What effects will Covid-19 have on the G7 stock markets? New evidence from a cross-quantilogram approach

Ngo Thai Hung
University of Finance-Marketing,
Ho Chi Minh City,
Vietnam
E-mail: hung.nt@ufm.edu.vn

With several commodity and financial markets allegedly performing poorly during the coronavirus disease (Covid-19) pandemic, the objective of this study is to examine how the pandemic has affected stock markets in the G7 economies. The study applies the recently developed cross-quantilogram model introduced by Han et al. (2016) to investigate quantile dependence between the conditional stock return distributions of G7 countries and the total daily global confirmed Covid-19 cases across investment horizons. The results reveal that the cross-quantile dependence between the confirmed Covid-19 cases and G7 stock returns is most significant in the short and medium term. The interlinkage weakens as the lag period lengthens. These findings imply that, in the short and medium term, stock markets in the G7 countries reacted negatively and disproportionately to the increase in the number of daily verified Covid-19 cases. Besides, cross-quantile correlations calculated from recursive subsamples indicate that they change over time, especially in low and medium quantiles, suggesting that they are prone to jumps and discontinuities in the dependence structures. The findings can aid investors and policymakers in better understanding stock market dynamics, particularly during times of great stress and unknown events.

Keywords:
Covid-19,
pandemic,
cross-quantilogram,
stock markets,
G7 countries

Introduction

Financial and commodity markets worldwide have plummeted owing to the global coronavirus disease (Covid-19) outbreak (Hung–Vo 2021, Chowdhury et al. 2021, Yousfi et al. 2021, Kincses–Tóth 2020, Hung 2021). The total number of confirmed

cases has surpassed 179 million (as of 24 June, 2021). The Covid-19 pandemic has triggered a global economic catastrophe as well as significant stock market falls (Szczygielski et al. 2021, Nyikos et al. 2021, Bulut–Korukoglu 2022, Antalóczy et al. 2022, Aritenang 2022, Kapás 2022, Fitriani et al. 2022, Thakur–Das 2022). Prior research has shown that diseases and crises negatively influence financial markets and the severity and timing of the impact vary according to country (Szczygielski et al. 2021, Matos et al. 2021). Yi et al. (2021) stated that the outbreak of Covid-19 has brought serious challenges to the global stock and bond markets. Le et al. (2021) confirmed that no other pandemic has had such an impact on global financial markets over the last century. Stock markets have been affected dramatically. Similarly, Ahmed et al. (2021) reported that the commodity markets also demonstrate abrupt movement similar to the stock market performance. For example, oil prices fell to a negative level in April 2020, and gold prices jumped from their lowest point in March to their greatest point in May 2020.

The following path can be used to explain the relationship between the Covid-19 outbreak and stock market values. First, owing to the Covid-19 shock, the sensitive characteristics of financial markets have seen marked increase in supply and demand swings (Wang et al. 2021, Ahmed et al. 2021, Izzeldin et al. 2021, Arif et al. 2021). For example, the Covid-19 pandemic triggered an economic downturn in many countries and sectors, including the consumer, service, and tourism sectors (Szczygielski et al. 2021, Le et al. 2021, Wang et al. 2021, Izzeldin et al. 2021). Second, as the pandemic becomes more severe, the number of confirmed cases rises, attracting media attention and coverage. Investor sentiment is influenced by asset allocation and portfolio selection, which contributes to financial market volatility (Yousfi et al. 2021, Albulescu 2021, O'Donnell et al. 2021). This tallies with Sun et al. (2021) finding that the massive panic created by the Covid-19 revelation is linked to increased stock market volatility. The stock markets' reaction to the outbreak has been the subject of several studies (Liu et al. 2021, Zaremba et al. 2020, Rahman et al. 2021, Gao et al. 2021, Shen–Zhang 2021, Hung 2020a). These studies revealed that the Covid-19 pandemic negatively impacts stock market returns. Overall, the Covid-19 pandemic adds to the stock market's decline and increases volatility (Wang et al. 2021).

Stock markets, as well as other asset markets such as currencies and commodities, have been severely impacted (Arif et al. 2021). Investors must examine portfolio diversification and possible asset allocation changes since most financial markets continue to experience large swings and are likely interconnected. The present study thus aims to examine the effects of Covid-19 on the stock markets of G7 countries – Canada, France, Germany, Italy, Japan, the United Kingdom (UK), and the United States (US). We use the G7 markets as a representative sample for our research. According to the World Bank, the G7 countries account for roughly 40% of global output. The G7 markets are the largest stock market group in the world in terms of trading volume and market capitalisation (Izzeldin et al. 2021, Jeribi–Fakhfekh 2020). Although the global pandemic has had an indiscriminate impact on stock markets

worldwide, the G7 markets have been the most severely impacted (Arif et al. 2021), even though the number of infections among G7 countries has varied significantly.

According to several recent studies, stock markets and the Covid-19 pandemic may have a nonlinear and asymmetric relationship (Iqbal et al. 2021). While several recent studies have examined the impact of Covid-19 on stock markets worldwide, the majority of these research have overlooked the possibility of an asymmetric nature of such an association, which has been suggested in previous stock market studies (Zaremba et al. 2020, Rahman et al. 2021, Sun et al. 2021, Gao et al. 2021, Albulescu 2021, Matos et al. 2021, Chen et al. 2021, Seven–Yilmaz 2021). It is possible that small and large changes in Covid-19 intensity will have distinct effects on stock market returns at different quantiles. We investigate the asymmetric association between the Covid-19 pandemic and stock market performance to address this research gap. Using the cross-quantilogram model, we explore how the addition of confirmed Covid-19 cases worldwide influence daily returns in the G7 stock markets. We hope to discover not only the asymmetric impact of various Covid-19 quantiles on stock market returns, but also how this influence varies throughout the bearish and bullish market scenarios of G7 stock returns.

