreover, Christos, Charalampos, and Eleni (2021) explored the potential for increased market connectedness during the 2007-2008 global financial crisis and the COVID-19 epidemic by assessing market activity through market returns and volatility. Their findings suggested that during periods of shocks, connectedness between markets heightened. They also demonstrated that shock spillover was not constant over time and increased during crises.

The global financial crisis (GFC) and the COVID-19 pandemic had a significant impact on the interdependence between financial markets. Umar and Gubareva (2021) examined the influence of media coverage of the COVID-19 pandemic on the volatility of Islamic equity indices, encompassing various sectors of economic activity. They discovered a strong correlation between the COVID-19 pandemic and financial market volatility. Simultaneously, they identified intervals of low correlation, suggesting that DJ Islamic equity indices offered diversification benefits and could potentially serve as a safe haven during the pandemic. Previous studies have employed complex network models to investigate static and dynamic properties of stock market networks. For instance, Aslam et al. (2020) compared the network properties of 56 global stock markets before and during the COVID-19 pandemic. The findings suggested that the pandemic significantly influenced financial networks, resulting in structural changes such as node modifications and reduced connectivity. The impact of COVID-19 varied based on the level of stock market development. Similarly, Memon and Yao (2021) utilized the minimum spanning tree (MST) method to explore the effect of the COVID-19 pandemic on the network structures and topology evolution of 58 global stock markets. They observed that the maximum correlation among global stock markets was detected during the first wave of the pandemic. Furthermore, the Chinese stock market exhibited weak correlation with other major stock markets worldwide.

Regarding sectoral volatility spillover during the pandemic, Gurua and Das (2021) investigated the impact of COVID-19 on volatility spillovers among ten major sector indices listed on the BSE in India. The results indicated that the energy, oil, and gas sectors were the primary net volatility transmitters. Similarly, Su and Liu (2021) examined the inter-sector volatility spillover relationship in the Chinese stock market from 2004 to 2020 and found that stock market risks were easily transmitted among sectors. In the context of the US, Zargar and Kumar (2021) explored the presence of spillovers of shocks related to investor mood, fear, sentiment, and policy uncertainty to the tourism sector. Likewise, Laborda and Olmo (2021) investigated volatility spillovers among seven economic sectors from July 2003 to December 2020. Utilizing the Diebold and Yilmaz (2012) approach, they identified banking and insurance, energy, technology, and biotechnology as the main networks through which shocks propagated to the rest of the economy. Banking and insurance were the largest transmitters of risk during the global financial crisis (2007–2009), while energy and technology were the largest transmitters of risk during the pandemic. More recently, Costa et al. (2022) examined the volatility connectedness of 11 sectoral indices in the US, suggesting an increase in network connectedness of US sectors during severe crises. Additionally, Choi (2022) investigated volatility spillovers among various industries during the COVID-19 pandemic from January 2018 to May 2021. The author found that the

pandemic increased volatility spillovers and observed that the energy sector had an intense effect on the US stock market in terms of volatility spillovers on Black Monday (March 9, 2020).

3. METHODOLOGY

To quantify the degree of volatility spillovers across sectors, we employ the connectedness approach developed by Diebold and Yilmaz (2012). This approach is grounded in variance decomposition within a VAR setup (Koop, Pesaran, & Potter, 1996; Pesaran & Shin, 1998), where the variance of forecast errors is dissected into contributions from different variables. Importantly, this decomposition is independent of the variable order. The spillover index procedure initiates with the equation for the N-variable stationary VAR (p):

$$X_t = \sum_{i=1}^{p} \Phi_i X_{t-i} + \varepsilon_t \qquad (1)$$

Where X_t is the N-dimensional vector of endogenous variables, Φ_i is the $N \times N$ matrix of the estimated coefficients, and ε_t is a vector of error terms that are independently and identically distributed.

We can write the moving average representation of the VAR (p) in Equation 1 as follows:

$$X_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \qquad (2)$$

Where the $N \times N$ coefficient matrices Ai follow the recursive formula:

$$A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \cdots + \Phi_p A_{i-p} \qquad (3)$$

A_0 is the identity matrix and $Ai = 0$ for $i < 0$.

Based on the generalized VAR framework, the variance decomposition of the H-step-ahead forecast error from variable i to variable j is shown in this equation:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} (e_i A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \sum A_h' e_i)}, \ \text{H=1,2}.........\text{N} \qquad (4)$$

In adherence to the Koop-Pesaran-Potter-Shin generalized VAR framework, the variance shares are not necessarily equal to 1: $\sum_{j=1}^{N} \theta_{ij}^{g}(H) \neq 1$

Diebold and Yilmaz (2012) therefore, suggest normalizing that $\theta_{ij}^{g}(H)$ to ensure that the information in the directional connectedness from market j to market i and from sector j to sector i is:

$$\widehat{\theta_{ij}}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \qquad (5)$$

Note that by construction, $\sum_{j=1}^{N} \widehat{\theta_{ij}}(H) = 1$ and $\sum_{j=1}^{N} \widehat{\theta_{ij}}(H) = N$

As in Diebold and Yilmaz (2012) we describe the total spillover index as the sum of spillovers across the range in all market (sector) classes.

$$TOTAL\ (h) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \theta_{ij(h)}^{g}}{N} * 100 \qquad (6)$$

Moreover, the directional spillovers received by the range of sector i from the range of all other sectors j is represented as follows:

$$FROM_i\ (h) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \theta_{ij(h)}^{g}}{N} * 100 \qquad (7)$$

In addition, the spillovers transmitted by the range of sector i to all other sectors j is represented as follows:

$$TO_i\ (h) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \theta_{ij(h)}^{g}}{N} * 100 \qquad (8)$$

Using the difference between the directional spillover indices (7) and (8), we can calculate the net spillovers from sector i to all other variables as follows:

$$NET_i\ (h) = TO_i\ (h) - FROM_i\ (h) \qquad (9)$$

3.1. Net Pairwise Volatility Spillovers

Directional spillovers can be dissected into pairwise directional spillovers, and the net pairwise directional connectedness is calculable as the disparity between the shocks transmitted from market (sector) i to all other markets (sectors) j. Specifically, this is defined as follows:

$$S_{ij}^g(H) = \frac{\hat{\theta}_{ij\,(H)}^g}{N} \qquad (10)$$

and the shocks spilled from j market (sector) to i market (sector) are defined as follows:

$$S_{ji}^g(H) = \frac{\hat{\theta}_{ij\,(H)}^g}{N} \qquad (11)$$

Generally, it is expected that $S_{ij}^g(H) \neq S_{ji}^g(H)$. The breakdown of spillovers into pairwise components allows us to discern the connections between investor sentiment, the stock market, and sector indices. This aids in identifying relevant relationships between directional spillovers and spillover indices. Positive net pairwise spillover indices indicate that variable i is a net transmitter of spillover effects, while negative values suggest that variable i is a net receiver of spillovers.

We employ a vector autoregressive model (VAR) with a 10-step error variance predictive horizon and a one-sided rolling estimation window of 100 trading days, to estimate rolling connectedness. This approach introduces a connectedness concept from rolling variance decompositions that monitors dynamic and directional connectedness in real time. It addresses time zone issues by considering cumulative rolling effects rather than intraday or end-of-day variance effects. This methodology also helps manage outliers in investor sentiment, which can pose challenges in VAR estimation.

4. DATA AND SUMMARY STATISTICS

This study investigates the impact of the Coronavirus (COVID-19) epidemic on the interconnectedness between Saudi Insurance, Tadawul, and sector indices in the Kingdom of Saudi Arabia.

Media coverage data were obtained from the RavenPack website (coronavirus.ravenpack.com), tracking the latest information on the novel coronavirus globally from sources such as Dow Jones Newswire and Stock Twits. Using artificial intelligence technology, RavenPack designed specific COVID-19 news-related indices. Following the methodologies of Subrahmanyam (2019), Ding et al. (2020), and Rognone et al. (2020), the Coronavirus Panic Index from Ravenpack Finance was employed. This index measures stress, panic, fear, or hysteria in media coverage of the COVID-19 pandemic from numerous news sources. The sample period covers January 4, 2016, to February 14, 2022, with two sub-periods: pre-COVID-19 (January 4, 2016, to February 28, 2020) and during COVID-19 (March 3, 2020, to February 14, 2022). Data was compiled from DataStream and RavenPack Finance, and continuously compounded daily returns were calculated as the natural logarithm percentage difference between two consecutive daily prices.

