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The impact of COVID-19 on the tourism and hospitality Industry: Evidence from international stock markets

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ABSTRACT

COVID-19 seriously affects the tourism and hospitality industry. In this study, we investigate the behavior of 40 tourism and hospitality stock market indices worldwide from two perspectives. First, empowered by the Granger causality test and network analysis, we test the spillover effects among these stock markets and find that the dynamics of interconnectedness network structures differ significantly in the pre-pandemic and in-pandemic periods. Second, we employ econometric models to explore how the influence of COVID-19 on these stock markets varies by considering the interconnectedness structure, the government response stringency index, and other country-level characteristics. We find that the interconnectedness structure significantly and robustly affects stock returns in the tourism and hospitality markets. Our investigation provides a better understanding of the impact of COVID-19 on tourism and hospitality industry.

1. Introduction

On March 11, 2020, the WHO publicly declared that “COVID-19 can be characterized as a pandemic.” The COVID-19 pandemic has had severe consequences for public health, economics, politics, and society (Gössling et al., 2020). As of August 2, 2022, there were 575,887,049 confirmed cases of COVID-19 and 6,398,412 deaths worldwide (WHO, 2022). In addition, COVID-19 caused immediate and long-term damage to a majority of industries (Yarovaya et al., 2021). It is clear that the tourism and hospitality industry, which plays a critical role in a nation’s, or even the global economy and community, is among the most negatively impacted economic sectors during the COVID-19 pandemic (Lin & Falk, 2021). The impact on the tourism and hospitality industry can be explained as a side effect of many government policy implementations, such as the enforcement of social distancing, public event cancellations, travel controls, stay-at-home requirements, and limitations on gathering size. These policies are implemented to contain the spread of COVID-19 and flatten the death and infection curves; however, they dramatically affect the tourism and hospitality industry (Chen et al., 2020). The COVID-19 pandemic has resulted in difficult times for the global tourism and hospitality industry (Clark et al., 2021). Based on the study of (Mazur et al., 2021), it can be seen that by March 2020, the hospitality and entertainment industry had lost more than 70 % of its market capitalization in United States, as indicated by the S&P1500 stock indices.

The tourism and hospitality industry highly vulnerable to environmental, political, and socioeconomic factors, have been widely studied in the past because of various political crises, wars, natural disasters, and pandemics (Barbhuiya & Chatterjee, 2020). However, as many studies have indicated, compared to previous crises, the economic crisis caused by COVID-19 is quite different in its scope,

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duration, and severity (Ding et al., 2021). Therefore, it is necessary to investigate the impact of COVID-19 on the tourism and hospitality industry.

There are several studies focusing on the influence of COVID-19 on the tourism and hospitality industry by using stock market data, those previous studies include the impact of COVID-19 on the changing distributions of travel and leisure industry returns using quantile regression models and daily stock data (Lee & Chen, 2022); the influence of government interventions on U.S. travel and leisure companies' returns (Chen et al., 2020); using daily stock data to investigate the influence of COVID-19 on travel or leisure industry in Spain (Gil-Alana & Poza, 2020), USA (Carter et al., 2022; Song et al., 2021), India (Pandey & Kumar, 2022), and Taiwan and Mainland China (Wang et al., 2022); investigating the performance of the stock market and volatility in the travel and leisure industry for three Nordic countries using daily data (Lin & Falk, 2021); the impact of government interventions on nine countries' travel and leisure industry return and volatility using panel quantile regression models (Wang et al., 2021).

These studies mainly concentrate on COVID-19′s influence on tourism and the hospitality market from either firm, one industry, or regional perspective. Few studies have focused on investigations from a global perspective. In addition, almost no study has considered the spillover effect among tourism and hospitality markets in different countries worldwide. The spillover effect exists in the global tourism and hospitality markets for the following reasons. First, the tourism and hospitality industry has become more interdependent (Mitra et al., 2019). Tourism and hospitality firms not only compete or cooperate in their home country but also compete and cooperate with other countries in the form of hotel chains, combo offers, and so on (Balli & Tsui, 2016). COVID-19 affects the global tourism and hospitality industry supply chain (Sigala, 2020), and thus leads to spillover effects. Second, tourism demand reveals an interdependent structure at the global level (Cao et al., 2017). However, many government response policies to COVID-19 have restricted people's movement. One country's tourism stock market distress caused by the panic of COVID-19 can quickly spread to other countries, resulting in a global spillover effect among tourism and hospitality markets in many countries, presenting a co-movement phenomenon. Thus, it is necessary to investigate the spillover effect in international tourism and hospitality markets.

In this study, we investigated the impact of COVID-19 on tourism and hospitality markets from two perspectives. First, by using a panel dataset consisting of tourism and hospitality stock market indices for 40 countries or regions, we test the spillover effect among the tourism and hospitality markets using the Granger causality test and network analysis. Specifically, we use the Granger causality test to estimate statistically significant spillover effects among these market indices and show interconnectedness between any paired markets if a spillover effect exists. We then construct a series of interconnectedness networks using the rolling window technique and explore the dynamics of the network structure according to three global interconnectedness measures (i.e., degree of centralization, transitivity, and density).

We find that the dynamic structure of interconnectedness differs significantly. Before the pandemic, the level of interconnectedness between different stock markets was low, and it increased after the pandemic, providing evidence for the existence of a higher spillover effect during the COVID-19 outbreak. To the best of our knowledge, there has been no research on the spillover effect in international tourism and hospitality stock markets. Second, we construct econometric models to investigate how the effect of COVID-19 on the tourism and hospitality stock market varies by considering the interconnectedness structure of the stock market, which is measured by the degree, closeness, and average nearest neighbor degree (ANND), government response stringency index (GRSI), and other country-level characteristics. We find that network interconnectedness significantly and robustly affects the stock returns of the tourism and hospitality markets.

This study contributes to the literature in three ways. First, we conducted a worldwide study to investigate the impact of the COVID-19 pandemic on the tourism and hospitality stock market in 40 countries, as the existing literature mainly focuses on regional or national analysis. Second, we explore the spillover effect and co-movement phenomenon among these stock markets through network analysis and demonstrate the statistically significant differences in the behavior of pre-pandemic and pandemic stock returns by investigating the dynamics of the interconnectedness network structure. Third, we present a better mapping and understanding of the possible determinants of tourism and hospitality stock market returns by incorporating local interconnectedness measures (i.e., the local network features of each stock market) into the econometric model. We empirically find that network interconnectedness can significantly explain the variations in tourism and hospitality market returns.

The remainder of this paper is organized as follows. Section two is a review of relevant literature; section three investigates the interconnectedness structure between different tourism and hospitality markets; section four presents the regression analysis and section five concludes the research findings.

2. Literature review

The rapid spread of COVID-19 has proven to have a global spillover effect between countries, causing unprecedented economic and financial distress. We believe that the unexpected health crisis differs from any previous disaster and is much worse than the global financial crisis (Baker et al., 2020). It has triggered an unparalleled response from the scientific community and spawned a growing volume of academic research that focuses on its economic and financial influence. For example, the interplay between COVID-19 and stock market returns (Dong et al., 2021; Li et al., 2021; Rehman et al., 2021), investment (Giofré, 2021), volatility (Li, 2021; Tissaoui et al., 2021); the impact of COVID-19 on commodities (Bakas & Triantafyllou, 2020; Corbet et al., 2021), exchange rates (Feng et al., 2021; Njindan Iyke, 2020), cryptocurrencies (Hsu et al., 2021; Wüstenfeld & Geldner, 2021), real estate (Ling et al., 2020; Tanrıvermiş, 2020) and bonds (Naeem et al., 2021; O'Hara & Zhou, 2021).

In addition to the aforementioned financial influence investigations, there is plenty of research exploring the impact of COVID-19 on the tourism and hospitality industry (Arbulú et al., 2021; Duro et al., 2021; Huang et al., 2021; Uğur & Akbıyık, 2020). As suggested by (Bai et al., 2020), the tourism industry is one of the most affected by the outbreak because it affects both the supply and demand for

Table 1
Summary Statistics for the Return Series for Selected 8 Countries.

	Australia	Spain	China	UK	India	Italy	Sweden	USA
Mean(X100)	0.04	−0.09	0.16	−0.01	0.07	−0.07	0.13	0.06
Std.dev	0.0191	0.0226	0.0183	0.0223	0.0165	0.0238	0.018	0.025
Median	0.0009	0	0.0002	0.0005	0.0011	0.0002	0	0.0012
Min	−0.1653	−0.2157	−0.0739	−0.1457	−0.1468	−0.2169	−0.1043	−0.134
Max	0.0803	0.1472	0.0775	0.119	0.066	0.1741	0.1386	0.1387
Skewness	−1.838	−2.5501	0.1562	−0.5142	−1.994	−1.0826	0.675	−0.36
Kurtosis	14.8304	29.7922	1.6202	10.0317	16.3546	20.6185	12.226	8.2551
JB_Value	5240.332***	20494.17***	61.8491***	2284.717***	6360.138***	9645.419***	3397.778***	1543.43***
ADF	−6.6448***	−6.3602***	−6.8739***	−7.6527***	−6.5254***	−6.3401***	−6.5685***	−7.6282***
PP	−597.051***	−684.683***	−547.466***	−448.553***	−567.839***	−605.925***	−543.831***	−558.539***
KPSS	0.0896	0.0952	0.2367	0.097	0.2575	0.0942	0.0998	0.1267
ARCH (20)	222.3586***	145.9978***	60.5218***	174.55***	168.5522***	64.5842***	151.8839***	93.9566***
Break Date	2020/3/23	2020/3/23	2020/3/31	2020/3/18	2020/3/23	2020/3/17	2020/3/19	2020/3/18

Note: JB is the empirical statistics of the Jarque-Bera test for normality. The ADF, PP, and KPSS tests are used to check the stationarity of the return's series. ARCH (20) denotes Engle's test to check the presence of ARCH effects up to 20 lags. *, **, and *** refer to significance levels of 10 %, 5 %, and 1 % for testing. Break Date is obtained by testing the structural changes in time series regression models.

travel. Furthermore, Sigala (2020) pointed out that COVID-19′s impact on tourism is uneven in space and time, and is large and international. Many countries have implemented a series of policy responses to prevent the spread of COVID-19. These policies, such as international, regional, and domestic restrictions, directly affect the tourism and hospitality industry's value chain. Some of these policies include social distancing, national and international travel restrictions, and stay-at-home requirements (Chen et al., 2020).

COVID-19′s impact on the tourism and hospitality industry, presented in existing studies, is mainly national or regional. Using a strong dependence model based on fractional integration, Gil-Alana and Poza (2020) provided evidence that COVID-19 had a permanent effect on the Spanish tourism sector. Lin and Falk (2021) used a "Markov regime-switching model" to investigate stock market volatility in three Nordic countries, and their results suggested that the COVID-19 period was full of idiosyncratic risk. Lee and Chen (2022) studied the international impact of COVID-19 in 65 countries and investigated the COVID-19 variables (i.e., deaths, confined cases, recovered cases) and government response stringency (GRSI) on travel and leisure industry stock returns via quantile regression.