We utilize the cross-quantilogram approach developed by Han et al. (2016) to analyse the impact of confirmed Covid-19 cases on the G7 stock markets. We take into account the non-linear dynamics (Naeem et al. 2021, Uddin et al. 2019, Shahzad et al. 2019, Liu et al. 2020) and tail dependence (Han et al. 2016) of financial data. Pham (2021b), Arif et al. (2021), and Rehman et al. (2021) bring to fore the potential of the cross-quantilogram framework in representing cross-quantile asymmetries in modelling the financial time series co-movements during the Covid-19 period. In this regard, our study contributes significantly to several strands of literature. First, our study adds to the growing literature on the association between the Covid-19 outbreak and stock markets in G7 countries. Earlier works concentrated on relationships between G7 stock markets and other financial markets during the Covid-19 outbreak (Izzeldin et al. 2021, Arif et al. 2021). Nevertheless, none of these studies have explored the considerable impact of the Covid-19 pandemic on stock markets in these countries. We have provided an excursion of literature by concentrating on relationships in different time horizons. Second, we contribute to the existing literature dependence structure by modelling the nexus between quantiles of selected variables based on the cross-quantilogram proposed by Han et al. (2016). More precisely, the study examines different lag structures (daily, weekly, monthly, and quarterly). Based on the information provided, investment strategies and portfolio selection can be developed and investment horizons can be selected accordingly (Rehman et al. 2021). Third, our research contributes to the regulatory discussion around the importance of Covid-19 and stock market co-movements. It also enhances our knowledge of the impact of the financial crisis on financial markets and stock prices. Our study examines the relationship between Covid-19 and stock markets, reporting that presidential opinions and policies influence investors, regulators, and managers' perceptions of financial market stability, especially for

investors seeking to limit tail risk in their portfolios. It further extends prior works (Liu et al. 2021, Zaremba et al. 2020, Rahman et al. 2021, Sun et al. 2021) which suggest that the Covid-19 outbreak has a significantly negative impact on stock markets. We pay attention to the tail distribution of confirmed Covid-19 cases and stock markets in G7 countries, which is indispensable as investors hunt for alternative assets capable of offsetting extreme losses in other asset classes (Rehman et al. 2021).

The remainder of the paper is organized as follows: literature review, methods and data, empirical results and conclusions.

Literature review

The current study is critical to developing a solid theoretical framework for understanding how the Covid-19 pandemic has adversely impacted financial markets. Liu et al. (2021) concentrated on the influence of the Covid-19 on the stock market crash risk in China using a generalized autoregressive conditional heteroskedasticity (GARCH) with a skewness model. The authors confirmed that conditional skewness reacts negatively to daily growth in total confirmed cases, which implies that the pandemic raises stock market crash risk. Zaremba et al. (2020) also illustrated that government interventions aimed at curbing the spread of Covid-19 have a significant impact on stock market volatility. Rahman et al. (2021) investigated how the Australian stock market responds to the uncertainties caused by the Covid-19 outbreak. Their results are also consistent with Liu et al. (2021) and Zaremba et al. (2020). Sun et al. (2021) also uncovered that the Covid-19 outbreak has an overall negative impact on stock markets, and there is a stronger positive relationship between individual investor sentiment and stock returns than usual.

Gao et al. (2021) found that the Covid-19 pandemic is the main reason for the sharp variation of the US and China stock markets. Similarly, Yousfi et al. (2021) made a comparative evaluation of the influence of the first and second waves of the Covid-19 outbreak on the US stock market. They revealed that the time-varying connectedness supports the existence of volatility transmissions among stock returns. Furthermore, the findings also indicate that the influence of market shocks on the correlation between the US and Chinese markets is asymmetric, and a link exists between the US stock returns and the Covid-19 pandemic during the first and second waves of the outbreak. Albulescu (2021) provides the same results as Gao et al. (2021) that the prolongation of the coronavirus pandemic is a vital source of financial volatility, challenging the risk management activity in the US. In the same vein, Matos et al. (2021) evaluated the conditional nexus in terms of time and frequency domains between S&P 500 markets and confirmed Covid-19 cases and related deaths. They indicate that the low-frequency cycles of the US market index can be used to predict death cycles in the US in an anti-phasic approach. Shen–Zhang (2021) focused on two groups of stocks in China to analyse the different market reactions to the Covid-

19 pandemic. The authors discovered a strikingly negative return on the event date, and the cumulative abnormal return shows a reversal trend. Chen et al. (2021) examined the impact of Covid-19 on the Chinese stock and bond markets. They revealed that the Covid-19 outbreak has a significant negative influence on the stock market and a positive influence on the bond market. Seven–Yilmaz (2021) explain the differences in the stock market falls across countries and suggest that the severity of the Covid-19 pandemic in each country impacted the equity market's reactions. O'Donnell et al. (2021) identified whether the growth in Covid-19 impacted stock market prices by looking into five regional epicentres, along with a global index. They highlighted that the daily totals of Covid-19 cases explained index price changes in Spain, Italy, the UK, and the US. Chowdhury et al. (2021) evaluated the impact of Covid-19 on the stock markets and economic activities worldwide and provided evidence that the Covid-19 pandemic has a negative impact on stock markets and that the number of lockdown days and restriction on movement have a negative influence on economic activities.

As per Iqbal et al. (2021), the shifting intensity levels of the Covid-19 pandemic have varied effects on the bearish and bullish market scenarios of cryptocurrencies. Furthermore, their outcomes reveal novel and asymmetric dynamics of this emergent asset class in the face of a highly stressful and unpredictable occurrence. The Covid-19 uncertainty has influenced practically all markets in terms of reduced returns and increased market volatility, according to Szczygielski et al. (2021). Asian markets appear to be more resilient to Covid-19-related uncertainty over time, while European, North American, and Latin American markets appear to be less resilient. Le et al. (2021) focused on the frequency-based networks of different financial assets in the tails of return distributions and found an asymmetric influence of the pandemic on the dependency of the financial networks. Wang et al. (2021) investigated the long-term relationship between confirmed Covid-19 cases and energy stock prices in 24 nations. Their results revealed a cointegration association between these variables. In addition, the authors also showed that the confirmed Covid-19 cases had negative impacts on stock prices under study. Similarly, during the first and second waves of the Covid-19 spread, Ahmed et al. (2021) investigated the impact of Covid-19 on the Indian stock and commodity markets. They showed that Covid-19 negatively influenced oil prices and stock market performance during the various phases of lockdown in India. By contrast, Covid-19 has a positive impact on gold prices in this nation.