Figure 1 depicts the dynamic returns of insurance, Tadawul, and sector indices, revealing increased volatility during the COVID-19 period, particularly between February and May 2020. Figure 1 also shows evidence of a trend shift after the pandemic outbreak, underscoring the necessity for distinct analyses during the pandemic period to comprehend its unique characteristics relative to the pre-pandemic period and explore potential hedging options to mitigate adverse effects on stock markets.

Figure 2 illustrates the volatility of the daily COVID-19 Panic Index, representing the percentage of total news items mentioning 'panic' or 'fear' in coronavirus-related news for the day. This figure emphasizes the substantial impact of investor psychology influenced by the health crisis on stock markets.
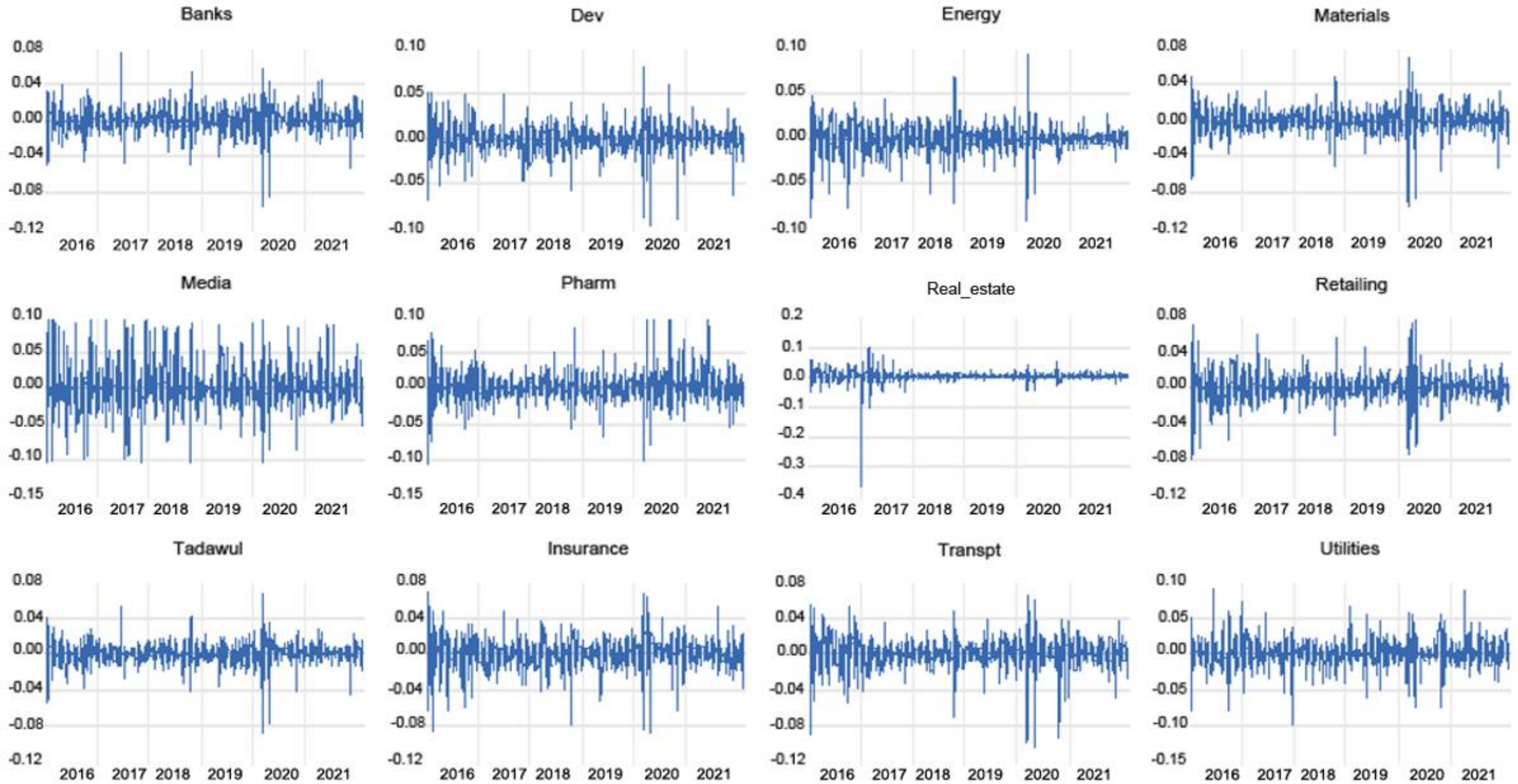
Figure 1. Time series of sector index returns and the Tadawul all-share index.

Figure 2 illustrates the daily volatility of the COVID-19 Panic Index, which measures the degree of panic and fear expressed in media coverage of the pandemic. Computed as the percentage of daily news stories mentioning the keywords 'panic' or 'fear' in coronavirus-related news, the Panic Index reveals the psychological impact of the pandemic on investors. The figure underscores that the heightened levels of panic and fear in the media during the pandemic had a substantial impact on stock markets. This likely played a role in increased market volatility and heightened risk aversion among investors.
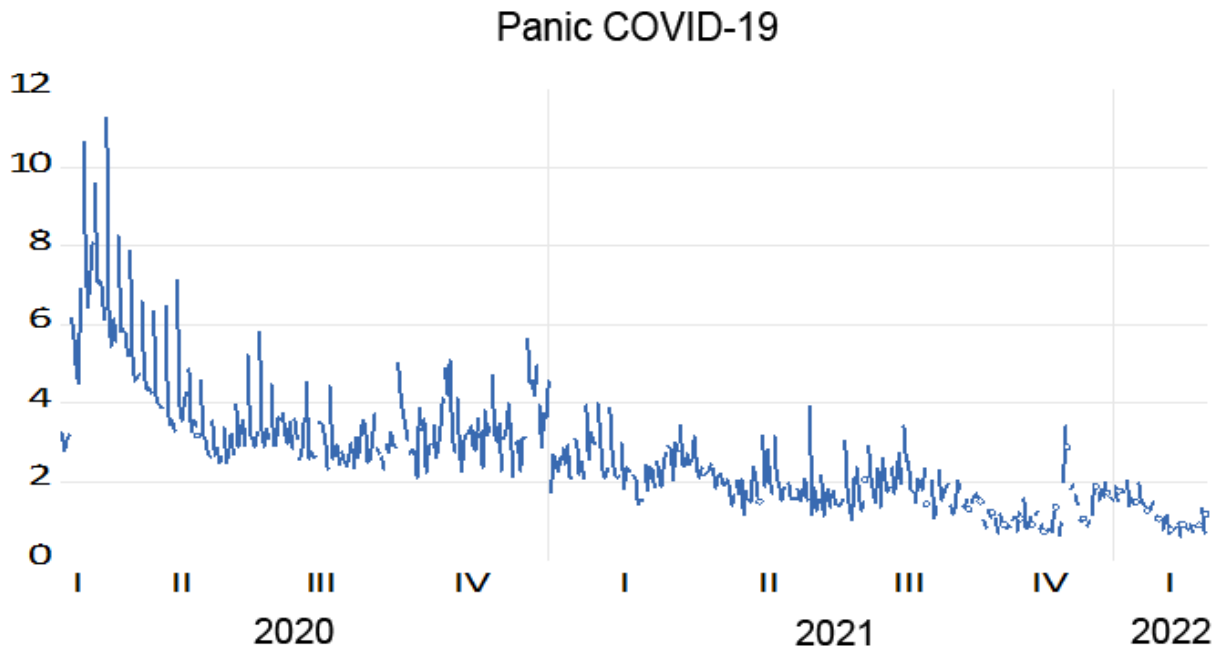

Figure 2. Evolution of the COVID-19 panic index.

Table 1. Descriptive statistics.