In addition to the COVID-19 literature, we also review the literature on the impact of previous economic shock events, such as SARS (Zeng et al., 2005) and the global financial crisis (GFC) of 2008 (Solarin, 2016). (Chen et al., 2005) used regression analysis to explore the relationship between macroeconomic and shock events (e.g., the 921 earthquakes, the 2003 Iraqi war, the SARS outbreak) and hotel stock returns. Chen et al. (2013) studied the impact of the SARS outbreak in Taiwan using an event study approach and found that hotel stock returns declined significantly over the month following the SARS outbreak. (Zopiatis et al., 2019) explored the relationship between the performance of tourism industry stock (i.e., returns and volatility) and the outbreak of unexpected non-macro incidents across five different regions, revealing that unexpected non-macro incidents, such as acts of terrorism, natural catastrophes, and war conflicts, could have a very short-term effect on the selected stock indices with a significant drop. Furthermore, (Wang et al., 2013) investigated the influence of enterovirus 71, dengue fever, SARS, and H1N1 on the stock market and found a significant abnormal return on company shares.

Although these disaster tourism impact studies use either a regression model or an event-study approach to explain the average conditions and focus on the determinants of the impact, no study has focused on the global spillover effect between countries as COVID-19 spreads. Obviously, COVID-19 affects the global supply chain of the tourism and hospitality industry, and distress in the tourism and hospitality stock market triggered by the panic of the disaster in one country can quickly spread to other countries, and thus may lead to the phenomenon of co-movement in the market (Mishra et al., 2020). Therefore, this study focuses on the spillover effect and investigates the interconnectedness structure among international tourism and hospitality stock markets.

3. Interconnectedness among world tourism and hospitality markets

3.1. Tourism and hospitality stock market data

The empirical dataset includes the daily closing prices of tourism and hospitality stock market indices of 40 countries or regions, including Australia, Spain, China, the United Kingdom, India, Italy, Mexico, Sweden, Korea, and the United States.[1] We downloaded the daily closing price series from Investing.com. The sampling period was from January 2019 to February 2021, which covers the announcement date of the COVID-19 pandemic. We calculate the return series by dividing the natural logarithm of the closing prices by the hysteretic closing prices.

Table 1 depicts the results of the descriptive analysis of stock returns for the eight selected countries because of limited space.[2] The average stock returns are close to zero over the entire sample interval, except for China and Sweden. Unconditional volatility

[1] For detail information for all the countries/regions and indices, please refers to Appendix A in the Online Appendix Materials.
[2] We present the descriptive analysis for all Tourism and Hospitality Stock indices in Appendix B in the Online Appendix Materials.

Table 2
Summary Statistics of the Stock Returns (×100) and Volatility for the Different Sub-periods.

	Return (X100)		Volatility	
	Mean	St.Dev.	Mean	St.Dev.
pre-pandemic period	−0.0238	1.3028	0.1663	0.0691
in-pandemic period	−0.0567	2.6913	0.3396***	0.1572

Note: *, **, and *** refer to significance levels of 10 %, 5 %, and 1 % for testing the mean difference between In-Pandemic period and Pre- Pandemic period.

characterized by standard deviation is the largest for the United States, followed by the tourism and hospitality stock market in Italy; the United States and Italy are among the hardest hit countries by COVID-19. The skewness for most of the tourism and hospitality stock markets is negative, except for Sweden. In addition, kurtosis values for most markets exceed three, except for China, which reveals that most countries have a leptokurtic distribution for their tourism and hospitality stock returns and points out the presence of outlier events. The distributional properties of most return series are not normal. This is further verified by the results of the Jarque–Bera (JB) test, which rejects the normality of the return distributions at a significance level of 1 %. We also perform ADF, PP, and KPSS tests to quantitatively examine the stationarity of these return series, and the results reveal that the market returns are all stationary series. We also conclude that all return series exhibit significant ARCH behavior, based on the ARCH test. Finally, the break dates obtained by testing the structural changes in the time-series regression model were mostly in March 2020. They were close to March 11, 2020, when the WHO announced that COVID-19 was a global pandemic. And summary statistics for the return series for all countries and regions can be seen in Table A1.

We further explored whether the stock markets react differently to the outbreak of the COVID-19 pandemic by comparing the return and volatility of tourism and hospitality stock markets between two different sub-periods: the pre-pandemic period, which was before March 11, 2020, and the in-pandemic period, which was after March 11, 2020.

Table 2 presents the summary statistics of stock returns and volatility for the two subperiods. The return of the tourism and hospitality stock market has a lower mean value during the in-pandemic period, but the mean difference is not significant. In addition, volatility increased by 100 % compared with the pre-pandemic period, and this mean difference is statistically significant, highlighting that COVID-19 significantly affected the volatility of the tourism and hospitality stock markets in all countries. These notable distinctions in the behavior of the tourism and hospitality stock markets between the two sub-periods constitute a major motivation for conducting further empirical analyses.

3.2. *Interconnectedness analysis from global perspective*

3.2.1. *Measure of interconnectedness*

We find that the volatility in the hospitality stock market generally increases sharply after the announcement of the COVID-19 pandemic, revealing that there is strong interconnectedness across markets in different countries due to the spillover effect (Diebold and Yilmaz, 2012). Thus, the analysis of the likely spillover effect across markets since the emergence of COVID-19 serves as an "early warning'' regarding the severity of crisis' consequences (Salisu et al., 2020). To measure the interconnectedness among these stock market indices, we use the pairwise Granger Causality Test to capture the interconnectedness of statistically significant causal relationships among these stock market indices (Billio et al., 2012). To investigate the dynamics of interconnectedness, it is more reasonable to measure not only the degree of interconnectedness between market indices but also the directionality of such relationships. The Granger causality test is an ideal technique to match such an objective, as it can estimate the interdependence of pairwise market indices and identify the direction of interdependence based on the forecast power of two time series for the corresponding market indices.

For any pairwise market index, we can obtain two corresponding time series X and Y based on the daily price. Time series X is said to be "Granger-cause" Y if the past value of X contains information that helps predict Y above and beyond the information contained in the past values of Y alone. The mathematical formulation of this test is based on the linear regressions of X on Y and X on Y.

$$X_t = \sum_{i=1}^{m} a_i X_{t-i} + \sum_{i=1}^{m} b_i Y_{t-i} + \epsilon_t^X \tag{1}$$

$$Y_t = \sum_{i=1}^{m} c_i Y_{t-i} + \sum_{i=1}^{m} d_i X_{t-i} + \epsilon_t^Y \tag{2}$$

Where ϵ_t^X and ϵ_t^Y are two uncorrelated white noise processes, m is the maximum lag considered, and a_i, b_i, c_i, and d_i are coefficients of the models. Granger causality implies that Y_t causes X_t when b_i is different from zero. Similarly, X_t causes Y_t when d_i differs from zero. When both b_i and d_i are different from zero, a feedback relationship exists between the time series X_t and Y_t. The Bayesian information criterion (BIC) was considered as the model selection criterion for the number of lags in the test. Causality is based on the F-test of the null hypothesis that coefficients b_i or d_i are equal to zero according to the direction of Granger causality.

In this study, we used the return of the tourism and hospitality market index to conduct Granger causality tests. However, we need to capture returns specifically pertaining to the tourism and hospitality industry, instead of general movements in the entire stock

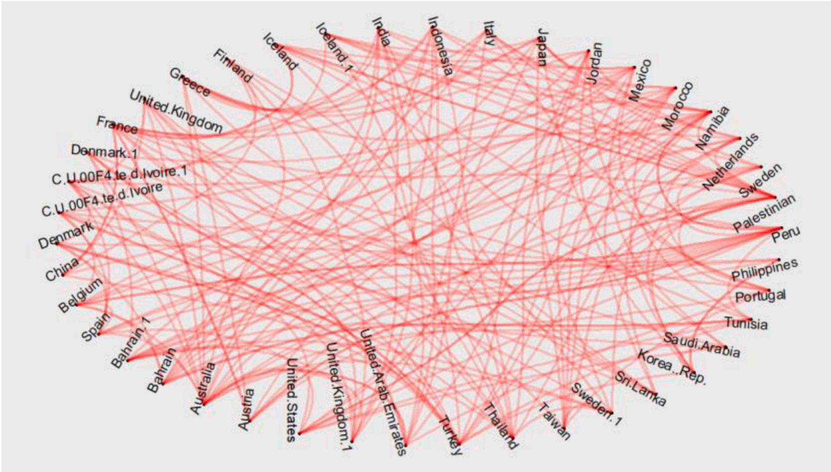

Fig. 1. The network diagram of interconnectedness structure in the rolling-window from July 1st, 2019 to January 1st, 2020.

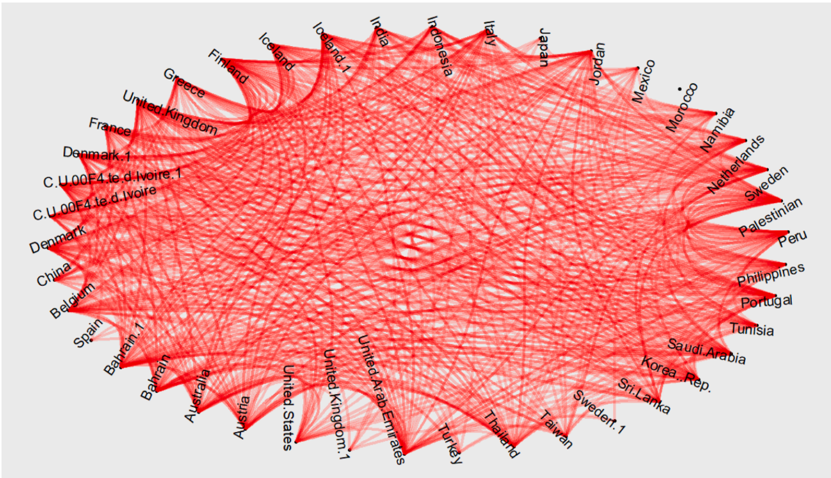

Fig. 2. The network diagram of interconnectedness structure in the rolling-window from March 1st, 2020 to September 1st, 2020.

market. To remove the effect of general market movements, we use the following initially estimated regression model:

$$r_{j,\tau} = \alpha_j + \beta_{1,j} r_{m,\tau-2} + \beta_{2,j} r_{m,\tau-1} + \beta_{3,j} r_{m,\tau} + \beta_{4,j} r_{m,\tau+1} + \beta_{5,j} r_{m,\tau+2} + \varepsilon_{j,\tau} \tag{3}$$

where $r_{j,\tau}$ represents the return of tourism and hospitality market j on day τ and $r_{m,\tau}$ denotes the return value based on the CRSP value-weighted index on day τ. Here we follow Dimson (1979) and employ both the lagged and led terms of tourism and hospitality market returns, considering nonsynchronous trading. The industry-specific return $W_{j,\tau}$ is calculated using the equation $W_{j,\tau} = \ln(1 + \widehat{\varepsilon_{j,\tau}})$.

3.2.2. Interconnectedness structure in world tourism and hospitality markets

To describe the interconnectedness between these tourism and hospitality stock markets, we use individual market returns to build directed Granger causality linkages (Billio et al., 2012) between tourism and hospitality stock markets. Granger causality[3] in market returns can be viewed as a proxy for return spillover effects across markets (Danielsson et al., 2011). In particular, if the return of the tourism and hospitality stock market in country A Granger-causes the return of the market in country B, we draw a direct link from A to B, because the Granger-causality test captures the lagged propagation of return spillovers across markets. Granger causality tests were performed using daily data with 125-day rolling windows. Thus, we can construct a network that depicts the interconnectedness structure of tourism and hospitality stock markets among the 40 countries in each rolling window.