In the context of G7 countries, Izzeldin et al. (2021) examined the influence of Covid-19 on stock markets and sectors (Consumer goods, consumer services, financials, healthcare, industrials, materials, oil & gas, technology, telecommunications, and utilities) using the ST-HAR model. Based on the daily prices covering the period from 24 April, 2018–24 April, 2020, their findings show strong transition evidence to a crisis regime for all countries and sectors, indicating the effect of Covid-19. More importantly, the UK and the US have been struck the hardest, with the most variability in their business sector's response. To assess the safe haven and

potential of Islamic equities for G7 countries, Arif et al. (2021) utilized the cross-quantilogram technique to compare the global financial crisis to the Covid-19 pandemic crisis. During the study period, the authors showed that Islamic stocks did not exhibit safe-haven characteristics for the G7 countries. Islamic stocks, in contrast, have shown that they can help diversify the G7 stock markets. Similarly, Jeribi–Fakhfekh (2020) claim that during the Covid-19 pandemic, G7 financial investors can benefit from portfolio diversification and hedging techniques using Bitcoin and Ethereum. Furthermore, the findings revealed that the predicted volatility of the US stock market has no bearing on the Japanese and Chinese stock markets. The number of confirmed Covid-19 cases and deaths has a considerable impact on the US stock market.

This bleak situation underscores the significance of our work in this context. Given the belief that Covid-19 has a significant impact on financial markets, particularly in advanced economies such as the G7, we contribute to the literature by investigating how global confirmed Covid-19 cases affect each stock market in the G7. In addition, earlier studies employed the conventional approaches and did not account for covering lags, while the cross-quantilogram technique covers the extreme value dependence with lags (Rehman et al. 2021). As a result, the current study uses cross-quantilogram and recursive sampling methodologies to examine the direction predictability in the nexus between confirmed Covid-19 cases and G7 stock markets to fill this research gap.

Methodology

The quantilogram developed by Linton–Whang (2007) measures the predictability of a stationary time series in different sectors of the distribution. Put differently, a quantilogram is a correlogram of quantile hits (Han et al. 2016) that tests the null hypothesis that no directional predictability exists in each time series. The predictability test is conducted by comparing a quantilogram to a point-wise confidence interval. Han et al. (2016) extended the univariate quantilogram framework to a multivariate setting to assess the dependence of quantiles between two stationary time series. Compared to conventional econometric frameworks, the cross-quantilogram has some primary advantages. Firstly, this method estimates the directional predictability from one-time series to other quantiles of each variable's distribution (Pham 2021b). The cross-quantilogram model is robust to misspecification error since it allows the dependence structure to co-move across the distribution of the pair of variables. Secondly, this approach can accept very long lags when compared to linear regression-type models. As a result, it is possible to calculate the strength of directional transmission over short, medium, and long investment periods. Thirdly, the cross-quantilogram model is based on quantile hits and hence does not depend on any movement condition (Pham 2021a), which is an essential

aspect when distributions of the time series are highly non-normal as found in financial data. The cross-quantilogram technique is described as follows.

Let us consider two stationary time series as $\{x_{i,t}, t \in Z\}$, $i = 1,2$. In the current study, $x_{1,t}$ and $x_{2,t}$ represent the Covid-19 confirmed cases and G7 stock markets, respectively. The density and distribution functions of series $x_{i,t}$ are denoted as $f_i(.)$ and $F_i(.)$. The quantile of $x_{i,t}$ is expressed as $q_i(\alpha_i) = \inf\{v : F_i(v) \geq \alpha_i\}$ for $\alpha_i \in (0,1)$, and the expression of two-dimensional series of quantiles are written by $(q_1(\alpha_1)q_2(\alpha_2))^{\tau}$ for $\alpha \equiv (\alpha_1, \alpha_2)^{\tau}$.

The cross-quantilogram for $\alpha-$quantile with k lags can be written as:

$$\rho_{\alpha}(k) = \frac{E\left[\Psi_{\alpha 1}\left(x_{1,t} - q_1(\alpha_1)\right)\Psi_{\alpha_2}\left(x_{2,t-k} - q_2(\alpha_2)\right)\right]}{\sqrt{E\left[\Psi_{\alpha 1}^2\left(x_{1,t} - q_1(\alpha_1)\right)\right]}\sqrt{E\left[\Psi_{\alpha_2}^2\left(x_{2,t} - q_2(\alpha_2)\right)\right]}} \quad (1)$$

for $k = 0, \pm 1, \pm 2, \ldots$ and where $\Psi_{\alpha}(\mu) \equiv 1[\mu < 0]$, $1(.)$ represents the indicator function and $1\left[x_{i,t} \leq q_i(\alpha_i)\right]$ is the quantile exceedance process.

In the case of two events, $\{x_{1,t} \leq q_{1,t}(\alpha_1)\}$ and $\{x_{2,t-k} \leq q_{2,t-k}(\alpha_2)\}$, $\rho_{\alpha}(k) = 0$ shows no cross dependence from event $\{x_{2,t-k} \leq q_{2,t-k}(\alpha_2)\}$ to event $\{x_{1,t} \leq q_{1,t}(\alpha_1)\}$.

To test the null hypothesis H_0: $\rho_{\alpha}(1) = \cdots = \rho_{\alpha}(k) = 0$ against the alternative hypothesis

H_a: $\rho_{\alpha}(k) \neq 0$ for some k.

Han et al. (2016) suggest the test statistic of Ljung-Box:

$$Q_{\alpha}^{*}(\rho) = T(T+2)\sum_{k=1}^{p}\hat{\rho}_{\alpha}^2(k)/(T-k) \quad (2)$$

where $\hat{\rho}_{\alpha}^2(k)$ is the sample cross-quantilogram, which is given as:

$$\hat{\rho}_{\alpha}^2(k) = \frac{\sum_{t=k+1}^{T}\Psi_{\alpha 1}\left(x_{1,t} - q_1(\alpha_1)\right)\Psi_{\alpha_2}\left(x_{2,t-k} - \hat{q}_2(\alpha_2)\right)}{\sqrt{\sum_{t=k+1}^{T}\Psi_{\alpha_1}^2\left(x_{1,t} - \hat{q}_1(\alpha_1)\right)}\sqrt{\sum_{t=k+1}^{T}\Psi_{\alpha_2}^2\left(x_{2,t-k} - \hat{q}_2(\alpha_2)\right)}} \quad (3)$$

where $\hat{q}_{i,t}(\alpha_i)(i = 1,2)$ represent the estimated quantile function for each variable.

Han et al. (2016) suggest applying the stationary bootstrap procedure to approximate the null distribution of the cross-quantilograms and the Q-statistic above, while avoiding any reliance on the asymptotic distribution's nuisance parameters. According to Pham (2021b), the stationary bootstrap is a block bootstrap method with blocks of random lengths. Let $\{K_j\}_{j \in N}$ be a sequence of independent and identically distributed (IID) random block lengths with a geometric distribution. Let $B_{K_j, L_j} = \left\{\left(x_{t,k}\right)\right\}_{t=K_j}^{K_j + L_j - 1}$ be the blocks of length L_j starting with the K_j th pair of observations.