Descriptive statistics \ Sector	Banks	Dev.	Energy	Materials	Media	Pharma	Real-estate	Retail	Tadawul	Insurance	Transport	Utilities	Panic_COVID_19
Panel A: Pre-COVID-19 period from 04/01/2016 to 28/02/2020													
Mean	0.0003	-0.0003	-8.15E-05	-2.40E-05	0.0001	-0.0001	-0.0003	-4.96E-06	5.11E-05	-0.0001	-0.0001	4.35E-05	
Median	0.000	0.000	0.000	0.000	-0.0009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Maximum	0.077	0.053	0.069	0.048	0.094	0.083	0.097	0.069	0.053	0.070	0.056	0.090	
Minimum	-0.047	-0.069	-0.086	-0.064	-0.104	-0.108	-0.367	-0.079	-0.056	-0.085	-0.091	-0.099	
Std. dev.	0.011	0.012	0.014	0.010	0.028	0.015	0.017	0.013	0.009	0.013	0.013	0.015	
Skewness	0.071	-0.222	-0.874	-0.524	0.555	-0.223	-8.259	-0.331	-0.424	-0.938	-0.957	-0.208	
Kurtosis	7.183	6.434	8.631	7.852	6.667	10.602	188.460	9.005	7.455	8.648	9.803	9.384	
Jarque-Bera	792.946	542.552	1573.428	1115.159	664.199	2624.145	1568750.	1652.030	930.656	1602.742	2259.913	1852.256	
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Panel B: Crisis period of COVID-19 from 03/03/2020 to 14/02/2022													
Mean	0.0013	0.0001	0.0003	0.0012	0.0025	0.0007	0.0003	0.0006	0.0011	0.0009	0.0006	0.0012	2.672
Median	0.001	0.0001	0.0002	0.002	0.0006	0.000	0.0004	0.0008	0.001	0.0009	0.001	0.0002	2.420
Maximum	0.056	0.080	0.092	0.070	0.094	0.095	0.048	0.076	0.068	0.069	0.066	0.089	11.280
Minimum	-0.093	-0.097	-0.091	-0.093	-0.104	-0.102	-0.049	-0.075	-0.087	-0.088	-0.105	-0.076	0.580
Std. dev.	0.013	0.015	0.010	0.014	0.024	0.021	0.008	0.014	0.011	0.014	0.016	0.016	1.524
Skewness	-1.844	-1.609	-0.489	-1.726	0.245	0.786	-0.945	-0.8828	-2.254	-0.963	-1.955316	-0.003613	1.762
Kurtosis	15.894	16.154	31.37	16.235	6.468	9.659	12.599	12.439	22.028	11.950	14.481	8.027	8.012
Jarque-Bera	3657.023	3728.754	16384.92	3804.036	249.514	951.897	1946.016	1875.122	7774.96	1704.257	2991.374	513.926	760.332
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Table 1 presents descriptive statistics for each sector index during the pre-COVID-19 and COVID-19 periods. In Panel A, summarizing the pre-COVID-19 period, the banking sector exhibited a higher return of 0.31% with a standard deviation of 1.13%, while the real estate sector had a lower return of −0.0352% with a standard deviation of 1.7427%. Mean values indicated negative returns for the insurance index (−0.0127%) and most other sectoral indices, except for banks (0.031%), media (0.016%), Tadawul (0.00511%), and utilities (0.00435%). Panel B details the summary statistics during the COVID-19 period, showing improved performance overall. The media sector had the highest return with a relatively higher standard deviation (2.38%). Additionally, sectors like DEV, energy, materials, pharma, real estate, retail, insurance, and transport displayed positive returns during COVID-19, following negative returns before the pandemic. Standard deviation values for all indices ranged between 1% and 2%, with the COVID-19 Panic Index having a standard deviation of 1.52 (Zhang, Hu, & Ji, 2020). The real estate sector had the lowest standard deviation, while the media sector had the highest during the COVID-19 pandemic. Returns data series for the Tadawul index and all sectoral indices, except for the media and pharma sectors, showed negative skewness. Furthermore, the Jarque–Bera statistic indicated that all data series were not normally distributed.

5. EMPIRICAL RESULTS AND DISCUSSION

In this section, we use Diebold and Yilmaz (2012) DY12 methodology to explore the dynamic spillover effects among insurance, Tadawul All-Share, and sector indices during the pre-COVID-19 and COVID-19 periods. This approach provides an ideal framework for connectivity analysis, enabling us to identify the primary risk transmission channel and detect the mechanisms of risk propagation in each market.

5.1. Volatility Spillover Connectedness Analysis before and during the COVID-19 Pandemic
5.1.1. Static Volatility Spillover Connectedness

Tables 2 and 3 present the DY12 total volatility spillovers estimates, detailing the connectedness parameters between insurance, Saudi Tadawul All-Share, and the sectoral indices before and during the COVID-19 crisis. The diagonal values signify how the insurance sector is influenced by other sectors, while the (i, j) elements of the tables demonstrate the impact of shocks to sector j on sector i's forecast error variance. Furthermore, the sum of the off-diagonal rows denotes the directional sentiment spillover of sector i from sector j (referred to as "FROM"), and the sum of the off-diagonal columns represents the directional contribution from sector i to sector j (referred to as "TO"). The "Net" spillover indicates the net transmitter and net recipients of the shocks. The difference between "To" and "From" illustrates the "Net connectedness" between the insurance sector and other sectors.

Panel A shows that the Tadawul All-Share Index was a net transmitter for insurance and other sectors in the pre-COVID-19 period. Its contribution to the forecast error variance of other markets ("To") was 10.68%, making it the highest contributor to total system volatility, followed by the materials and transport sectors. In contrast, the real estate and media sectors were the lowest contributors to spillover in the system. In these panels, the Saudi Tadawul Index, material, and transport sectors were the largest receivers of spillovers from other sectors. The real estate sector received 3.83% of the spillovers from the other sectors, and the media sector received 4.77%. Note that the sectors were mainly affected by their own shocks, which was consistent with the findings of Costa et al. (2022) and Li et al. (2021). On the other hand, the insurance sector received more spillovers from the transport and retail sectors than from the real estate sector. However, the retail, energy, pharma, and media sectors were net receivers of spillovers.

Table 2. Static connectedness matrix between insurance, Tadawul all-share, and sectoral indices before the COVID-19 crisis.

Panel A: Period of pre-COVID-19 from 04/01/2016 to 28/02/2020

	Insurance	Tadawul	Energy	Retail	Utilities	Banks	Materials	Media	Pharma	Re. mgt. dev.	Real-estate	Transport	From
Insurance	22.90	12.18	7.27	7.53	4.17	7.19	10.46	3.60	5.34	7.16	1.75	10.45	6.43
Tadawul	8.56	17.11	6.90	7.03	4.79	14.25	14.18	2.80	5.54	8.30	1.76	8.78	6.91
Energy	8.16	10.93	26.91	4.98	4.78	6.07	10.58	3.20	4.72	7.28	2.38	10.01	6.09
Retail	8.86	11.80	5.56	28.56	3.32	7.23	9.28	3.40	5.98	5.89	1.79	8.33	5.95
Utilities	6.23	10.38	6.78	4.19	37.40	6.73	8.22	2.17	5.00	5.67	0.96	6.26	5.22
Banks	7.04	19.75	5.28	6.09	4.20	23.25	13.10	2.03	4.51	6.34	1.28	7.12	6.40
Materials	8.40	16.20	7.56	6.29	4.41	10.74	19.33	2.99	5.88	7.46	1.75	8.98	6.72
Media	7.02	7.41	5.40	5.74	2.49	3.87	6.80	42.75	4.51	4.76	1.76	7.49	4.77
Pharma	6.40	9.98	6.01	6.38	4.31	5.82	9.08	2.96	31.72	6.61	1.94	8.78	5.69
Re. mgt... dev	7.54	12.60	6.92	5.14	4.24	7.06	9.76	2.80	5.25	25.94	3.33	9.41	6.17
Real-estate	3.96	5.50	4.81	3.31	1.40	2.87	4.78	1.93	3.43	7.11	54.09	6.80	3.83
Transport	9.68	11.38	8.30	6.63	3.77	6.69	10.28	3.53	6.24	8.12	2.77	22.62	6.45
TO	6.82	10.68	5.90	5.28	3.49	6.54	8.88	2.62	4.70	6.23	1.79	7.70	70.62%
Net	0.394	3.769	-0.191	- 0.675	-1.726	0.148	2.155	-2.153	-0.991	0.054	- 2.035	1.252	
Conclusion	Net-transmitter	Net-transmitter	Net- recipient	Net- recipient	Net- recipient	Net-transmitter	Net-transmitter	Net- recipient	Net- recipient	Net- recipient	Net- recipient	Net-transmitter	