Figs. 1 and 2 show two interconnectedness structures of the international tourism and hospitality stock market for two rolling-

[3] More information about Granger-causality test, please refers to the Appendix C in the Online Appendix Materials.

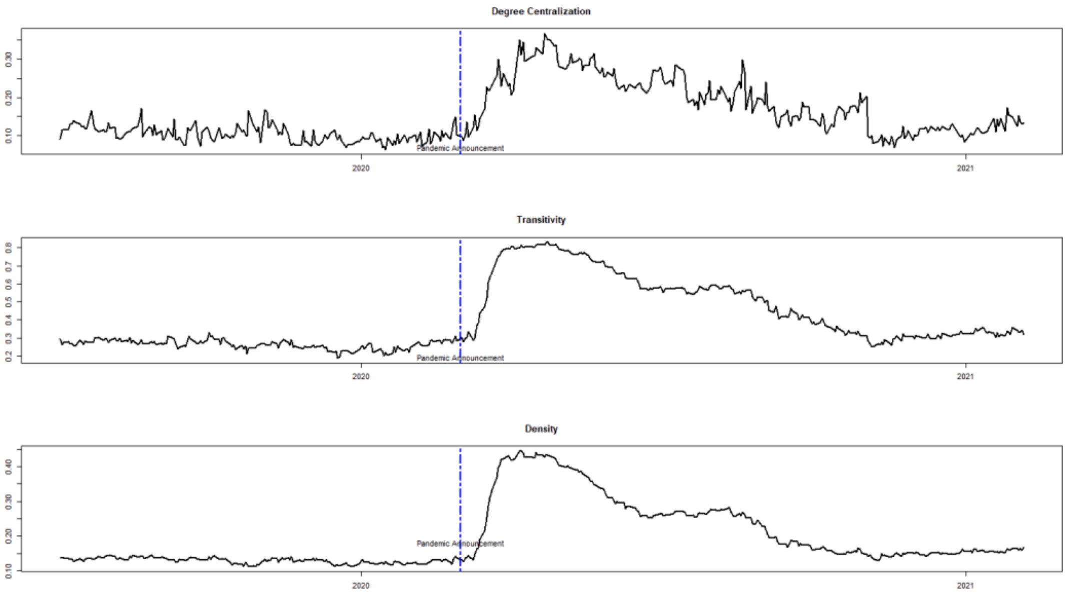

Fig. 3. The dynamic of the three interconnectedness measures for daily network for the tourism and hospitality stock markets from June 2019 to February 2021. The vertical line indicates the time of the COVID-19 Pandemic Announcement by WHO, which indicates two subsamples: Pre-Pandemic period and In-Pandemic period.

Table 3
Summary Statistics of the Interconnectedness Measures in the Different Sub-periods.

	Degree of Centralization		Transitivity		Density	
	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.
pre-pandemic period	0.1204	0.0519	0.3143	0.1478	0.1561	0.0800
in-pandemic period	0.2147 ***	0.0398	0.5607***	0.0603	0.2553***	0.0314

Note: *, **, and *** refer to significance levels of 10 %, 5 %, and 1 % for testing the mean difference between In-pandemic period and the pre-pandemic period.

window sub-periods: July 1st, 2019, to January 1st, 2020, and March 1st, 2020, to September 1st, 2020. These are representative time periods encompassing both pre-pandemic and in-pandemic periods. The interconnectedness structure is depicted by the network diagram of Granger causality relationships, which are statistically significant at the 5 % level among the tourism and hospitality stock market returns of these 40 countries. We can see that the degree of interconnectedness among these markets dramatically increases from the sub-period March 1st, 2020, to September 1st, 2020.

To comprehensively investigate the interconnectedness structure of the tourism and hospitality stock markets, we introduce the following global interconnectedness measures[4] based on the entire network topology.

First, we present the degree of centralization, defined as the number of linkages, as the proportion of all possible linkages in these markets. The degree of centralization measures the fraction of statistically significant Granger causality relationships in the tourism and hospitality markets. Second, we used a transitivity measure. Transitivity, known as the clustering coefficient in the network, is defined as the frequency at which triangular connections occur in the network. Transitivity measures the probability that neighbors of one tourism and hospitality stock market have a statistically significant Granger causality relationship. Third, we introduce density, which measures the magnitude in a network's density. All three measures are normalized by the number of stock markets in the network so that proper benchmarking can be performed between these networks.

Fig. 3 shows the changes in the three interconnectedness measures for the daily network of the tourism and hospitality stock markets from June 2019 to February 2021. We can see that all three measures have similar evolutionary trends. They vary slightly during the pre-pandemic period, but fluctuate intensely during the in-pandemic period. Taking transitivity, for example, during the pre-pandemic period, transitivity varies between 0.2 and 0.4, but shows a significant increase at the beginning of the In-Pandemic period, exceeding 0.8. Thus, we can conclude that the interconnectedness structure is highly dynamic among these tourism and hospitality markets; these dynamics are different between the pre-pandemic and in-pandemic periods. Therefore, there is a significant

[4] We investigate the interconnectedness from both global and local perspectives. For the definition of global interconnectedness measures and local interconnectedness measures, please refers to Appendix D in the Online Appendix Materials.

spillover effect in tourism and hospitality markets between countries, which is supported by the interconnectedness analysis.

To verify the conclusion numerically, we further conducted summary statistics of the three network measures. Table 3 presents the numerical results, where the values of the three measures in the in-pandemic period all doubled compared with the corresponding values in the pre-pandemic period at a significance level of 1 %. The variation in these measures was also high between the two subperiods. COVID-19 has had a significantly negative impact on the world's tourism and hospitality stock markets, leading to a high spillover effect between countries.

4. Regression analysis

As mentioned above, the interconnectedness structure is significantly different between the pre-pandemic and in-pandemic periods, and there is a high spillover effect in the tourism and hospitality markets between countries after the announcement of the COVID-19 pandemic. Further, we investigate whether the local interconnectedness structure (the local network feature of each stock market), as well as the COVID-19 variables and country-level characteristics, can explain the change in stock market returns.

4.1. The determinants of tourism and hospitality stock market return

To estimate the impact of COVID-19 on the stock returns of the global tourism and hospitality industry, we consider a range of variables that may drive the performance of tourism and hospitality stock markets. First, we needed to quantify the spread of COVID-19. We used the change in the number of cases as our primary proxy for the spread of COVID-19. In particular, we closely followed Ding et al., who computed the growth rate of the cumulative number of confirmed cases in each country. The growth rate,$GRC_{i,t}$ was calculated using $GRC_{i,t} = ln(1 + CCC_{i,t}) - ln(1 + CCC_{i,t-1})$. where i and t are the index country and day, respectively. $CCC_{i,t}$ represents the cumulative number of confirmed cases in country i on day t. Notably, to strengthen our findings, similar to Erdem (2020) and Iyke (2020), we corroborate our findings with the cumulative number of confirmed deaths ($CCD_{i,t}$). The growth in the confirmed death rate, $GRD_{i,t}$, is calculated using $GRD_{i,t} = ln(1 + CCD_{i,t}) - ln(1 + CCD_{i,t-1})$.

Second, we consider three variables to measure the local interconnectedness structure: degree, closeness, and ANND. The three variables are local network features of each stock market used to measure the local interconnectedness structure. In particular, degree is defined as the total number of connections linked to the node, which measures the sum of the number of stock markets that significantly Granger-cause the focal market and the number of stock markets that are significantly Granger-caused by the focal market. Closeness is calculated as the reciprocal of the sum of the shortest path lengths between the markets in one country and the other country, which measures the number of steps between two markets on average. ANND is defined as the average degree of the nearest neighbor for each market, and measures the neighbor's interconnectedness structure for the focal market.

Third, we employ the Chicago Board Options Exchange Volatility Index (VIX) and crude oil prices (Oil). VIX is the global stock market uncertainty index and can measure the level of market risk and investors' sentiments such as fear and stress. The VIX has been verified to have a significant influence on travel and leisure industry returns (Grechi et al., 2017). In a study by Mohanty et al. (2014), crude oil price had a negative influence on the tourism and hospitality stock markets.

Finally, we utilize several control variables to capture country-specific heterogeneity: government response stringency index (GRSI), GDP per capita (GDPC), and human development index (HDI). The GRSI measures the strictness of government responses and has a score from 0 to 100, with higher scores describing countries with stricter government responses. GDPC measures a country's economic growth and development. HDI is an indicator provided by the United Nations Development Programme that considers life expectancy, education, and per capita income (Haug et al., 2020). The HDI provides a basic overview of a country's human development involving three key dimensions and reflects how well people can enjoy a long and healthy life.

4.2. Panel data regression models

Our empirical model for tourism and hospitality stock returns is based on the daily closing price series. The method we used to estimate the regression model of panel data is based on the one-way fixed effects model, which was employed to address the individual-specific effect. The form of the fixed effects model is written as:

$$Return_{i,t} = \beta_1 Return_{i,t-1} + \beta_2 GRC_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \alpha_i + \varepsilon_{i,t} \quad (4)$$

where all subscript notation (i, t) refer to the value taken from country *i* at time *t*. Specifically, $Return_{i,t}$ is the stock index return and $Return_{i,t-1}$ is the first lag of $Return_{i,t}$. $GRC_{i,t}$ is the proxy for COVID-19, representing the growth rate of COVID-19 confirmed cases. $Interconnectedness_{i,t}$ is the local interconnectedness structure for tourism and hospitality stock markets in each country, which can be measured by the three network measures: degree, closeness (CC), and ANND; Oil_t is the WTI crude oil price return. VIX_t is the Chicago Board Options Exchange (CBOE) Volatility Index. $GRSI_{i,t}$ is the government response stringency index proposed by the Oxford University. $GDPC_{i,t}$ is the GDP per capita, which measures the country's economic development level. $HDI_{i,t}$ is the human development index. α_i is individual-specific effect. Here, we do not consider the time-fixed effects as some of our data are time-invariant variables that are correlated with individual-specific fixed effects. We also do not consider the country-fixed effect because the country-fixed effects estimation approach requires estimating country-specific intercepts, which can significantly reduce the number of degrees of freedom (Zaremba et al., 2020). Thus, we turn to include region-fixed effects to control the variations that vary across regions but are constant over time. Furthermore, we also consider another high-level individual effect— income-fixed effects. In detail, we check the

Table 4
Summary Statistics.