The stationary bootstrap procedure creates the bootstrap samples $\left\{\left(x_{t,k}^{*}\right)\right\}_{t=k+1}^{T}$, which are applied to estimate the conditional quantile function $\hat{q}_{t,k}^{*}(\alpha)=\left[\hat{q}_{1,t}^{*}(\alpha_1),\hat{q}_{2,t-k}^{*}(\alpha_2)\right]$.

The cross-quantilogram based on the bootstrapped sample is:

$$\hat{q}_{\alpha}^{*}(k)=\frac{\sum_{t=k+1}^{T}\Psi_{\alpha_1}\left(x_{1,t}^{*}-\hat{q}_{1,t}^{*}(\alpha_1)\right)\Psi_{\alpha_2}\left(x_{2,t-k}^{*}-\hat{q}_{2,t-k}^{*}(\alpha_2)\right)}{\sqrt{\sum_{t=k+1}^{T}\Psi_{\alpha_1}^{2}\left(x_{1,t}^{*}-\hat{q}_{1,t}^{*}(\alpha_1)\right)}\sqrt{\sum_{t=k+1}^{T}\Psi_{\alpha_2}^{2}\left(x_{2,t-k}^{*}-\hat{q}_{2,t-k}^{*}(\alpha_2)\right)}} \quad (4)$$

In this study, we considered 1000 bootstrapped estimates of $\hat{\rho}_{\alpha}^{*}(k)$ to build the confidence intervals for the test statistic in equation (2).

To estimate the entire dependence structure between the Covid-19 and stock markets in G7 countries through a diversity of market conditions and investment horizons, we conducted the cross-quantilograms for 11 quantiles:
($\alpha_1, \alpha_2 \in$ (0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95)) and 4 lags lengths: daily ($k = 1$), weekly ($k = 5$), monthly ($k = 22$) and quarterly ($k = 66$). The selection of these lags is in line with earlier works (Arif et al. 2021, Pham 2021a, Uddin et al. 2019). As a result, for each pair of examined indicators, this study estimates 11×11×4=484 cross-quantilograms, and each cross-statistical quantilogram's significance is calculated using 100 stationary bootstraps.

Data

Our research is based on the daily closing prices of the G7 member countries – S&P PTX in Canada, the CAC 40 in France, the DAX 30 in Germany, the FTSE MIB in Italy, the NIKKEI 325 in Japan, the FTSE 100 in the UK, and the S&P 500 in the US. From 20 January, 2020 to 1 June, 2021, we tracked the information transmission from daily global confirmed Covid-19 cases. The stock market indices and Covid-19 data come from the Datastream and Our World in Data platforms, respectively (https://ourworldindata.org/coronavirus). After converting to log values, the series was divided by 100, and this transformation is validated by the literature (Iqbal et al. 2021, Gao et al. 2021, Sun et al. 2021, Yousfi et al. 2021). The stock market returns were calculated as the log difference for successive equities indices as $r_t = \log(P_t) - \log(P_{t-1})$, where r_t is the return from period t to $t+1$, P_t and P_{t+1} are data points at the respective periods t and $t+1$.

The current study concentrates on the G7 countries since they have the most developed economies globally, accounting for more than 64 percent of global net worth and 46 percent of GDP (Jiang et al. 2020). Meanwhile, governmental interventions, economic reforms, and financial regulatory actions varied greatly between their economies. Furthermore, the G7 stock markets have grown highly efficient after a long period of development. Stock prices can accurately and swiftly

reflect the impact of the Covid-19 pandemic on the stock markets, allowing for a more comprehensive examination of the stock market reaction to the Covid-19 pandemic. Specifically, we used the stock indices of the G7 countries, which are considered representative cases in the study because they had the highest number of confirmed cases worldwide as of August 2020 (Qing et al. 2020). The descriptive statistics for the data are shown in Table 1.

Table 1

Summary statistics of confirmed Covid-19 cases and stock returns

	Covid-19	Canada	France	Germany
Mean	0.015717	0.001507	0.001039	0.001314
Max	1.386294	0.112323	0.086110	0.109692
Min	–8.114923	–0.137203	–0.139488	–0.139053
Std. Dev	0.264222	0.017107	0.016775	0.017358
Skewness	–28.28258	–1.035854	–0.393530	–0.153264
Kurtosis	878.2367	19.81400	11.71943	12.43334
J-B	32820.862***	12245.44***	3270.313***	3800.823***
ADF	–31.66283***	–12.18808***	–10.94312***	–10.95582***
	Italy	Japan	UK	US
Mean	0.001005	0.000901	0.000403	0.001607
Max	0.082815	0.068413	0.101330	0.089347
Min	–0.198318	–0.066794	–0.129005	–0.131492
Std. Dev	0.017042	0.012846	0.016765	0.018017
Skewness	–1.758690	0.268790	–0.195962	–0.532489
Kurtosis	24.23118	6.488352	10.99548	9.061982
J-B	19760.43***	531.5239***	2734.138***	1616.290***
ADF	–10.45939***	–10.02953***	–11.89430***	–10.54586***

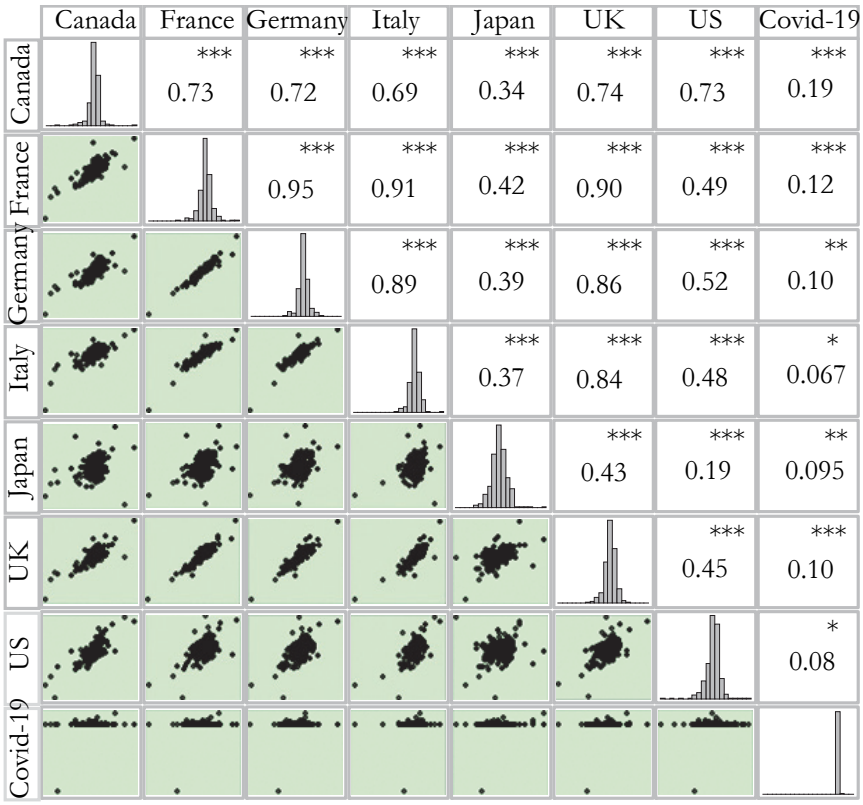
*** Illustrates a 5% significance level.