Panel B. Period of COVID-19 crisis 03/03/2020 to 14/02/2022

	Insurance	Tadawul	Energy	Retail	Utilities	Banks	Materials	Media	Pharma	Dev.	Real-estate	Transport	COVID-19 panic	From
Insurance	20.21	10.62	8.34	7.84	3.71	7.06	9.22	4.25	2.59	8.71	8.24	8.97	0.22	6.14
Tadawul	7.5	14.23	10.62	7.95	4.93	12.43	12.36	3.89	2.02	8.77	6.45	8.44	0.41	6.6
Energy	7.2	13.03	17.52	7.29	3.56	9.97	11.06	3.79	2.2	8.57	7.4	8.01	0.41	6.34
Retail	7.73	11.08	8.4	19.74	4.23	8.14	9.66	4.7	1.24	8.5	6.73	8.89	0.95	6.17
Utilities	5.48	10.43	6.29	6.41	30.03	7.26	9.52	3.94	1.35	6.66	5.05	7.22	0.37	5.38
Banks	6.43	16.08	10.51	7.59	4.44	18.33	11.84	2.89	1.5	7.1	5.43	7.33	0.53	6.28
Materials	7.19	13.77	10.03	7.74	5.03	10.26	15.89	3.9	2.22	8.66	6.36	8.57	0.38	6.47
Media	6.29	8.29	6.6	7.16	3.92	4.81	7.44	30.04	2.58	7.41	7.25	8.02	0.2	5.38
Pharma	5.73	6.57	5.28	2.93	2.27	3.75	6.52	3.89	45.68	5.47	4.37	7.3	0.22	4.18
Dev	7.75	11.08	8.86	7.84	3.99	6.85	9.88	4.52	2.19	18.61	7.6	10.66	0.18	6.26
Real-estate	8.1	9.53	8.54	7.49	3.67	6.28	8.58	5.03	1.89	8.98	22.52	9.01	0.36	5.96
Transport	7.95	10.49	8.21	8.06	4.27	6.96	9.59	4.73	2.89	10.49	7.65	18.15	0.58	6.3
COVID-19 panic	1.92	4.59	4.69	4.66	1.22	4.67	2.9	1.33	0.08	2.49	2.01	3.95	65.49	2.65
To	6.1	9.66	7.41	6.38	3.48	6.8	8.35	3.61	1.75	7.06	5.73	7.41	0.37	74.12
Net	-0.04	3.06	1.07	0.21	-1.90	0.52	1.89	-1.78	-2.43	0.80	-0.22	1.12	-2.28	
Conclusion	Net-recipient	Net-transmitter	Net-transmitter	Net-transmitter	Net- recipient	Net-transmitter	Net-transmitter	Net-recipient	Net-recipient	Net-transmitter	Net-recipient	Net-transmitter	Net-recipient	

Table 3. Static connectedness matrix between insurance, Tadawul all-share, and sectoral indices during the COVID-19 crisis.

Panel A: Period of pre-COVID-19 from 04/01/2016 to 28/02/2020

	Insurance	Tadawul	Energy	Retail	Utilities	Banks	Materials	Media	Pharma	Re. mgt. dev.	Real-estate	Transport	From
Insurance	22.90	12.18	7.27	7.53	4.17	7.19	10.46	3.60	5.34	7.16	1.75	10.45	6.43
Tadawul	8.56	17.11	6.90	7.03	4.79	14.25	14.18	2.80	5.54	8.30	1.76	8.78	6.91
Energy	8.16	10.93	26.91	4.98	4.78	6.07	10.58	3.20	4.72	7.28	2.38	10.01	6.09
Retail	8.86	11.80	5.56	28.56	3.32	7.23	9.28	3.40	5.98	5.89	1.79	8.33	5.95
Utilities	6.23	10.38	6.78	4.19	37.40	6.73	8.22	2.17	5.00	5.67	0.96	6.26	5.22
Banks	7.04	19.75	5.28	6.09	4.20	23.25	13.10	2.03	4.51	6.34	1.28	7.12	6.40
Materials	8.40	16.20	7.56	6.29	4.41	10.74	19.33	2.99	5.88	7.46	1.75	8.98	6.72
Media	7.02	7.41	5.40	5.74	2.49	3.87	6.80	42.75	4.51	4.76	1.76	7.49	4.77
Pharma	6.40	9.98	6.01	6.38	4.31	5.82	9.08	2.96	31.72	6.61	1.94	8.78	5.69
Re. mgt... dev	7.54	12.60	6.92	5.14	4.24	7.06	9.76	2.80	5.25	25.94	3.33	9.41	6.17
Real-estate	3.96	5.50	4.81	3.31	1.40	2.87	4.78	1.93	3.43	7.11	54.09	6.80	3.83
Transport	9.68	11.38	8.30	6.63	3.77	6.69	10.28	3.53	6.24	8.12	2.77	22.62	6.45
TO	6.82	10.68	5.90	5.28	3.49	6.54	8.88	2.62	4.70	6.23	1.79	7.70	70.62%
Net	0.394	3.769	-0.191	- 0.675	-1.726	0.148	2.155	-2.153	-0.991	0.054	- 2.035	1.252	
Conclusion	Net-transmitter	Net-transmitter	Net- recipient	Net- recipient	Net- recipient	Net-transmitter	Net-transmitter	Net- recipient	Net- recipient	Net-transmitter	Net- recipient	Net-transmitter	

Panel B. Period of COVID-19 crisis 03/03/2020 to 14/02/2022

	Insurance	Tadawul	Energy	Retail	Utilities	Banks	Materials	Media	Pharma	Dev.	Real-estate	Transport	Covid-19 panic	From
Insurance	20.21	10.62	8.34	7.84	3.71	7.06	9.22	4.25	2.59	8.71	8.24	8.97	0.22	6.14
Tadawul	7.5	14.23	10.62	7.95	4.93	12.43	12.36	3.89	2.02	8.77	6.45	8.44	0.41	6.6
Energy	7.2	13.03	17.52	7.29	3.56	9.97	11.06	3.79	2.2	8.57	7.4	8.01	0.41	6.34
Retail	7.73	11.08	8.4	19.74	4.23	8.14	9.66	4.7	1.24	8.5	6.73	8.89	0.95	6.17
Utilities	5.48	10.43	6.29	6.41	30.03	7.26	9.52	3.94	1.35	6.66	5.05	7.22	0.37	5.38
Banks	6.43	16.08	10.51	7.59	4.44	18.33	11.84	2.89	1.5	7.1	5.43	7.33	0.53	6.28
Materials	7.19	13.77	10.03	7.74	5.03	10.26	15.89	3.9	2.22	8.66	6.36	8.57	0.38	6.47
Media	6.29	8.29	6.6	7.16	3.92	4.81	7.44	30.04	2.58	7.41	7.25	8.02	0.2	5.38
Pharma	5.73	6.57	5.28	2.93	2.27	3.75	6.52	3.89	45.68	5.47	4.37	7.3	0.22	4.18
Dev	7.75	11.08	8.86	7.84	3.99	6.85	9.88	4.52	2.19	18.61	7.6	10.66	0.18	6.26
Real-estate	8.1	9.53	8.54	7.49	3.67	6.28	8.58	5.03	1.89	8.98	22.52	9.01	0.36	5.96
Transport	7.95	10.49	8.21	8.06	4.27	6.96	9.59	4.73	2.89	10.49	7.65	18.15	0.58	6.3
Covid-19 panic	1.92	4.59	4.69	4.66	1.22	4.67	2.9	1.33	0.08	2.49	2.01	3.95	65.49	2.65
To	6.1	9.66	7.41	6.38	3.48	6.8	8.35	3.61	1.75	7.06	5.73	7.41	0.37	74.12
Net	-0.04	3.06	1.07	0.21	-1.90	0.52	1.89	-1.78	-2.43	0.80	-0.22	1.12	-2.28	
Conclusion	Net-recipient	Net-transmitter	Net-transmitter	Net-transmitter	Net- recipient	Net-transmitter	Net-transmitter	Net-recipient	Net-recipient	Net-transmitter	Net-recipient	Net-transmitter	Net-recipient	

Note: "From" shows the total spillovers received by a particular market from all other markets, and "To" refers to the spillover effect directed by a particular market to all other markets. The term "Net" indicates the difference between "To" and "From," where a positive value means a net contributor of volatility and a negative value refers to a net receiver of risk from other markets.

Panel B explores the directional spillovers (net receiver and net transmitter) between insurance, Tadawul All-Share Index and the sector indices between March 3, 2020, and February 14, 2022. Before the COVID-19 pandemic, the insurance sector was a transmitter of volatility spillovers. However, during the COVID-19 pandemic, it turned into a receiver of volatility spillovers.

In the presented table, the "from" column indicates that all sectors gain substantial information from the system, with returns ranging from 2.65% to 6.60%. However, their contributions to the system exhibit significant variation, with the COVID-19 Panic Index making the smallest contribution at only 2.65%. This can be attributed to the fact that these sectors generally constitute a substantial portion of the economic structure in Saudi Arabia and exhibit high interconnectedness with other sectors. It is noteworthy that despite the heightened market risk due to the pandemic, negative sentiments did not appear to trigger any selling decisions, as evidenced by the higher mean return during this period.