Variables	No. of obs.	min	max	Mean	SD	Median
Lag variable						
$Return_{i,t-1}$	9328	−0.21771	0.293565	0.000859	0.020467	0
Main variable						
$GRC_{i,t}$	9328	−0.23631	2.393557	0.031833	0.079004	0.01062
Interconnectedness variables						
Degree	9328	2	66	20.17399	11.95614	17
CC	9328	0.330709	0.913043	0.616572	0.09332	0.6
ANND	9328	5.2	47.66667	22.55782	9.9004	19.08013
Control variables						
$Oil_{i,t}$	9328	−37.63	56.85	38.66459	10.48423	40.55
$VIX_{i,t}$	9328	13.68	82.69	29.72188	10.01438	26.87
$GRSI_{i,t}$	9328	2.78	100	62.13094	16.29191	63.89
$GDPC_{i,t}$	9328	5212.556	67119.13	35833.65	19299.29	42878.82
$HDI_{i,t}$	9328	0.538	0.949	0.840898	0.11158	0.892

Table 5
Pearson Correlation Results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)$Return_{i,t-1}$	1									
(2)$GRC_{i,t}$	−0.0563	1								
(3) Degree	0.0309	0.1111	1							
(4) CC	0.0266	0.1250	0.8944	1						
(5) ANND	0.0537	0.1774	0.7340	0.6929	1					
(6)$Oil_{i,t}$	−0.0154	−0.2644	−0.4466	−0.3829	−0.7609	1				
(7)$VIX_{i,t}$	−0.0729	0.4267	0.3386	0.3714	0.5327	−0.6931	1			
(8)$GRSI_{i,t}$	0.0945	0.0169	0.1220	0.1234	0.2332	−0.2256	0.1037	1		
(9)$GDPC_{i,t}$	0.0004	−0.0042	0.2810	0.2582	0.1035	−0.0288	0.0533	−0.0125	1	
(10)$HDI_{i,t}$	−0.0027	−0.0014	0.2694	0.2485	0.0998	−0.0298	0.0568	0.0241	0.9619	1

region-fixed effects by grouping the countries into seven different regions (East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, North America, South Asia, Sub-Saharan Africa), and the income-fixed effects are checked by grouping the countries into three different income levels (High income, Lower middle income, Upper middle income). Fixed effects model can reduce the selection bias and we consider it is more appropriate to include region and income specific fixed effects models rather than country-fixed effects models.

For comparison study, we consider another three regression models. The first model considered the interaction effect between COVID-19 and the control variables based on the baseline regression in Equation (4); the second model is pooled OLS regression model which use standard ordinary least squares (OLS) regression without any cross-sectional or time effects; the third model is pooled OLS regression model with interactions. The three models are expressed as follow:

$$Return_{i,t} = \beta_1 Return_{i,t-1} + \beta_2 GRC_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \beta_9 GRC_{i,t} \times GRSI_{i,t} + \beta_{10} GRC_{i,t} \times GDPC_{i,t} + \beta_{11} GRC_{i,t} \times HDI_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{5}$$

$$Return_{i,t} = \beta_0 + \beta_1 Return_{i,t-1} + \beta_2 GRC_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \varepsilon_{i,t} \tag{6}$$

$$Return_{i,t} = \beta_0 + \beta_1 Return_{i,t-1} + \beta_2 GRC_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \beta_9 GRC_{i,t} \times GRSI_{i,t} + \beta_{10} GRC_{i,t} \times GDPC_{i,t} + \beta_{11} GRC_{i,t} \times HDI_{i,t} + \varepsilon_{i,t} \tag{7}$$

Before presenting the regression results, we provide the descriptive statistics for all variables in Table 4.

In particular, Table 4 shows the minimum, maximum, mean, standard deviation, median values of lag variable: $Return_{i,t-1}$; main variable:$GRC_{i,t}$; interconnectedness variables: Degree, CC, ANND; and five control variables: Oil_t, VIX_t, $GRSI_{i,t}$, $GDPC_{i,t}$, $HDI_{i,t}$. The total number of observations is 9328.

In addition to the descriptive analysis, we also conduct Pearson correlation analysis to test the correlation relationships between all variables. Pearson correlation coefficient is used to indicate the degree to which two variables are linear correlated. According to the Pearson correlation results in Table 5, we can see that interconnectedness variables of Degree, CC and ANND, ANND and Oil_t, Oil_t and $VIX_{i,t}$, $GDPC_{i,t}$ and $HDI_{i,t}$ are correlated.

Table 6
Baseline models' results without interactions.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Degree	0.0043***	0.0041**	0.0047***						
	(0.0009)	(0.0009)	(0.0009)						
CC				0.0104***	0.0097 ***	0.0115***			
				(0.0025)	(0.0026)	(0.0026)			
ANND							0.0087***	0.0086***	0.0088***
							(0.0016)	(0.0016)	(0.0016)
Return_lag	0.0228 **	0.0220**	0.0216**	0.0226**	0.0219**	0.0215**	0.0217**	0.0208**	0.0208**
	(0.0102)	(0.0103)	(0.0102)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0102)
GRC	−0.0340***	−0.0337***	−0.0340***	−0.0340***	−0.0337***	−0.0339***	−0.0333***	−0.0330 ***	−0.0333***
	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0029)
GRSI	0.0135***	0.0152 ***	0.0136***	0.0134***	0.0150***	0.0131***	0.0133***	0.0152***	0.0132***
	(0.0016)	(0.0018)	(0.0016)	(0.0016)	(0.0018)	(0.0016)	(0.0016)	(0.0018)	(0.0016)
VIX	−0.0168***	−0.0168***	−0.0168***	−0.0180 ***	−0.0179***	−0.0181***	−0.0171***	−0.0170***	−0.0170***
	(0.0026)	(0.0027)	(0.0026)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0026)
Oil	−0.0114***	−0.0113***	−0.0111***	−0.0133***	−0.0132***	−0.0131***	−0.0070**	−0.0067 **	−0.0069**
	(0.0024)	(0.0024)	(0.0024)	(0.0023)	(0.0023)	(0.0023)	(0.0027)	(0.0027)	(0.0027)
GDPC	0.0035	0.0016	0.0118***	0.0037	0.0023	0.0118***	0.0039*	0.0020	0.0109***
	(0.0023)	(0.0030)	(0.0033)	(0.0023)	(0.0029)	(0.0033)	(0.0023)	(0.0029)	(0.0033)
HDI	−0.0125*	−0.0017	−0.0164**	−0.0126*	−0.0037	−0.0163**	−0.0122*	−0.0012	−0.0155**
	(0.0069)	(0.0104)	(0.0070)	(0.0069)	(0.0104)	(0.0070)	(0.0068)	(0.0104)	(0.0069)
Region fixed	No	Yes	No	No	Yes	No	No	Yes	No
Income fixed	No	No	Yes	No	No	Yes	No	No	Yes
Obs	8046	8046	8046	8046	8046	8046	8046	8046	8046
Adjusted R^2	0.40464	0.404287	0.411497	0.398689	0.39861	0.404937	0.412709	0.414138	0.415846

Note: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

4.3. Baseline empirical results

In this subsection, we first concentrate on the investigation of individual variables' influence on tourism and hospitality stock market returns based on regression model (4) and (6). Subsequently, we explored the interaction effect among these variables based on Equation (5) and (7). Table 6 shows the results of the fixed effects models and pooled OLS regression model estimating the panel data's regression model without interaction terms. We need to mention that the all model results' tables hereinafter don't show the estimates of the intercept terms. It is because for pooled regression model, the intercept term is identical for all units. But for each fixed effects model, it has the distinctive intercept for each unit so the intercept term is non-fixed. For simplicity, we remove the estimating results of all models' intercepts so that we can combine the results in one table. In addition, we introduced three variables (Degree, CC, ANND) to measure the local interconnectedness structure from different perspectives, but only one interconnectedness measure is employed at a time. In detail, in Table 6, the model 1, model 2 and model 3 present the results of pooled OLS regression model, the region-fixed effect model, and income-fixed effects model, respectively, by considering the degree as the interconnectedness measure. Similarity, model 4–6 presents the results by considering the CC as the interconnectedness measure, and model 7–9 presents the results by considering the ANND as the interconnectedness measure.

First, we can see that the local interconnectedness structure positively and significantly influences tourism and hospitality stock market returns, as the corresponding three variables are positive values at significance level of 1 %. Indeed, higher value of local interconnectedness denotes that there are more linkages between the corresponding country with other countries, such as more tourism and hospitality industry supply chain linkages among these countries (Mitra et al., 2019), and tourism demand interdependence structure (Cao et al., 2017). Thus, if the tourism and hospitality industry is hit by an adverse shock, then having higher interconnectedness provides more channels to diversify away the effect. Thus, the interconnectedness can increase the supply chain stability, facilitate risk sharing and diversify the risk during the pandemic, which indicates that the local interconnectedness structure positively and significantly influences tourism and hospitality stock market returns.

Second, we observe that the tourism and hospitality stock return is positively correlated with serial lagged return, which indicates positive serial correlation. A positive serial correlation does not violate market efficiency and shows the power of partial adjustment of the market (Rosenberg & Rudd, 1982). The coefficient of the lagged variable indicates the lagged response to the market. We find that the magnitude of the return lagged coefficient is neither large nor small, indicating that the non-synchronous response is medium.

Third, GRC, which measures the growth rate of the cumulative number of confirmed cases, has noteworthy negative impacts on stock returns, which is also supported by the work of Gil-Alana and Poza (2020) and (Lee & Chen, 2022). The increasing number of COVID-19 confirmed cases signifies that the virus transmission is still continuing, and there is an underlying risk endangering the healthcare system. People get infected and seek medical support, which brings about sudden rising healthcare demands. With the rapid growth of infected people, hospitals lose capacity and doctors are overloaded. Many medical resources, such as intensive care units (ICUs), beds, protective clothing, and masks, are occupied and consumed quickly. This result demonstrates the concerns regarding unmet healthcare demands and healthcare system instability.

Fourth, Table 6 shows that overall tourism and hospitality stock returns react positively to government intervention. This result indicates that restriction policies strengthen market confidence and provide more advantages than disruptions. Effective stringent policies can prevent the spread of COVID-19, prevent or subdue investor panic, protect public safety, and maintain a stable economic environment. Even though some lockdown and quarantining policies have generated a certain degree of short-term negative influence on people's travel and economic activities, our results prove that the stock market response to government interventions is overall positive, which is also supported by the work of Lee and Chen (2022) and Wang et al. (2021).

Fifth, the VIX has a negative impact on the change in tourism and hospitality stock market returns. This is because the VIX contains information on short-term market volatility in the next month. The VIX is often used as a proxy for global stock market uncertainty and investor fear sentiment. The upward variation of the VIX indicates that the market becomes pessimistic, and the overall market situation becomes more unstable; thus, stock returns are adversely affected. Our VIX results are similar to those of (Grechi et al., 2017), (Ersan et al., 2019), (Lee & Chen, 2022), and (Wang et al., 2021).

Sixth, we investigate the effect of crude oil prices on stock returns, and the result is consistent with what the literature has documented (Lee & Chen, 2022; Mohanty et al., 2014; Qin et al., 2021): it negatively interacts with the stock returns. Crude oil is important for global economic stability and development because it is one of the most important natural resources worldwide. If the oil price increases sharply, it has a huge impact on the budgets of families, companies, and governments with rising costs. Thus, crude oil price shocks will increase financial market uncertainties, reduce cash flow, and depress stock returns.