A quick look at the summary statistics of the index returns in Table 1 uncovers some intriguing characteristics of the included stock returns. All seven stock markets experienced positive average returns during the sample period. Compared to the stock market indices, the standard deviations for confirmed Covid-19 cases are higher, as expected given the large co-movements in the number of confirmed Covid-19 cases over the research period. Each series has a negative skewness and a kurtosis greater than four, indicating that the tails are larger than they are in a normal distribution. This is formally validated by the Jarque–Bera test statistics. Lastly, the Augmented Dickey–Fuller (ADF) unit root tests show that all examined variables are stationary at level. As a result, modelling the cross-quantilograms can perfectly capture the influence of confirmed Covid-19 cases on stock markets in G7 countries.

The general distribution of the concerned variables and pairwise relationships between series are depicted graphically in Figure 1. Figure 1 clearly shows that none of the variables under study had a normal distribution, with the strongest connection between stock markets and confirmed Covid-19 cases.

Figure 1

Plots of distribution and the pair-wise correlations of the variables



* Illustrates a 1% significance level. ** Illustrates a 5% significance level. *** Illustrates a 10% significance level.

Empirical results

Cross-quantilogram analysis

This section depicts the cross-quantile dependency between global confirmed Covid-19 cases and G7 stock market returns analyses in the form of heat maps for different lag lengths. Heat maps depict the cross-quantile unconditional bivariate correlation between two distributions. The x-axis represents the global confirmed Covid-19 cases quantiles, whereas the y-axis represents the stock market returns of G7 countries. The quantile distributions of the variables are defined by the x- and y-axes and highlighted

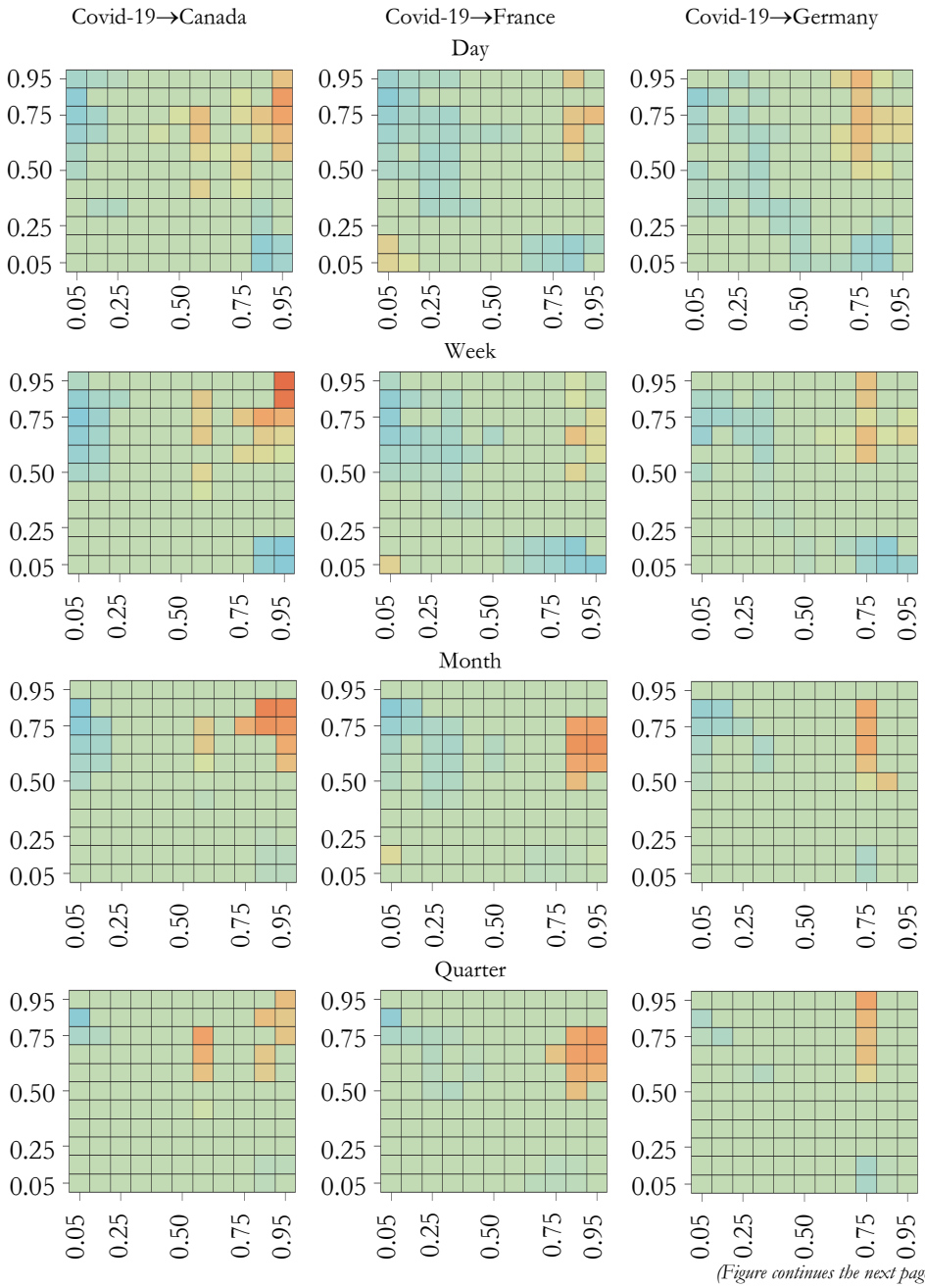
by quantile hits [q = (0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95)]. Each heat map has 121 (11 x 11) cells representing the quantile combinations of the variables. The correlations are displayed on a colour scale (ranging from –1.0 to +1.0). The absence of predictable directionality in the care quality commission (CQC) is shown by a cell with a correlation of zero. We considered four alternative lag orders: lag 1 (1 day), lags 5 (week), lags 22 (month), and lags 66 (quarter). This information can be used to help develop investment strategies and portfolio selections based on time horizon (lag structure). For cross-quantile correlations that are statistically insignificant, the heat maps were set to zero, indicating a lack of predictable directionality. Overall, with lags ranging from daily to quarterly, this method captured quantile dependencies. The lags lengths considered in the heat maps are noted on the left-hand side of the figures. Figure 2 shows that global confirmed Covid-19 cases and G7 stock market returns are heterogeneously integrated across time horizons.