The "To" row shows that Tadawul All-Share Index is the top contributor to the system, with a total contribution of 9.66%, while the healthcare sector has the lowest return of only 1.75%. By estimating the net-connectedness, we find that Tadawul All-Share Index and sectors such as energy, retail, banking, materials, development, and transport are risk transmitters, while insurance, pharma, utilities, media, real estate, and COVID-19 Panic are risk receivers.

Finally, we estimate the total connectedness to uncover the average level of risk spillover within sectors, which reaches 74.12%, indicating a high spillover intensity in the Saudi stock market sectors. In summary, spillover effects are more intense during the COVID-19 pandemic than before this crisis, with retail and transport being more affected by the COVID-19 Panic Index than the development sector. All sectors are the highest contributors to risk spillovers from their own shocks.

5.1.2. Dynamic Spillover Analysis before and during the COVID-19 Pandemic

The dynamic volatility spillover index provides a more detailed analysis of how risk transmission and connectedness change over time. It considers the impact of political and financial turbulence on spillovers and allows for a more refined analysis of the intensity and direction of spillovers across insurance, Tadawul All-Share Index, and sectoral indices. This index is estimated over a 200-day rolling window using a 10-day step-ahead forecast horizon for a variance decomposition matrix. Using this approach, we can capture the changes in spillovers during the different phases of the pandemic and study the evolution of risk transmission over time.

5.1.2.1. Total Information Spillover Effect

The temporal evolution of the dynamic DY12 spillover index is depicted in Figure 3 for two distinct periods: before COVID-19 (Panel A) and during the pandemic (Panel B). In Panel A, the DY12 spillover index ranges from 64% in 2018 to 80% in 2019, indicating a notable increase in total volatility spillovers and a profit decline in 2019, attributed to falling crude oil prices. This vulnerability to oil price fluctuations can be linked to Saudi Arabia's oil-dependent economy. The rise in total risk spillovers among insurance, Tadawul All-Share Index, and sector indices during significant events diminishes portfolio diversification benefits, emphasizing the importance of considering alternative safe-haven assets in sector-stock portfolios. Panel B of Figure 3 demonstrates the high sensitivity of the time-varying total spillover index to political and economic turmoil, particularly during the COVID-19 crisis. Notably, the graphical evidence reveals a substantial increase in the total spillover index in 2020, peaking at about 75%, followed by subsequent fluctuations. The significant effect of the COVID-19 Panic Index on Saudi stock market spillovers is observed, particularly in March 2020, coinciding with economic hardships and the pandemic, leading to increased stress in financial markets.

The evolving spillovers and their fluctuations during economic, energy, and health crises underscore the need for investors and speculators to remain vigilant in monitoring spillover strength to hedge against increasing risks in the Saudi stock market. The severity and deep uncertainty of the COVID-19 pandemic significantly impacted various industries and investor sentiment in the Saudi stock market, resulting in fluctuations in total connectedness across stock sectors. These findings align with previous studies reporting higher volatility levels during the pandemic period. Additionally, the total spillover index decreased between 2021 and 2022, with a significant increase in mid-2022, attributed to effective government measures to monitor COVID-19, such as lockdowns and social distancing restrictions. The relationships among insurance, stocks, and sectors are influenced by financial, economic, and geopolitical events, emphasizing the need for effective risk management strategies to mitigate potential losses.

5.1.2.2. Total Net Directional Connectedness as a Rolling Sample

The study investigated pairwise net volatility spillovers among the Tadawul All-Share and sector indices both before and during the COVID-19 pandemic to gain a deeper understanding of the dynamic behavior of spillover. The total volatility spillover index underwent decomposition into two directional spillovers: the receiver of volatility spillovers (referred to directionally as 'from') and the transmitter of volatility spillovers (referred to directionally as 'to'). The net dynamic volatility spillover index was subsequently calculated by subtracting the directional 'to' spillovers from the directional 'from' spillovers.

The analysis of total directional connectedness provides information on the dynamic performance of each sector in terms of directional spillovers. Figure 4 (Panel A) shows the evolution of total net connectedness for Tadawul All-Share Index and the sectoral indices. The results indicate that insurance, media, pharma, retail, transport, and utilities, exhibited net receiving behavior prior to COVID-19. The study observed that the economic uncertainty of 2019-2020 led to the transmission of large magnitudes of negative volatility spillovers.
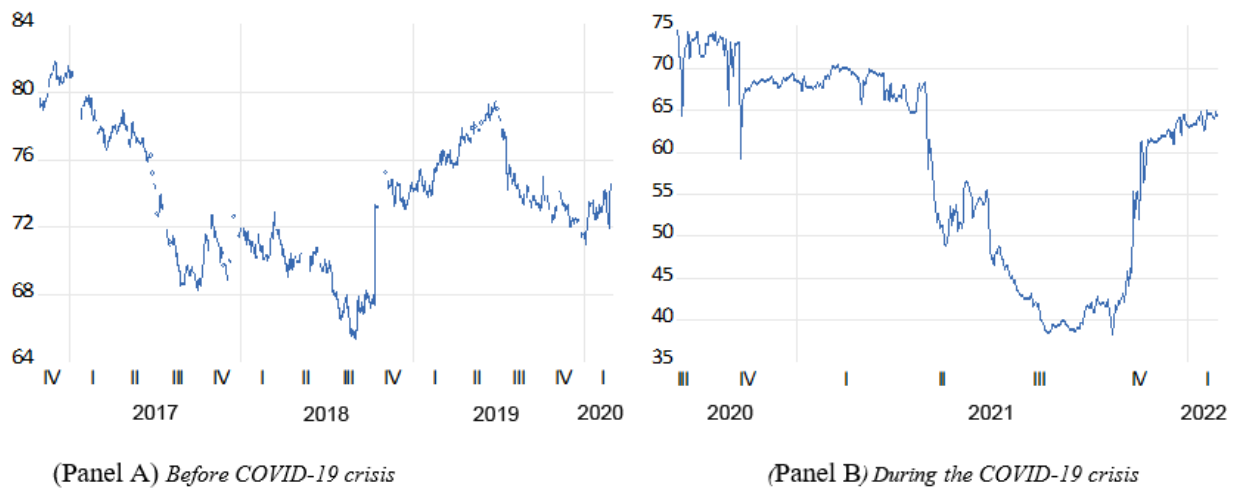

(Panel A) *Before COVID-19 crisis*   (Panel B) *During the COVID-19 crisis*

Figure 3. Total dynamic volatility spillovers of insurance, Tadawul all-share, and sectoral indices.