Seventh, GDPC is observed to respond positively to stock returns only in the income-fixed effects model, while the pooled OLS regression model and region-fixed effects model do not show any significance. This is because GDPC captures a country's economic development level. The fundamental level of return is somewhat correlated with the GDPC. Meanwhile, since GDPC indicates the development level of the country, the income level of the nation is strongly associated with GDPC, so a significant GDPC effect is only seen in the income-fixed effects models. Finally, stock returns react to HDI in a negative manner, but the effect is only observed in Models 3, 6, and 9. The reason that the effect is negative is that the overall society is fighting this unprecedented pandemic, and many social resources are consumed to decrease the increasing number of confirmed cases and provide infected patients with sufficient healthcare services. Although people can enjoy a long and healthy life, the economic development is ignored and depressed since many economic activities have stopped, so the efficiency of the whole society is affected. Investors hold pessimistic attitudes towards economic development, even though the HDI goes up in the short term.

Table 7 shows the results of the panel data regression with interactions, following Eqs. (5) and (7). The interaction model was employed to explore the interaction between GRC and three country-level variables (i.e., GRSI, GDPC, and HDI).

Table 7
Baseline models results' with interactions.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Degree	0.0041***	0.0040***	0.0046***						
	(0.0009)	(0.0009)	(0.0009)						
CC				0.0093***	0.0088***	0.0105***			
				(0.0025)	(0.0026)	(0.0026)			
ANND							0.0078***	0.0077***	0.0078***
							(0.0016)	(0.0016)	(0.0016)
Return_lag	0.0148**	0.0144**	0.0136**	0.0148**	0.0144**	0.0136**	0.0143**	0.0137**	0.0133**
	(0.0102)	(0.0102)	(0.0102)	(0.0102)	(0.0103)	(0.0102)	(0.0102)	(0.0102)	(0.0102)
GRC	−0.4170***	−0.4067***	−0.4128***	−0.4090***	−0.3987***	−0.4042***	−0.3995***	−0.3884***	−0.3944***
	(0.0738)	(0.0741)	(0.0738)	(0.0738)	(0.0741)	(0.0738)	(0.0737)	(0.0740)	(0.0737)
GRSI	0.0067***	0.0075***	0.0061***	0.0066***	0.0074***	0.0060***	0.0068***	0.0079***	0.0064***
	(0.0017)	(0.0019)	(0.0018)	(0.0017)	(0.0019)	(0.0018)	(0.0017)	(0.0019)	(0.0018)
VIX	−0.0154*** (0.0027)	−0.0155***	−0.0154***	−0.0164***	−0.0165***	−0.0166***	−0.0157***	−0.0158***	−0.0157***
		(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Oil	−0.0103***	−0.0104***	−0.0101***	−0.0123***	−0.0123***	−0.0121***	−0.0067**	−0.0067**	−0.0067***
	(0.0024)	(0.0024)	(0.0024)	(0.0023)	(0.0023)	(0.0023)	(0.0027)	(0.0027)	(0.0027)
GDPC	−0.0002	−0.0007	0.0083**	0.0002	0.0001	0.0084**	0.0006	0.0002	0.0078**
	(0.0025)	(0.0031)	(0.0035)	(0.0025)	(0.0031)	(0.0035)	(0.0025)	(0.0031)	(0.0035)
HDI	−0.0026	0.0008	−0.0066	−0.0028	−0.0013	−0.0067	−0.0038	−0.0001	−0.0073
	(0.0076)	(0.0109)	(0.0077)	(0.0076)	(0.0109)	(0.0077)	(0.0076)	(0.0109)	(0.0077)
GRC × GRSI	0.1139***	0.1131***	0.1152***	0.1133***	0.1127***	0.1145***	0.1122***	0.1109***	0.1133***
	(0.0122)	(0.0123)	(0.0122)	(0.0122)	(0.0123)	(0.0122)	(0.0122)	(0.0122)	(0.0122)
GRC × GDPC	0.0576	0.0534	0.0537	0.0557	0.0513	0.0519	0.0459	0.0415	0.0418
	(0.0354)	(0.0355)	(0.0354)	(0.0354)	(0.0355)	(0.0354)	(0.0354)	(0.0354)	(0.0354)
GRC × HDI	−0.0878	−0.0761	−0.0751	−0.0858	−0.0736	−0.0737	−0.0423	−0.0296	−0.0293
	(0.1151)	(0.1153)	(0.1151)	(0.1151)	(0.1153)	(0.1151)	(0.1151)	(0.1153)	(0.1151)
Region fixed	No	Yes	No	No	Yes	No	No	Yes	No
Income fixed	No	No	Yes	No	No	Yes	No	No	Yes
Obs	8046	8046	8046	8046	8046	8046	8046	8046	8046
Adjusted R^2	0.497353	0.493728	0.505329	0.490088	0.487022	0.497218	0.501017	0.498493	0.504931

Note: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

Table 8
Baseline models' results using weekly data without interactions.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Degree	0.0031**	0.0027**	0.0033**						
	(0.0021)	(0.0021)	(0.0020)						
CC				0.0098**	0.0082**	0.0109 *			
				(0.0063)	(0.0064)	(0.0064)			
ANND							0.0067*	0.0068*	0.0067*
							(0.0037)	(0.0037)	(0.0037)
Return_lag	0.1906***	0.1889**	0.1902***	0.1909***	0.1892***	0.1905***	0.1896***	0.1877***	0.1892***
	(0.0255)	(0.0256)	(0.0255)	(0.0255)	(0.0256)	(0.0255)	(0.0255)	(0.0256)	(0.0255)
GRC	−0.0266**	−0.0254**	−0.0264**	−0.0267**	−0.0255**	−0.0265**	−0.0257**	−0.0244**	−0.0255**
	(0.0117)	(0.0118)	(0.0117)	(0.0117)	(0.0118)	(0.0117)	(0.0117)	(0.0118)	(0.0117)
GRSI	0.0149***	0.0184***	0.0147***	0.0148***	0.0182***	0.0146***	0.0148***	0.0184***	0.0147***
	(0.0036)	(0.0040)	(0.0036)	(0.0036)	(0.0040)	(0.0036)	(0.0036)	(0.0040)	(0.0036)
VIX	−0.0375***	−0.0372***	−0.0375***	−0.0374***	−0.0371***	−0.0374***	−0.0376***	−0.0372***	−0.03752***
	(0.0063)	(0.0063)	(0.0063)	(0.0063)	(0.0063)	(0.0063)	(0.0063)	(0.006268)	(0.006256)
Oil	−0.0271***	−0.02644***	−0.0268***	−0.02603***	−0.02573***	−0.02559***	−0.02281***	−0.02164***	−0.02273***
	(0.0061)	(0.0062)	(0.0062)	(0.0064)	(0.0064)	(0.0064)	(0.0071)	(0.0071)	(0.0071)
GDPC	0.0053	0.0005	0.0108	0.0053	0.0008	0.0110	0.0055	0.0005	0.0100
	(0.0051)	(0.0065)	(0.0073)	(0.0051)	(0.0065)	(0.0074)	(0.0050)	(0.0065)	(0.0073)
HDI	−0.0251*	−0.0019	−0.0276*	−0.0252*	−0.0032	−0.0279*	−0.0248	−0.0010	−0.0269*
	(0.0152)	(0.0231)	(0.0154)	(0.0152)	(0.0231)	(0.0154)	(0.0152)	(0.0231)	(0.0154)
Region fixed	No	Yes	No	No	Yes	No	No	Yes	No
Income fixed	No	No	Yes	No	No	Yes	No	No	Yes
Obs	8046	8046	8046	8046	8046	8046	8046	8046	8046
Adjusted R^2	0.420094	0.40669	0.406736	0.422685	0.410731	0.408532	0.422685	0.410731	0.408532

Note: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

Table 9
Regression results using growth rate of confirmed deaths without interactions.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Degree	0.0046***	0.0044***	0.0051***						
	(0.0009)	(0.0103)	(0.0009)						
CC				0.0116***	0.0107***	0.0127***			
				(0.0025)	(0.0026)	(0.0026)			
ANND							0.0094***	0.0092***	0.0094***
							(0.0016)	(0.0016)	(0.0016)
Return_lag	0.0243**	0.0234**	0.0231**	0.0241**	0.0232**	0.0229**	0.0231**	0.0221**	0.0223**
	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)
GRD	−0.0225***	−0.0223***	−0.0224***	−0.0225***	−0.0223***	−0.0224***	−0.0219***	−0.0218***	−0.0218***
	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0024)
GRSI	0.0139***	0.0159***	0.0136***	0.0138***	0.0157***	0.0134***	0.0137***	0.0159***	0.0135***
	(0.0016)	(0.0018)	(0.0016)	(0.0016)	(0.0017)	(0.0016)	(0.0016)	(0.0018)	(0.0016)
VIX	−0.0182***	−0.0181***	−0.0182***	−0.0196***	−0.0194***	−0.0197***	−0.0185***	−0.0184***	−0.0185***
	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Oil	−0.0116***	−0.0114***	−0.0113***	−0.0136***	−0.0134***	−0.0134***	−0.0068**	−0.0065**	−0.0067**
	(0.0024)	(0.0024)	(0.0024)	(0.0023)	(0.0024)	(0.0023)	(0.0027)	(0.0027)	(0.0027)
GDPC	0.0034	0.0011	0.0115***	0.0037	0.0019	0.0116***	0.0038*	0.0016	0.0105***
	(0.0023)	(0.0030)	(0.0033)	(0.0023)	(0.0030)	(0.0033)	(0.0023)	(0.0029)	(0.0033)
HDI	−0.012*	0.0009	−0.0158**	−0.0122*	−0.0013	−0.0158**	−0.0118*	0.0014	−0.0149**
	(0.0069)	(0.0104)	(0.0070)	(0.0069)	(0.0104)	(0.0070)	(0.0069)	(0.0104)	(0.0070)
Region fixed	No	Yes	No	No	Yes	No	No	Yes	No
Income fixed	No	No	Yes	No	No	Yes	No	No	Yes
Obs	8046	8046	8046	8046	8046	8046	8046	8046	8046
Adjusted R^2	0.035723	0.035804	0.036348	0.351898	0.352809	0.357656	0.366801	0.369703	0.369136