In the heat map setting, we take into consideration confirmed Covid-19 cases to be predictability for a G7 stock market under two situations. First, significant positive estimates can be found in the top left corner of a heat map, which implies that stock returns of G7 countries are followed by a highly positive number of confirmed Covid-19 cases. Second, the entire distribution of the heat map indicates negative relationships and disconnection between the confirmed Covid-19 cases and G7 stock markets, except the US, since only blue and green colours are represented in the heat map.

Further, Figure 2 shows the full sample cross-quantilogram outcomes for the G7 stock markets and confirmed Covid-19 cases. In row one, which reports the findings for a 1-day causal relationship, we observe a substantial orange colour present in the high quantile distributions for the G7 stock markets and confirmed Covid-19 cases. These observations demonstrate a significant positive interdependence. This demonstrates a positive nexus between Covid-19 and G7 stock markets across the high quantiles of the distribution, in particular, with longer lags, the nexus strengthens. In contrast, a negative relationship exists between the examined variables across low and medium quantiles of distribution at the higher- and lower-left corners. This indicates that future positive G7 stock returns will follow extreme negative Covid-19 shocks in the next periods. The heat maps for the Covid-19 and G7 stock returns at the short-run investment horizon illustrate a mix of green and blue, suggesting a negative association across different distribution quantiles, which implies that the G7 stock markets are the main receivers of the Covid-19 shocks.