The study's findings indicate that the Saudi Tadawul All-Share is the most influential factor in transmitting risk to the energy, banking, and material sectors before COVID-19. These sectors represent a significant portion of the Saudi stock market, with materials and finance being the largest, followed by transport and energy. Therefore, the performance of the Tadawul All-Share Index is a crucial indicator of the Saudi stock market's overall health.
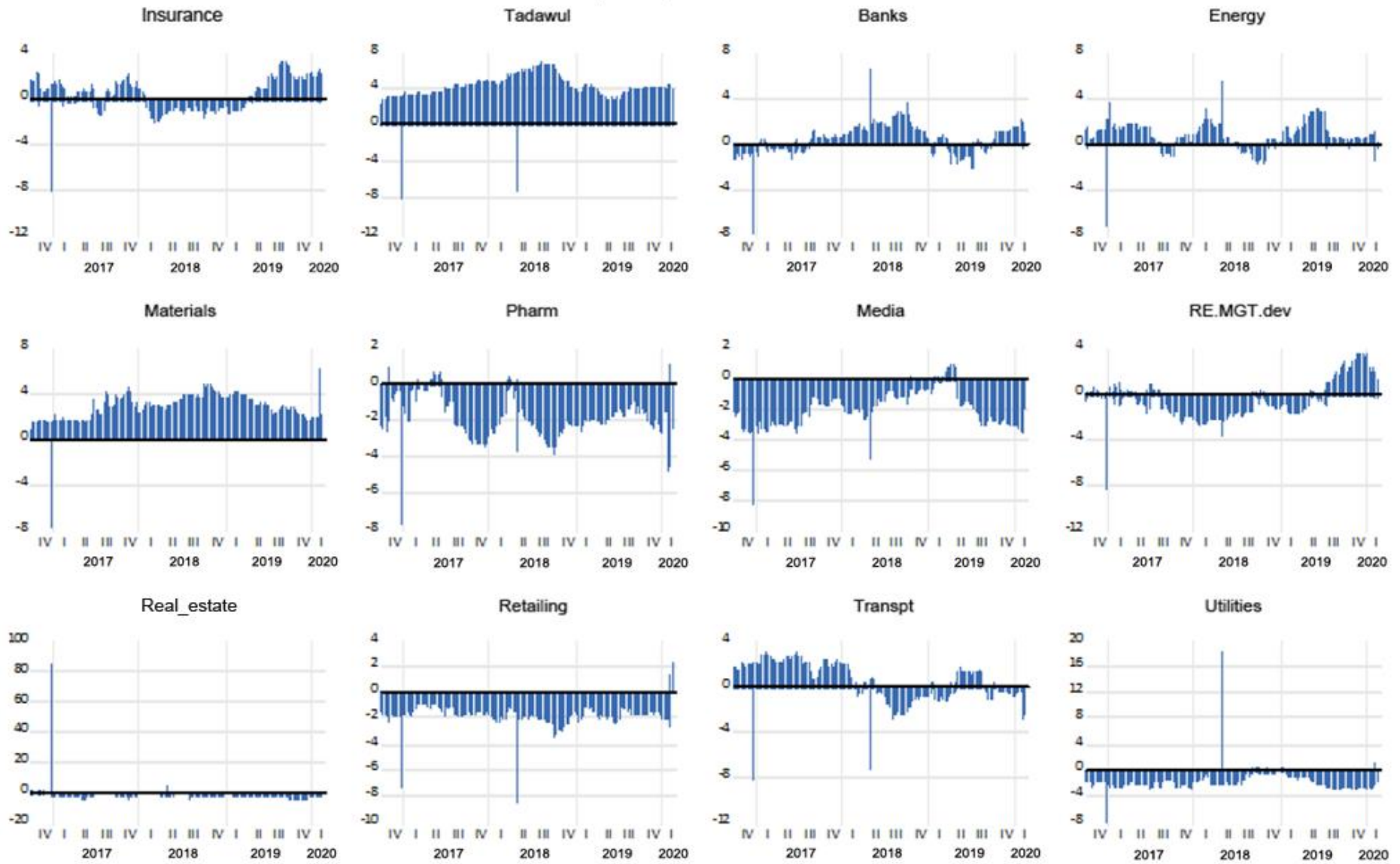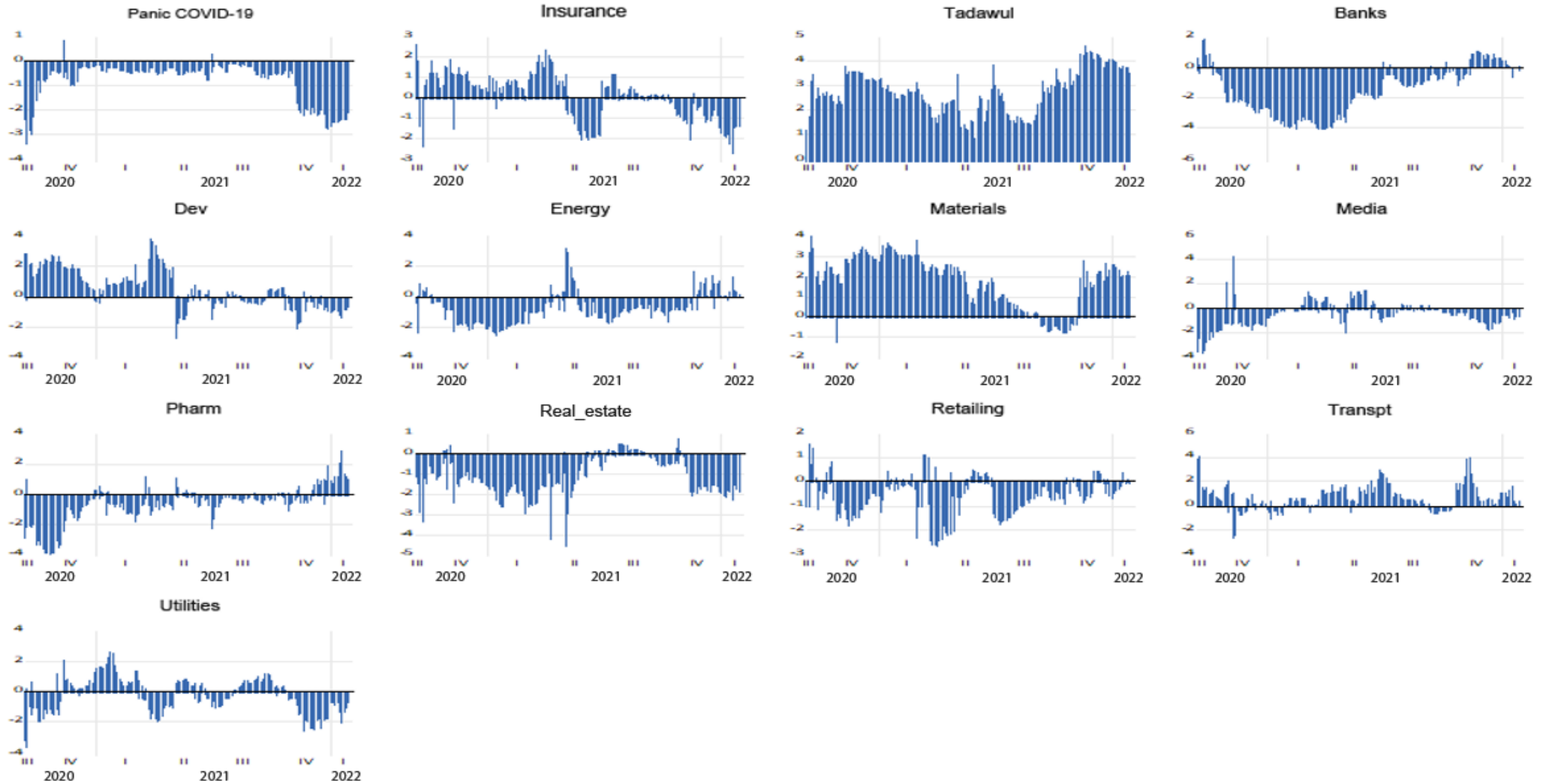
(Panel A) Pre-COVID-19

Figure 4. illustrates the rolling sample net total directional connectedness.

Note: If the spillover index is negative (Positive), the corresponding epidemic news index is the net transmitter (Receiver) of volatility spillover information.

Furthermore, during the COVID-19 pandemic, the analysis shows that the Tadawul All-Share Index and sectorial indices such as development, materials, and transport consistently exhibit the highest net risk transmission. This highlights the critical role of stocks in spreading financial contagion during crises. On the other hand, insurance and panic about COVID-19 appear to be the largest net receivers of risk, indicating that these variables were most affected by the pandemic. However, during the COVID-19 pandemic, sectors such as banking, energy, media, pharma, real estate, and related industries became net recipients of volatility spillovers compared to the pre-pandemic period.

This resulted in:

This led to a decline in fees charged by banks, adversely impacting their profits. Additionally, the energy sector faced severe repercussions from global lockdowns and the oil price war between Saudi Arabia and Russia. The pandemic, being health-related, triggered a significant surge in volatility within the health-related sectors, given their pivotal role in effectively managing the crisis. Specifically, the media sector witnessed a heightened global demand for services during lockdowns, with telecommunications emerging as a crucial mode of communication amid the pandemic. Furthermore, lockdown measures resulted in increased time spent at home, driving up demand for utilities and other daily necessities.

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In conclusion, the COVID-19 pandemic significantly affected various sectors, resulting in increased volatility and changes in consumer behavior. Indeed, policymakers and investors need to consider these effects when making decisions about affected industries.