Note: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

Table 10
Regression results using growth rate of confirmed deaths with interactions.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Degree	0.0044***	0.0042***	0.0048***						
	(0.0009)	(0.0009)	(0.0009)						
CC				0.0102***	0.0096***	0.0115***			
				(0.0025)	(0.0026)	(0.0026)			
ANND							0.0083***	0.0082***	0.0084***
							(0.0016)	(0.0016)	(0.0016)
Return_lag	0.0146**	0.0141**	0.0134**	0.0145**	0.0140**	0.0134**	0.0137**	0.0131**	0.0129**
	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0103)
GRD	−0.2947***	−0.2871***	−0.2908***	−0.2909***	−0.2831***	−0.2869***	−0.2860***	−0.2781***	−0.2820***
	(0.0614)	(0.0616)	(0.0614)	(0.0614)	(0.0615)	(0.0614)	(0.0614)	(0.0615)	(0.0614)
GRSI	0.0081***	0.0094***	0.0076***	0.0080***	0.0092***	0.0074***	0.0081***	0.0095***	0.0077***
	(0.0017)	(0.0019)	(0.0017)	(0.0017)	(0.0019)	(0.0017)	(0.0017)	(0.0019)	(0.0017)
VIX	−0.0190***	−0.0190***	−0.01905***	−0.0202***	−0.0201***	−0.0203***	−0.0193***	−0.0193***	−0.0193***
	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Oil	−0.0109***	−0.0108***	−0.0106***	−0.0128***	−0.0128***	−0.0127***	−0.0068**	−0.0067**	−0.0068**
	(0.0024)	(0.0024)	(0.0024)	(0.0023)	(0.0023)	(0.0023)	(0.0027)	(0.0027)	(0.0027)
GDPC	0.0009	−0.0002	0.0088**	0.0011	0.0006	0.0089***	0.0014	0.0005	0.0081**
	(0.0024)	(0.0031)	(0.0034)	(0.0024)	(0.0031)	(0.0034)	(0.0024)	(0.0031)	(0.0034)
HDI	−0.0048	0.0017	−0.0085	−0.0049	−0.0004	−0.0084	−0.0052	0.0014	−0.0083
	(0.0073)	(0.0107)	(0.0074)	(0.0073)	(0.0107)	(0.0074)	(0.0073)	(0.0107)	(0.0074)
GRD × GRSI	0.0899***	0.0889***	0.0906***	0.0894***	0.0885***	0.0890***	0.0892***	0.0880***	0.0899***
	(0.0087)	(0.0088)	(0.0087)	(0.0088)	(0.0088)	(0.0088)	(0.0087)	(0.0088)	(0.0088)
GRD × GDPC	0.0367	0.0344	0.0339	0.0363	0.0338	0.0337	0.0308	0.0286	0.0281
	(0.0293)	(0.0293)	(0.0293)	(0.0293)	(0.0294)	(0.0293)	(0.0293)	(0.0293)	(0.0293)
GRD × HDI	−0.0544	−0.0489	−0.0455	−0.0557	−0.0494	−0.0475	−0.0315	−0.0263	−0.0229
	(0.0899)	(0.0900)	(0.0899)	(0.0899)	(0.0900)	(0.0899)	(0.0898)	(0.0899)	(0.0898)
Region fixed	No	Yes	No	No	Yes	No	No	Yes	No
Income fixed	No	No	Yes	No	No	Yes	No	No	Yes
Obs	8046	8046	8046	8046		8046		8046	8046
Adjusted R^2	0.478215	0.4749	0.485154	0.471437	0.46857	0.477674	0.483401	0.481489	0.486248

Note: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

According to Table 7, we can see that the magnitude, polarity, and significance level of the three interconnectedness factors (degree, CC, ANND), return lagged, GRC, GRSI, VIX, oil, and GDPC effects show almost no change, as shown in Table 6. In addition, the main GDPC effect in income-fixed Models 3, 6, and 9 is still significant, but the significance level is reduced by 5 %. The HDI also loses its significance. This implies that neither GDPC nor HDI are strong indicators that contribute to the variation in tourism and hospitality stock returns. As for the interaction terms, we can see that only the interaction term of $GRC \times GRSI$ is highly significant, with a positive relationship. This result implies that the negative effect of the rapid growth of confirmed cases diminishes when countries carry out more stringent government interventions and also confirms the effectiveness of government interventions such as travel bans, lockdowns, quarantine, and social distancing policies in reducing the number of COVID-19 confirmed cases. Overall, a government's stringency response helps encourage investors and maintain stock prices when the number of COVID-19 confirmed cases in the country increases.

4.4. Robustness checks

We performed the robustness checks for the results in three ways. Firstly, we re-estimate the baseline regression models using weekly data. Secondly, we use GRD, which is defined as the growth rate of confirmed deaths, as a proxy for the COVID-19 variable. Thirdly, we employ a two-stage panel data regression model to account for endogeneity concerns (Kremer & Nautz, 2013).

4.4.1. Using weekly level data

The first way to check the models' robustness is to re-estimate the baseline regression models expressed in equation (4) and (6) with other frequency data.

In Section 4.3, daily stock return data is used to estimate the all regression models and here we plan to use weekly level data to confirm whether the observed effects are robust. Thus, we first convert the daily level data into weekly level by summing up the daily level value of each variable. Then, the prepared weekly data is used to re-estimate the models in Eqs. (4) and (6). The estimation results are shown in Table 8. According to Table 8, firstly, we can confirm that the effects of three interconnectedness variables and GRC are robust since the P-values are significant even though their significance level has reduced. Secondly, the effect of return lag variable is also robust and the significance level has increased. Thirdly, the effects of GRSI, VIX, and Oil are also robust and their results are consistent with what is shown in Section 4.3. GDPC effect is not robust since the coefficient is not significant in any models including the income-fixed effects model, which is different from section 4.3′s result. HDI maintains its significant effect, which is consistent with section 4.3′s results.

4.4.2. Using growth rate of confirmed deaths

We use the growth rate of confirmed deaths as an alternative variable to measure COVID-19 to avoid arbitrariness in the selection of a proxy for the pandemic. In particular, we use the growth rate in the cumulative number of confirmed deaths (GRD) instead of GRC and build the following models:

$$Return_{i,t} = \beta_1 Return_{i,t-1} + \beta_2 GRD_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{8}$$

$$Return_{i,t} = \beta_1 Return_{i,t-1} + \beta_2 GRD_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \beta_9 GRD_{i,t} \times GRSI_{i,t} + \beta_{10} GRD_{i,t} \times GDPC_{i,t} + \beta_{11} GRD_{i,t} \times HDI_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{9}$$

$$Return_{i,t} = \beta_0 + \beta_1 Return_{i,t-1} + \beta_2 GRD_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \varepsilon_{i,t} \tag{10}$$

$$Return_{i,t} = \beta_0 + \beta_1 Return_{i,t-1} + \beta_2 GRD_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \beta_9 GRD_{i,t} \times GRSI_{i,t} + \beta_{10} GRD_{i,t} \times GDPC_{i,t} + \beta_{11} GRD_{i,t} \times HDI_{i,t} + \varepsilon_{i,t} \tag{11}$$

where models of Eqs. (8) and (10) have no interactions and models of Eqs. (9) and (11) explore the interaction effect.

Tables 9 and 10 present the regression results using the GRD. From them, we can confirm the robustness of our earlier findings in Tables 6 and 7. Notably, GRD negatively and significantly affected tourism and hospitality stock market returns. Unlike GRC, which indicates the transmission rate of the virus, GRD indicates the human fatality rate of the virus. Aging countries with a large percentage of elderly are especially severe because this group is more vulnerable to COVID-19; they could die from their basic diseases, infected with a higher severe case rate than young and middle-aged patients (Daoust, 2020; Liu et al., 2020). However, the population is aging rapidly in many countries such as Japan and Germany. According to WHO statistics, the number of people aged over 60 is 1 billion, and this number is estimated to increase to 1.4 billion by 2030 and 2.1 billion by 2050.[5] Thus, this result indicates the vulnerability of an aging society and public fear of death. In addition, we find that the other four variables (interconnectedness, VIX, oil, and GRSI) in Tables 6 and 7 have the same significant effect on returns, as shown in Tables 6 and 7. This implies that these four independent variables are strong indicators, and their effects on returns are robust, even though we use GRD as a proxy for COVID-19. Meanwhile, we observed a significant interaction term of $GRD \times GRSI$. This accords with what we observed in Table 6: governments' effective reactions undermine the negative impact of GRD because a series of government policies can reduce the possibility of social

[5] https://www.who.int/health-topics/ageing#tab=tab_1.

interactions, control the growth rate of confirmed cases, and protect the public from death. Finally, we notice that the adjusted R^2, which indicates the percentage of variation in which the dependent variable can be explained by the useful independent variables, is smaller than that in Tables 6 and 7. This means that GRC is a better proxy than GRD, but overall, we confirm the COVID-19 effect on stock returns.

4.4.3. Two-stage panel data regression

A critical issue in identifying the determinants of tourism and hospitality stock market returns may be endogeneity. To further verify the results against possible endogeneity concerns, we used two-stage panel data regression. Endogeneity can result from simultaneity, reverse causality, or omitted variable biases.

In the first stage, we regress "GRC" on exogenous variables, the instrument should satisfy-two requirements: firstly, it should correlate with $GRC_{i,t}$ but uncorrelated with $Return_{i,t}$; secondly, it should be conceptually valid. We select four instruments that satisfy the exogeneity conditions. First, we employ $GRC_{i,t-1}$, the first lag of $GRC_{i,t}$, which assumes the process to be autoregressive of order 1 and shows that today's values of GRC are determined by its past values (Kizys et al., 2021; Zaremba et al., 2020). Second, we used PD, which denotes population density. It is a fundamental factor affecting the transmission of COVID-19 coronavirus (Zaremba et al., 2021). Third, we employed the $Age65$ which represents the number of people over 65. Finally, we include HB, which denotes the hospital beds per thousand, as a proxy for hospital equipment. Indeed, the elderly are the most vulnerable to the COVID-19 coronavirus and the capacity of hospital equipment is essential for infected patients to receive treatment. The first-stage regression was as follows:

$$GRC_{i,t} = \gamma_0 + \gamma_1 GRC_{i,t-1} + \gamma_2 PD_{i,t} + \gamma_3 Age65_{i,t} + \gamma_4 HB_{i,5} + \vartheta_t \tag{12}$$

In the second stage, we use the fitted values from the first stage as covariates. The validity of the instruments is tested using the Hansen-J test to identify any restrictions. To explore the effects, we build the following models in the second stage:

$$Return_{i,t} = \beta_1 Return_{i,t-1} + \beta_2 \widehat{GRC}_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{13}$$

$$Return_{i,t} = \beta_1 Return_{i,t-1} + \beta_2 \widehat{GRC}_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \beta_9 \widehat{GRC}_{i,t} \times GRSI_{i,t} + \beta_{10} \widehat{GRC}_{i,t} \times GDPC_{i,t} + \beta_{11} \widehat{GRC}_{i,t} \times HDI_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{14}$$

$$Return_{i,t} = \beta_0 + \beta_1 Return_{i,t-1} + \beta_2 \widehat{GRC}_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \varepsilon_{i,t} \tag{15}$$

$$Return_{i,t} = \beta_0 + \beta_1 Return_{i,t-1} + \beta_2 \widehat{GRC}_{i,t} + \beta_3 Interconnectedness_{i,t} + \beta_4 Oil_t + \beta_5 VIX_t + \beta_6 GRSI_{i,t} + \beta_7 GDPC_{i,t} + \beta_8 HDI_{i,t} + \beta_9 \widehat{GRC}_{i,t} \times GRSI_{i,t} + \beta_{10} \widehat{GRC}_{i,t} \times GDPC_{i,t} + \beta_{11} \widehat{GRC}_{i,t} \times HDI_{i,t} + \varepsilon_{i,t} \tag{16}$$

where models of Eqs. (13) and (15) have no interactions and models of equation (14) and (16) explore the interaction effect.

Table 11 summarizes the coefficient estimates for the two-stage panel data regression model without interactions. In this time, the fitted value of variable "DCT" shows a mild significant effect in most models, the return lag only shows a significance level at 10 %, and the other four variables (interconnectedness, VIX, Oil, GRSI) keep the same effects as revealed in the baseline model. The GDPC effect is significant only in the income fixed effects model. The HDI effect was not significant in any of the models. The adjusted R^2 was relatively small, indicating that additional useless independent variables were used. From this result, we can confirm the robustness of interconnectedness, VIX, Oil, GRSI effects in all models, and the GDPC effect under the income-fixed effects model.