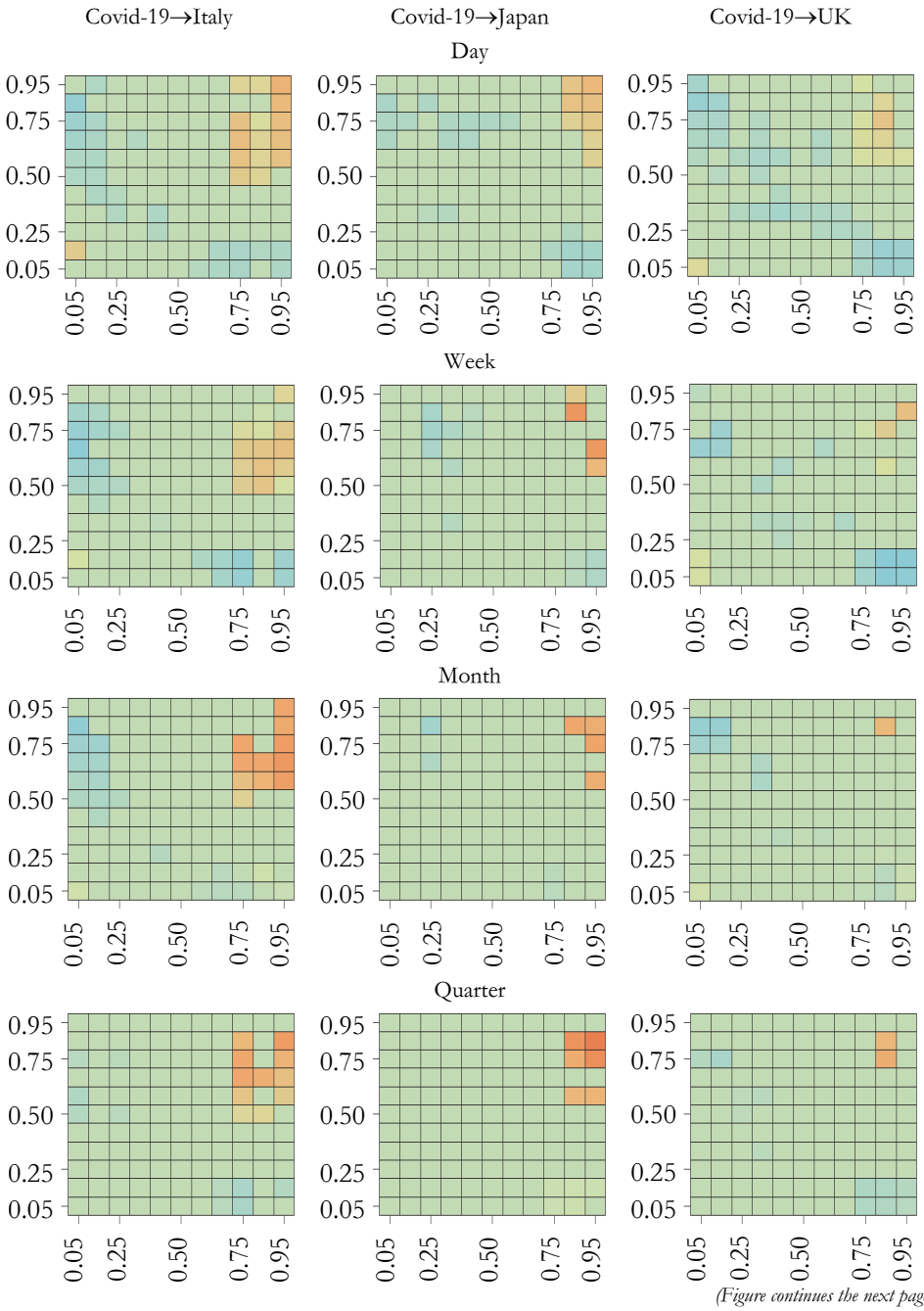
Figure 2

Cross-quantilogram heat maps between Covid-19 outbreak and G7 stock markets



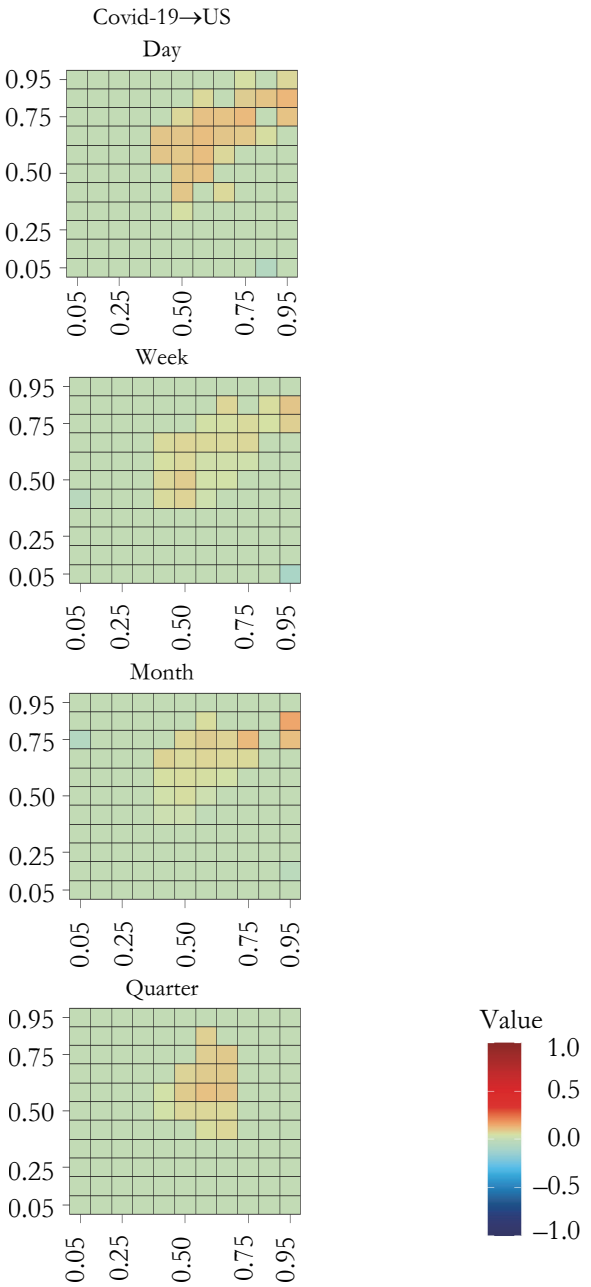
(Figure continues the next page.)

(Continued.)



(Figure continues the next page.)

(Continued.)



Notes: → demonstrates the direction of predictability. The heat maps are separated for four-time horizons: daily (k=1), weekly (k=5), monthly (k=22), and quarterly (k =66). In each heat map, the vertical axis shows the returns quantiles of G7 stock markets, while the horizontal axis illustrates quantiles of the Covid-19 pandemic. The colour scale at the bottom demonstrates the numerical values of the heat map colours.

A visual comparison of cross-quantilogram across the seven countries in Figure 2 demonstrates that Covid-19 generally has a stronger predictive power over stock markets in Canada, Japan, France, Germany, Italy, the UK, and the US because the correlation between the two variables for these pairs oscillates between positive and negative. In the upper quantile of Covid-19, there is positive predictability for these nations with all lags. The cross-quantilogram heat map for the pairs of Covid-19, Germany, France, Japan, Italy, Canada, and the UK are dominated by blue, which means that these stocks strongly respond to the growth in the number of Covid-19 cases. By contrast, the positive relationships for the Covid-19 with the US are unveiled at lag 1 (day), 5 (week), and 22 (month). However, at 66 lags (quarter), the green colour in some quantiles shows weak connections between variables. This suggests insignificant interdependence between Covid-19 and G7 stock returns.

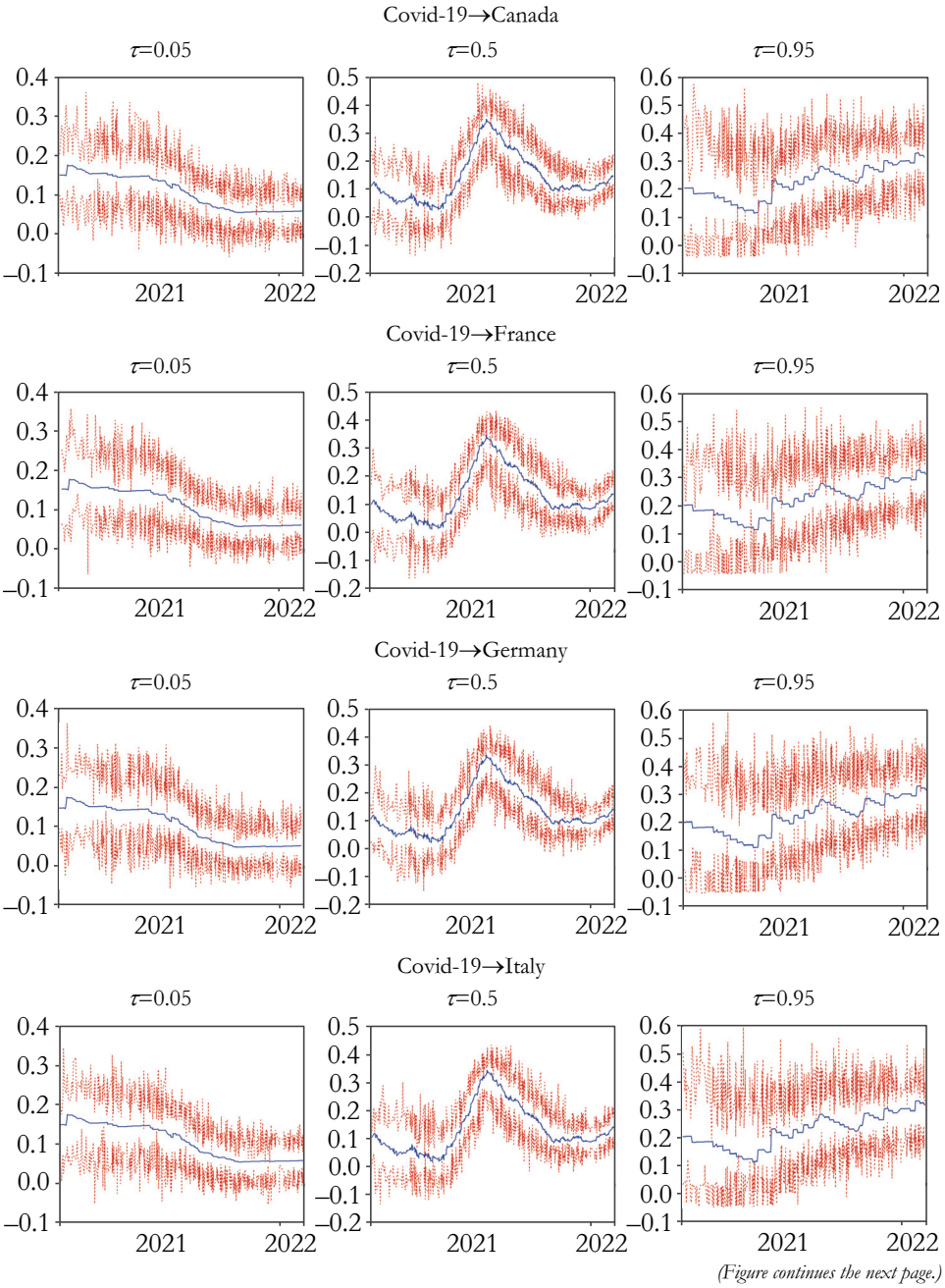
Overall, the cross-quantile correlation between confirmed Covid-19 cases and G7 stock returns is fundamentally short and medium run, according to our findings. As the lag period lengthens, the link weakens. These findings suggest that in the short and medium-term, the stock markets in the G7 countries reacted negatively and overwhelmingly to the increase in the number of confirmed cases. In the long run, however, this relationship is relatively shaky. Owing to problematic stock market investors and the projected negative impact of Covid-19 early on and the surge in confirmed cases, this is not surprising. As the number of confirmed cases in the G7 countries rises, stock market returns fall. These findings are consistent with the results of several previous studies which show a strengthening nexus between confirmed Covid-19 cases and stock market prices (Albulescu 2021, Ashraf 2020, Baker et al. 2020, Chen et al. 2021, Chowdhury et al. 2021, Shen–Zhang 2021).