5.1.2.3. Pairwise Net Directional Connectedness from Insurance to Sector Indices in a Rolling Sample

Figure 5 and 6 present the pairwise net directional spillovers from insurance to sector indices before and during the COVID-19 crisis. We examine the transmission of volatility shocks between insurance and other sectors by displaying the directional spillovers. Most sectoral indices were more affected by the COVID-19 crisis, while some sectors were less affected by this pandemic. We found that the pairwise net directional connectedness between insurance and sectors such as banking, energy, materials, and transport is positive before and during the COVID-19 pandemic. This is a promising task as the insurance industry plans to launch an international project that will intersect and exchange different sectors from financial and economic perspectives. Notably, the direct volatility spillover from insurance to DEV has sharply decreased, except during the period of 2019-2020, indicating that insurance has been a risk receptor during this period. This finding suggests that investors were concerned about the economic outlook due to the COVID-19 pandemic. Based on the results, the insurance sector is negatively affected by external shocks, such as oil price drops, economic slowdowns, and the COVID-19 crisis. This is reflected in its role as a net receiver of spillovers from the utilities, media, pharma, and related sectors during the sample period. However, despite its vulnerability to such shocks, insurance remains an essential product for portfolio allocation. Interestingly, the spillover effects of insurance show a similar trajectory throughout the sample period, with different magnitudes. Notably, there were significant spikes in spillover effects during the periods of 2016-2017 and 2019-2020, corresponding to the drop in oil prices, the economic slowdown in China, and the COVID-19 crisis. These findings highlight the importance of considering the impact of external factors on the insurance sector and its spillover effects on other sectors when making investment decisions.
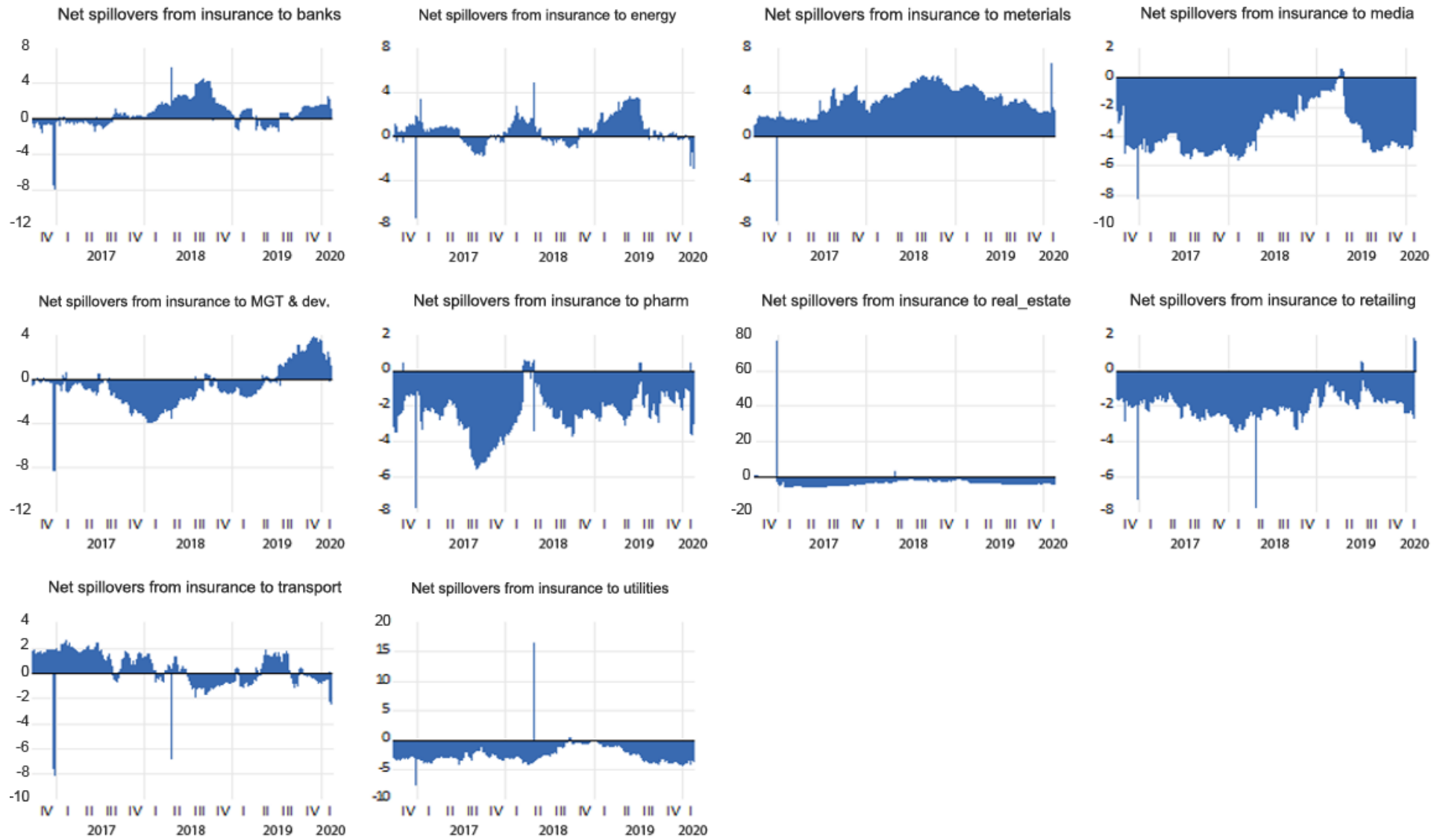
Figure 5. Rolling sample pairwise net directional connectedness between the insurance and sector indices before the COVID-19 crisis.
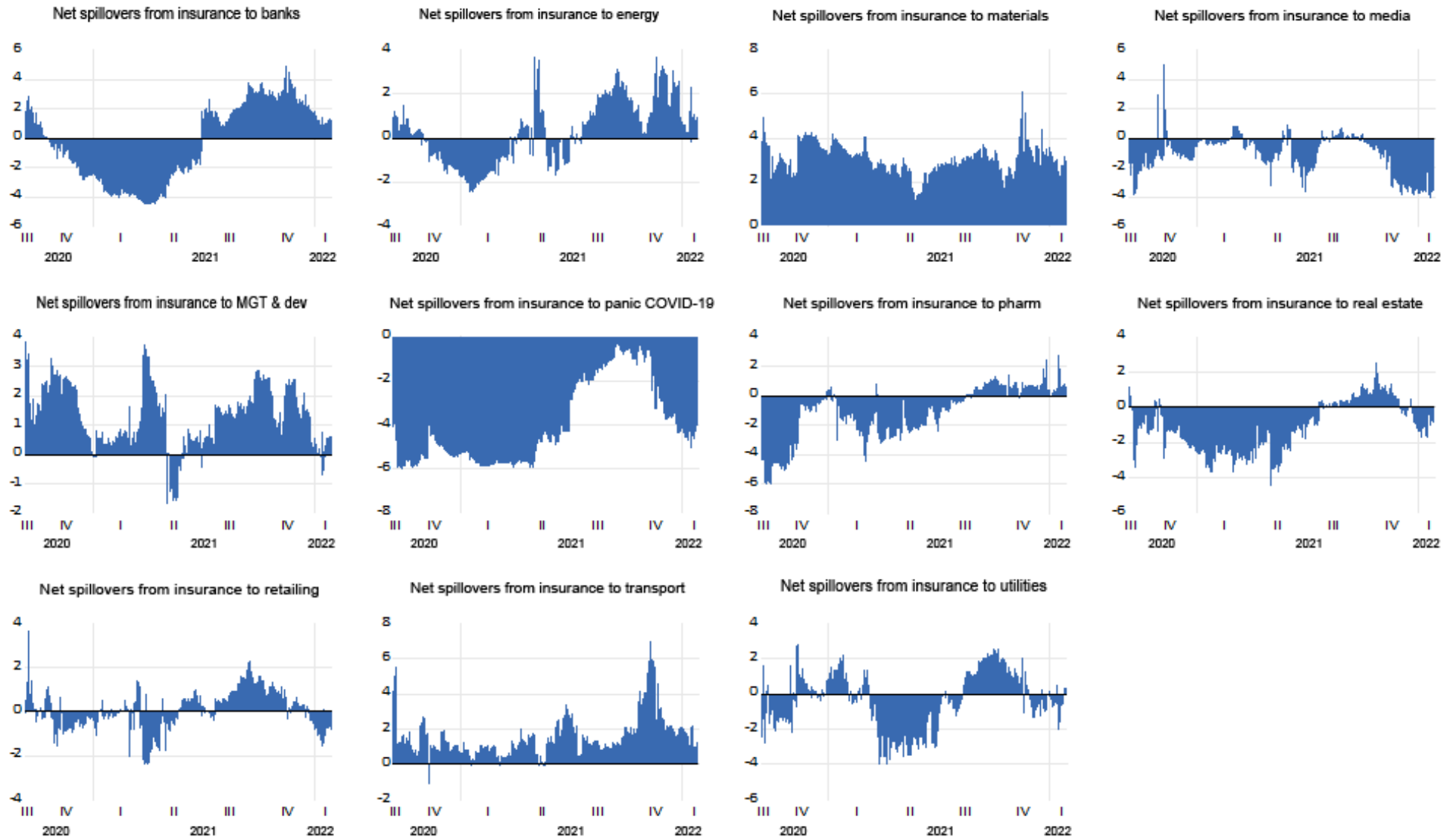
Figure 6. Rolling sample pairwise net directional connectedness between the insurance and sector indices during the COVID-19 crisis.
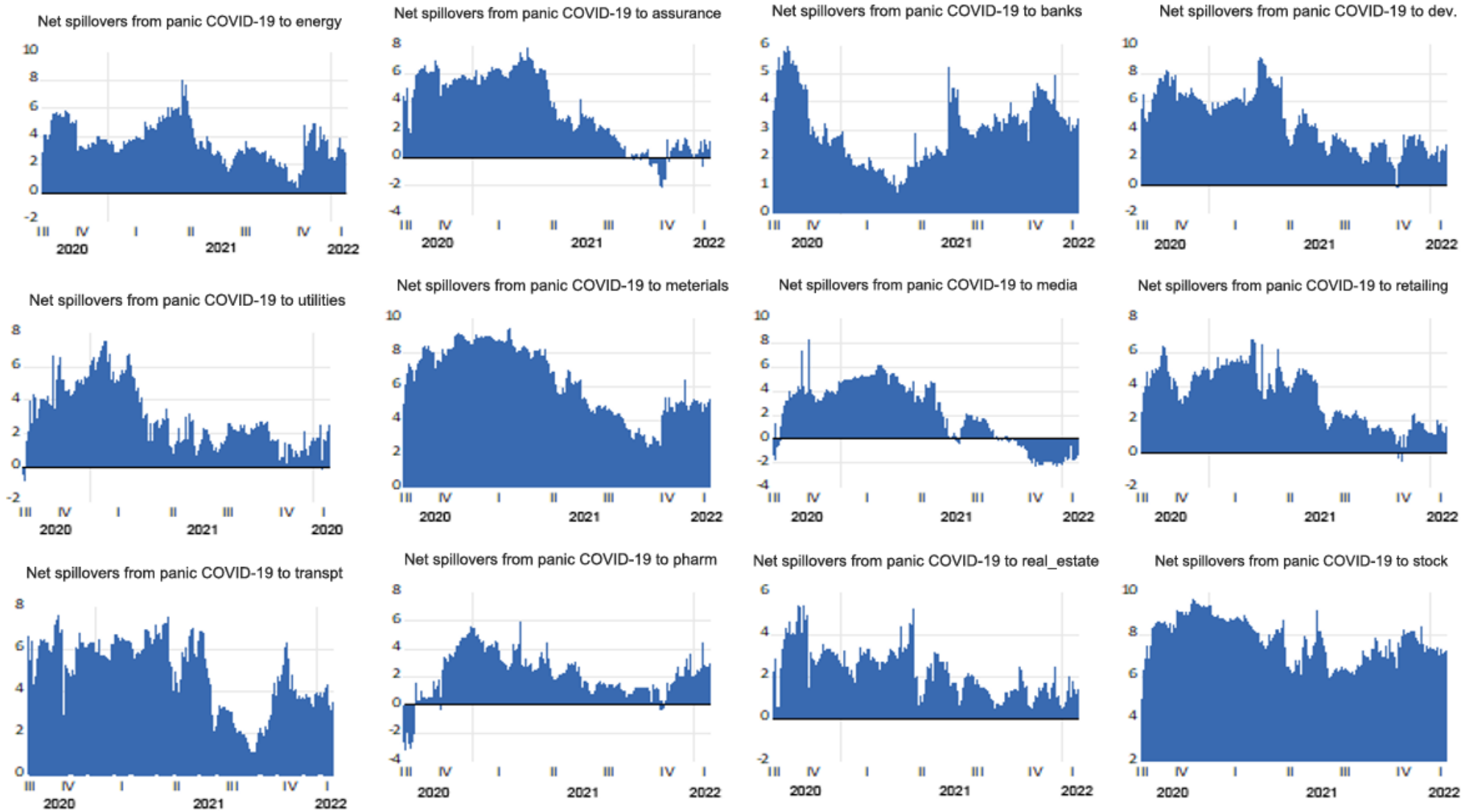
Figure 7. Rolling sample pairwise net directional connectedness between the COVID-19 panic index and the insurance, Saudi Tadawul all-share, and sector indices.