Table 12 presents the results of the two-stage regression analysis with the interaction effect. These regression results strongly support most of our previous findings. Specifically, the effects of interconnectedness (degree, CC, ANND), COVID-19 (i.e., the fitted value of variable "DCT"), GRSI, VIX, oil, and $\widehat{GRC \times GRSI}$ on stock returns are robust, while GDPC and HDI effects are insignificant and temporary.

5. Conclusions and limitations

The COVID-19 pandemic has severely impacted the global economy. The tourism and hospitality industry bore the brunt because of various policies, such as visa restrictions, flight restrictions, border closures, and social quarantines. In this study, we investigate this influence on the tourism and hospitality markets from a new perspective. Regarding the existence of the spillover effect, we first employ the Granger-causality test to identify the statistically significant spillover effect and construct a network of interconnectedness to depict the co-movement phenomenon among the tourism and hospitality markets using country-level panel data. Second, we further explore whether the interconnectedness structure can explain the variation in market returns by incorporating it with other determinants (the spread of COVID-19, the VIX, crude oil price, etc.). We find that the interconnectedness structure among these tourism and hospitality markets, measured by three global network indicators (degree of centralization, transitivity, and density), is significantly different between the pre-pandemic and in-pandemic periods. The interconnectedness of the network is denser during the pandemic period owing to the influence of COVID-19. In addition, we find that the local interconnectedness structure, measured by three local network features (degree, ANND, and CC), can significantly and positively influence market returns. We also confirm that GRC and GDC, which are proxies for the spread of COVID-19 and have a negative influence on market returns, and GRSI, which measures the government's response stringency, and has a significantly positive impact on stock returns.

This study provides a better understanding of the influence of the COVID-19 pandemic and provide profound insights and

Table 11
Two-stage Panel Data Regression Results without Interactions.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
degree	0.0397*** (0.0010)	0.0040*** (0.0010)	0.0044*** (0.0010)						
CC				0.0090*** (0.0027)	0.0090*** (0.0027)	0.0102*** (0.0027)			
ANND							0.0098*** (0.0016)	0.0101*** (0.0017)	0.0098*** (0.0016)
Return_lag	0.0206* (0.0107)	0.0201* (0.0108)	0.0182* (0.0107)	0.0206* (0.0108)	0.0201* (0.0108)	0.0181* (0.0108)	0.0191** (0.0107)	0.0185* (0.0107)	0.0170* (0.0107)
$\widehat{GRC}$	−0.0266* (0.0058)	−0.0331* (0.0058)	−0.0288* (0.0058)	−0.0264* (0.0058)	−0.0321* (0.0058)	−0.0284* (0.0058)	−0.0467** (0.0058)	−0.0534** (0.0058)	−0.0478** (0.0058)
GRSI	0.0169*** (0.0020)	0.0178*** (0.0020)	0.0179*** (0.0020)	0.0169*** (0.0020)	0.0177*** (0.0020)	0.0178*** (0.0020)	0.0172*** (0.0020)	0.0182*** (0.0020)	0.0182*** (0.0020)
VIX	−0.0270*** (0.0027)	−0.0272*** (0.0027)	−0.0268*** (0.0027)	−0.0280*** (0.0028)	−0.0282*** (0.0028)	−0.0279*** (0.0028)	−0.0275*** (0.0027)	−0.0276*** (0.0027)	−0.0272*** (0.0027)
Oil	−0.0123*** (0.0025)	−0.0122*** (0.0025)	−0.0117*** (0.0025)	−0.0142*** (0.0024)	−0.0142*** (0.0024)	−0.0137*** (0.0024)	−0.0065** (0.0028)	−0.0062** (0.0028)	−0.0063** (0.0028)
GDPC	0.0007 (0.0026)	0.0011 (0.0030)	0.0104*** (0.0034)	0.0010 (0.0026)	0.0019 (0.0030)	0.0104*** (0.0034)	0.0007 (0.0026)	0.0013 (0.0030)	0.0096*** (0.0033)
HDI	0.0017 (0.0088)	0.0036 (0.0109)	0.0078 (0.0091)	0.0018 (0.0088)	0.0014 (0.0109)	0.0076 (0.0097)	0.0032 (0.0088)	0.0051 (0.0109)	0.0084 (0.0090)
Region fixed	No	Yes	No	No	Yes	No	No	Yes	No
Income fixed	No	No	Yes	No	No	Yes	No	No	Yes
Obs	8046	8046	8046	8046	8046	8046	8046	8046	8046
Adjusted R^2	0.255309	0.253986	0.275601	0.248925	0.24758	0.268119	0.276429	0.276387	0.29181

Note: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

Table 12
Two-stage Panel Data Regression with Interactions.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
degree	0.0041***	0.0041***	0.0046***						
	(0.0010)	(0.0010)	(0.0010)						
CC				0.0085***	0.0083***	0.0098***			
				(0.0027)	(0.0027)	(0.0027)			
ANND							0.0094***	0.0094***	0.0093***
							(0.0016)	(0.0017)	(0.0016)
Return_lag	0.0127	0.0122	0.0101	0.0129	0.0123	0.0104	0.0118	0.0113	0.0096
	(0.0107)	(0.0108)	(0.0107)	(0.0107)	(0.0107)	(0.0108)	(0.0107)	(0.0107)	(0.0107)
$\widehat{GRC}$	−0.6401***	−0.6273***	−0.6121***	−0.6208***	−0.6095***	−0.5921***	−0.5971***	−0.5846***	−0.5677***
	(0.1450)	(0.1452)	(0.1449)	(0.1449)	(0.1451)	(0.1449)	(0.1445)	(0.1448)	(0.1445)
GRSI	0.0039	0.0042	0.0042*	0.0041	0.0042	0.0044*	0.0048*	0.0053**	0.0052***
	(0.0025)	(0.0026)	(0.0026)	(0.0025)	(0.0026)	(0.0026)	(0.0025)	(0.0026)	(0.0026)
VIX	−0.0265***	−0.0267***	−0.0263***	−0.0274***	−0.0276***	−0.0274***	−0.0271***	−0.0274***	−0.0270***
	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)
Oil	−0.0105***	−0.0105***	−0.0098***	−0.0126***	−0.0126***	−0.0121***	−0.0053*	−0.0053*	−0.0052*
	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)	(0.0024)	(0.0028)	(0.0028)	(0.0028)
GDPC	−0.0030	−0.0023	0.0067**	−0.0026	−0.0013	0.0069*	−0.0023	−0.0013	0.0067*
	(0.0031)	(0.0034)	(0.0038)	(0.0031)	(0.0034)	(0.0038)	(0.0031)	(0.0034)	(0.0038)
HDI	0.0078	0.0072	0.0143	0.0079	0.0048	0.0141	0.0066	0.0058	0.0121
	(0.0105)	(0.0121)	(0.0107)	(0.0104)	(0.0121)	(0.0107)	(0.0104)	(0.0121)	(0.0107)
$\widehat{GRC \times GDPC}$	0.0511	0.0484	0.0413	0.0129	0.0123	0.0393	0.0391***	0.0366	0.0296
	(0.0325)	(0.0326)	(0.0325)	(0.0325)	(0.0326)	(0.0325)	(0.0324)	(0.0325)	(0.0324)
$\widehat{GRC \times GRSI}$	0.0025***	0.0025***	0.0026***	−0.6208***	−0.6095***	0.0025***	0.0024	0.0024***	0.0025***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
$\widehat{GRC \times HDI}$	−0.0454	−0.0297	0.0349	0.0041	0.0042	0.0387	0.0571	0.0724	0.1330
	(0.2508)	(0.2514)	(0.2509)	(0.2510)	(0.2516)	(0.2511)	(0.2505)	(0.2512)	(0.2508)
Region fixed	No	Yes	No	No	Yes	No	No	Yes	No
Income fixed	No	No	Yes	No	No	Yes	No	No	Yes
Obs	8046	8046	8046	8046	8046	8046	8046	8046	8046
Adjusted R^2	0.336123	0.3349	0.359512	0.326819	0.325974	0.348525	0.35209	0.350923	0.369681

Note: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

Table A1
Summary statistics for the return series for all Countries and regions.

Code	Breakdate	Min	Max	Median	Mean	Std.dev	Skewness	Kurtosis	JB_Value	ADF	PP	KPSS	ARCH
AUT	2020/3/19	−0.10632	0.121416	0.000526	−6.00E-05	0.017965	−0.23677	9.48993	2028.685***	−6.73357***	−553.252***	0.1515	106.063***
AUS	2020/3/23	−0.1653	0.080284	0.000935	0.000414	0.019119	−1.83802	14.83038	5240.332***	−6.64477***	−597.051***	0.089555	222.3586***
BHR	2020/9/2	−0.04731	0.047927	0	−0.00064	0.005309	−0.67987	33.26337	24861.95***	−7.60512***	−391.653***	0.032947	33.17564***
ESP	2020/3/23	−0.21567	0.147167	0	−0.00093	0.022625	−2.55014	29.79216	20494.17***	−6.36016***	−684.683***	0.095238	145.9978***
BEL	2020/3/16	−0.08192	0.068685	1.11E-05	0.000377	0.014512	−0.06857	4.965367	555.622***	−7.5442***	−477.351***	0.075915	83.41342***
CHN	2020/8/18	−0.08314	0.068051	0.000704	−0.00039	0.018573	−0.31476	1.378311	52.15122***	−7.39893***	−559.044***	0.099989	58.19294***
DNK	2020/3/18	−0.12349	0.129841	−0.00033	−0.00032	0.017913	0.407451	14.81836	4944.826***	−8.26328***	−516.104***	0.025955	83.62523***
CIV	#######	−0.06788	0.045163	0	−0.00017	0.013046	−0.32693	4.249502	416.5282***	−5.65041***	−683.413***	0.091202	68.24099***
DNK	2020/3/18	−0.09826	0.044407	0	−5.29E-05	0.009816	−2.50912	24.19702	13700.98***	−6.09566***	−726.025***	0.052289	112.7786***
FRA	2020/3/18	−0.13067	0.077586	0.000162	−0.0002	0.014297	−1.39998	16.18387	6055.091***	−7.72064***	−618.804***	0.099389	101.3358***
GBR	2020/3/18	−0.24554	0.104805	0.000913	0.000338	0.024202	−2.26192	22.7265	12047.83***	−7.37447***	−534.647***	0.079997	69.63654***
FIN	#######	−0.1306	0.257402	−0.00055	−0.00095	0.024625	2.36323	32.57173	24299.32***	−7.51039***	−525.901***	0.083146	33.29075***
ISL	2020/2/7	−0.12968	0.046434	0	−0.00042	0.013523	−1.89628	17.52378	7214.673***	−6.4253***	−535.527***	0.052116	58.70203***
IND	2020/3/23	−0.14676	0.066024	0.001119	0.000659	0.016499	−1.99402	16.35457	6360.138***	−6.52537***	−567.839***	0.257516	168.5522***
IDN	2020/3/19	−0.06903	0.075037	−0.00058	−0.00076	0.014159	−0.11199	6.452475	937.7105***	−8.53417***	−537.285***	0.068721	225.0933***
ITA	2020/3/17	−0.21688	0.174136	0.000174	−0.00067	0.023819	−1.08257	20.61848	9645.419***	−6.3400***8	−605.925***	0.094229	64.5842***
JPN	2020/3/16	−0.04832	0.056472	0.000497	0.000929	0.011126	−0.09936	2.974365	200.7071***	−8.41195***	−510.571***	0.058703	169.709***
JOR	2020/6/9	−0.01968	0.021033	−0.00014	−0.00057	0.006066	−0.17954	1.329723	43.19488***	−7.10396***	−390.949***	0.145427	111.1225***
MEX	2020/4/3	−0.08733	0.04816	0.000639	0.000146	0.012656	−0.73971	5.786685	802.5526***	−6.96546***	−506.73***	0.113776	120.1307***
MAR	2020/4/27	−0.10497	0.095277	0	−0.00081	0.023619	−0.2593	4.367767	435.885***	−6.28509***	−621.691***	0.106508	88.6322***
NAM	2020/5/14	−0.11919	0.097314	−0.00012	−0.00073	0.022622	0.027183	4.382769	432.884***	−8.50208***	−500.328***	0.252022	39.52999***
NLD	2020/3/23	−0.103	0.055244	0.000563	0.000284	0.011971	−1.29097	12.13699	3457.514***	−7.16654***	−511.849***	0.044118	111.2928***
SWE	2020/3/19	−0.1043	0.138569	0	0.001302	0.017963	0.674973	12.22599	3397.778***	−6.56854***	−543.831***	0.099844	151.8839***
PAL	2020/10/8	−0.04692	0.028134	0	−2.16E-05	0.005327	−0.52893	14.78418	4932.309***	−6.08902***	−487.86***	0.257738	2.858149***
PER	#######	−0.04262	0.106701	0	0.000999	0.009668	2.649774	29.04206	19550.85***	−7.99261***	−593.549***	0.253987	19.64155***
PHL	2020/3/19	−0.07377	0.066905	−8.74E-05	2.98E-06	0.012914	−0.53191	7.443255	1271.044***	−6.61175***	−540.126***	0.07614	180.2183***
PRT	2019/4/30	−0.1034	0.090656	−4.15E-05	4.01E-05	0.013852	−0.34958	10.6937	2579.874***	−7.8255***	−541.896***	0.270752	42.68727***
TUN	2020/5/12	−0.02895	0.020188	−0.00033	−0.00039	0.006969	−0.09752	1.084365	27.75925***	−7.60403***	−488.375***	0.063944	77.77485***
SAU	2020/3/23	−0.09895	0.063902	0.000782	0.000483	0.014906	−1.49765	9.906343	2405.689***	−6.93612***	−485.038***	0.069301	176.5194***
KOR	2020/3/23	−0.10021	0.092796	−0.00013	−0.00019	0.020534	−0.40963	3.768227	335.2349***	−6.80346***	−551.115***	0.200371	99.91683***
LKA	2019/5/15	−0.02334	0.015225	0	−2.60E-07	0.002732	−0.2624	15.49898	5399.053***	−6.89154***	−515.011***	0.140154	29.61313***
SWE	2020/3/23	−0.11236	0.057968	0	0.000562	0.012933	−1.21999	14.51317	4862.355***	−6.6867***	−508.637***	0.07392	103.9604***
TWN	2020/3/19	−0.08216	0.059605	−0.0002	−0.00017	0.012371	−0.36109	8.59829	1673.336***	−7.39136***	−482.932***	0.063275	187.4381***
THA	2020/3/24	−0.10818	0.075523	0.000203	−0.00022	0.013453	−1.28159	16.45221	6223.137***	−6.76092***	−669.863***	0.077258	138.1225***
TUR	2020/3/23	−0.15739	0.080439	0.004115	0.003309	0.024866	−1.00557	5.395296	745.7736***	−5.90506***	−571.06***	0.285429	128.5559***
ARE	2020/3/19	−0.053	0.082643	−0.00017	0.000149	0.013706	0.939848	6.50068	1029.668***	−7.45317***	−515.752***	0.229508	119.7425***
USA	2020/3/18	−0.134	0.138718	0.001183	0.000557	0.025013	−0.36002	8.255093	1543.43***	−7.62819***	−558.539***	0.126705	93.95662***
BHR	2020/8/10	−0.02761	0.027153	0.000515	0.000691	0.004936	0.127873	10.17161	2325.93***	−6.65297***	−365.151***	0.212973	83.52073***
CHN	2020/3/31	−0.07391	0.077499	0.000209	0.00161	0.018343	0.156158	1.62022	61.84913***	−6.87394***	−547.466***	0.23668	60.52178***
CIV	2019/5/7	−0.10262	0.060596	−0.0005	−0.00067	0.013948	−0.11379	10.65228	2550.256***	−7.95365***	−508.846***	0.039077	30.22704***
GBR	2020/3/18	−0.14575	0.119015	0.000517	−0.00013	0.022347	−0.5142	10.03175	2284.717***	−7.65269***	−448.553***	0.097025	174.55***
ISL	2020/2/7	−0.12968	0.046431	0	−0.00047	0.013574	−1.90416	17.40342	7123.054***	−6.41469***	−537.202***	0.050656	64.21227***
GBR	2020/3/18	−0.14655	0.115634	0.000586	−0.00011	0.022384	−0.55208	9.782779	2177.618***	−7.64706***	−451.695***	0.095709	178.2643***

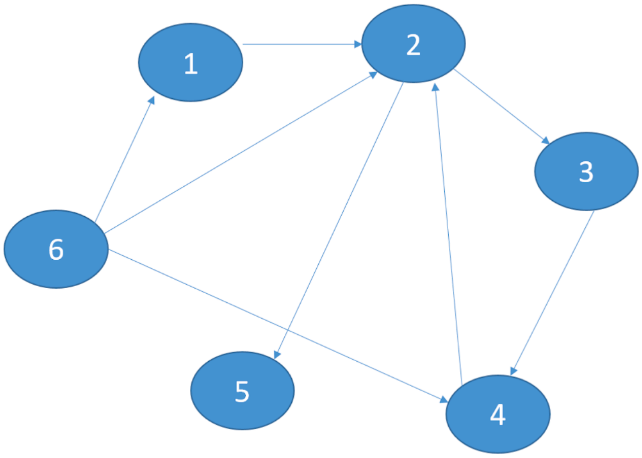

Fig. 4. A six-nodes network.

implications for stakeholders like government policy makers, stock market investors, and managers of the tourism sectors. Specifically, the results of this study can help governments and policymakers better manage the risks of unexpected disasters similar to the novel coronavirus pandemic in the future. The role of government interventions in the tourism and hospitality markets is advocated and favored because the government policies are demonstrated to have achieved good results. As for the other stakeholders in the tourism and hospitality stock markets, it is better to monitor the real-time spillover effect of the dynamic environment, be aware of the unforeseen contagion risk, keep a close eye on the government policies, optimize the investment decisions, and diversify the investment risk. As for the managers of tourism sectors, they have to realize that COVID-19 has a great negative impact on this industry and they need to take immediate actions in response to the pandemic, including shutting down sometimes, reducing the operating cost, and taking new managerial strategies accordingly.

However, our study has several limitations. First, the investigation period was relatively short owing to the nature of the abrupt pandemic. A longer study period may have allowed the evaluation and verification of our findings. Second, we only have a limited dataset because of data availability constraints (e.g., some countries may have no tourism and hospitality market index); there are possibly some other variables that may influence market returns, but we were unable to fully capture them. These issues should be discussed in future studies. Third, it is interesting to investigate the differences between the general and sectorial market indices but regrettably, the major research work in this paper is to investigate the impact of COVID-19 on the tourism and hospitality industry, we have not extended the discussion with a comparative study to compare the differences between the general market and sectorial specific impacts. Further research work can elaborate more on this topic.

CRediT authorship contribution statement

Yan Liu: Conceptualization, Methodology, Data curation, Project administration, Writing – original draft, Writing – review & editing. **Xian Cheng:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Software, Writing – original draft, Writing – review & editing. **Stephen Shaoyi Liao:** Supervision, Investigation, Funding acquisition, Resources.

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.

Data availability

Data will be made available on request.

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Appendix

Appendix A. Summary statistics for the return series for all Index.

Appendix B. Interconnectedness measures

Network analysis starts with constructing a series of networks. After the networks have been constructed, it is time to analyzing the network structure, capturing the difference in the network measures, etc. Each network has a unique structure and the network structure could be presented with several network measures. If we analyze the global measures of the network, instead of analyzing each node, we view the whole network as the smallest analyzing unit. In contrast, if we keep eye on the local network measures, it implies our analysis is node-wise.

B1. Global interconnectedness measures

For the ease of illustration, we draw a six-nodes network as an example to show what are the global interconnectedness measures and local interconnectedness measures respectively.

In this paper, we employ-three measures of global interconnectedness: degree of centralization, transitivity and density.

Firstly, **degree of centralization** is the simplest centrality measure, defined as the percentage of existing degree of all nodes over all possible degree in the network. The degree of a node is the total count of connections in the network. In this case, the count of existing degree is 16, and the count of all possible degree is 6*5 = 30. Thus, the degree of centralization is 0.53.

Secondly, **transitivity** means the overall probability that a network have adjacement nodes interconnected. Transitivity reveals that the existence of clusters, subgroups cliques within the network. Transitivity is the ratio calculated as follows:

$$\text{Transivity} = \frac{theobservednumberofclosedtriplets}{themaximumpossiblenumberofclosedtriplets}$$

In this case, the observed number of closed triples is 5, and the maximum possible number of closed triples is 42. Thus, the value of transitivity equals to 0.12.

Thirdly, **density** measures the health and effectiveness of the network, illustrates that the proportion of actual connections in the potential connections. In this scenario, "potential connection" is the connection between two nodes that potentially exist, which only correlates with the number of the nodes. "Actual connection" refers to the connection that truly exists.

$$\text{Density} = \frac{theobservednumberofactualconnections}{thenumberofpotentialconnections}$$

In this case, the observed number of actual connections is 8, the number of potential connections is 15. Thus, the value of density equals to 0.53.

B2. Local interconnectedness measures

Three node-wise interconnectedness measures: degree, closeness, and Average Nearest Neighbor Degree (ANND) are employed as the interconnectedness variables in the estimation model.

Degree is the simplest measure of centrality, which defined as the total count number of connections linked to the node. Degree is normalized to (0,1). For example, as Fig. 1 shows, the degree value of node 1 is 2.

Closeness is measure of centrality for a network, which is calculated as the reciprocal of the sum of the shortest paths' length between one country and the other country. Closeness measures the average farness between countries. The mathematic expression of closeness is:

$$\text{closeness} = \frac{1}{N^*(N-1)}{}^* \sum_{A=1}^{N} \sum_{B \neq A} C_{AB}$$

where C_{AB} is the length of the shortest path form country A to country B, and we let C_{AB} = N-1 if country A and country B are separated without any path. Closeness is also normalized to (0,1).

For example, as Fig. 1 shows, the closeness value of node 1 is 1/1 + 1/2 + 1/3 + 1/2 + 1/2 = 2.83.

Average Nearest Neighbor Degree (ANND) is defined as the average degree of the nearest neighbor for each Country. For example, if country ***i*** has statistically significant Granger causality relationships with ***k*** countries, the mean value of the degree for ***k*** countries is the average nearest neighbor degree of country ***i***. ANND is also normalized to (0,1). For example, as Fig. 4 shows, the ANND value of node 1 is (3 + 5)/2 = 4.

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