During the COVID-19 pandemic, Figure 6 indicates that insurance transmits volatility shocks to the DEV, materials, and transport sectors while it is a net receiver of the COVID-19 Panic Index. The analysis of the pairwise net connectedness between insurance and the sectorial indices indicates higher values during the COVID-19 pandemic than before. Moreover, the results reveal that insurance dominates the net pairwise connectedness and significantly affects banks, energy, pharma, and related sectors for three months in 2020, except in 2022.

This confirms that these sectors are net risk receivers, as shown in Figure 5. Similarly, the transport and DEV sectors appear to be both net transmitters and receivers throughout the analysis. Therefore, the net directional impact of insurance on the sector indices is higher during the first and third waves of the COVID-19 pandemic.

5.2. Rolling sample Pairwise Net Directional Connectedness between the COVID-19 Panic Index and Tadawul All-Share Index, the Insurance and Sector Indices

In this section, our objective is to investigate the spillover mechanism of each variable in the system. We find that shocks from COVID-19 significantly impact the Tadawul All-Share Index, insurance, and the sector indices. However, the insurance sector and the Tadawul All-Share Index demonstrate different responses to COVID-19.

Figure 7 illustrates the transmitters and recipients of spillovers over time from the COVID-19 Panic Index (which measures investor sentiment) to the Tadawul All-Share Index, insurance, and sector indices. The results indicate that panic emotion is the primary information transmitter to the Tadawul All-Share Index, insurance, and sector indices over most of the sample period. During this period, the insurance and other sectors primarily acted as information transmitters, while the pharma sector largely functioned as a recipient of information spillover from the COVID-19 Panic Index. This result confirms that this health crisis increased uncertainty in the Saudi stock market.

Conversely, the net pairwise directional connectedness between the COVID-19 Panic Index and the sectors indicates that it acts as a risk transmitter during the COVID-19 pandemic. The COVID-19 Panic Index dominates the net pairwise connectedness and significantly affects the energy, banking, development (DEV), materials, real estate, transportation, and utilities sectors in 2020 and 2021, confirming that these sectors are net risk transmitters. Consequently, investors should pay closer attention to the influence of panic emotions on these markets during the COVID-19 pandemic, making flexible investment decisions to mitigate risks and maximize profits.

Furthermore, we observe more pronounced directional spillover effects between the COVID-19 Panic Index and all sectors during the impactful event period. This suggests that the shock spillover effect between the COVID-19 Panic Index and the transportation index is higher. Simultaneously, the significant fluctuations in these markets could intensify panic emotions in society and amplify the dissemination of misinformation.

6. CONCLUSION

Examining the impact of the COVID-19 pandemic on global stock markets stands as one of the most significant events in recent years. Understanding the pandemic's influence on insurance and sector indices and to identify how shocks propagate across sectors during the crisis are crucial for effective risk management and portfolio diversification. This study investigates the risk spillover between COVID-19-related news indices, the insurance industry, the Tadawul All-Share Index, and other sector indices in Saudi Arabia. Employing the methodology proposed by Diebold and Yilmaz (2012), we measure total, net, and directional volatility spillovers for 11 sectors.
The findings of our study offer vital insights into the dynamics of risk spillovers among different sectors of the Saudi stock market during the COVID-19 pandemic. Our analysis unveils that the Tadawul All-Share Index played a dominant role as a net transmitter of risk to other sectors and insurance in the pre-COVID-19 period. This suggests that the Saudi stock market was more susceptible to external shocks and had a more pronounced impact on the insurance industry during this period. Furthermore, our analysis of the overall dynamic spillover effect highlights the importance of the epidemic-related news index as a key driver of volatility spillovers between the Tadawul All-

Share Index, sector indices, and insurance during major events. The total spillover effect was significantly higher during the COVID-19 pandemic crisis, with the index reaching its maximum value of 75%. The COVID-19 Panic Index dominates the net pairwise connectedness and considerably affects the energy, banking, development (DEV), materials, real estate, transportation, and utilities sectors in 2020 and 2021. This indicates that the pandemic profoundly influenced the interconnectedness of different sectors in the Saudi stock market.

Finally, our examination of the pairwise net spillover effects between the COVID-19 Panic Index and the different sectors revealed that the insurance sector was more susceptible to spillover effects than the global Saudi stock market. These findings suggest that investors should consider diversifying their portfolios across different sectors and asset classes to minimize their exposure to idiosyncratic risks and better manage their portfolio risks in times of crisis.

In summary, this study offers insights into the volatility spillover relationships among various sectors of the Saudi stock market during the COVID-19 pandemic. Contributing to the expanding literature on volatility spillovers in times of turmoil, the study emphasizes the necessity for further research in this domain to enhance risk management and policymaking practices. Our empirical findings hold significant implications for portfolio managers and investors. Additionally, they provide guidance for financial regulators and policymakers to discern transmission relationships and paths of volatility spillover risk across different markets, enabling them to make strategic decisions and implement appropriate policies to mitigate market distortions and uphold the financial stability of the financial system.

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