Time-varying cross-quantilogram analysis

We provided quantile dependence between the concerned indicators for the entire sample period in a time-static condition during the sample period shown. In this case, however, the quantile-hit approach was unable to reflect the dynamic properties of interdependence. Therefore, in this section, we analysed the dependence structure in a time-varying setting using recursive subsample estimations. The objective of this study was to detect any potential changes in cross-quantile correlation through time. In recent literature, recursive subsample estimation was commonly used to measure the time-varying relationship between financial variables (Hung 2020b, Uddin et al. 2019).

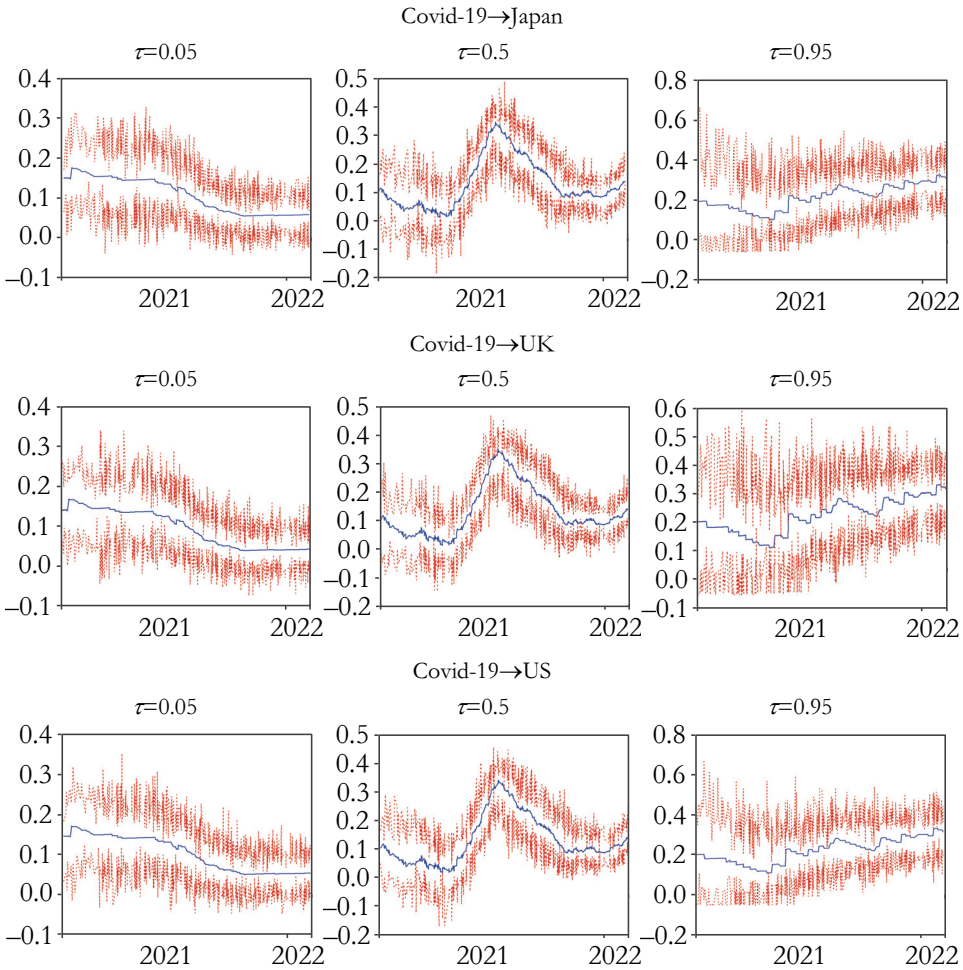
Figure 3

Recursive cross-quantilograms between Covid-19 outbreak and G7 stock markets



(Figure continues the next page.)

(Continued.)



Notes: We used a rolling window to estimate the cross-quantilogram coefficients. The figure shows the recursive cross-quantilogram between the series *(COVID→STOCK)* when both are at the 5%, 50%, and 95% quantiles. → shows the direction of predictability. The blue lines illustrate the time-varying cross-quantilogram coefficients through the recursive subsampling procedure. The red lines indicate 95% bootstrapped confidence intervals, which are obtained from 1000 bootstrap replications.

To investigate variations in the causal relationships between the confirmed Covid-19 cases and the G7 stock indexes over the research period, we used recursive sampling with a 252-day rolling window to quantity the dynamic correlation in each step, and the estimation process continued in the same way until the last observation of the sample. Figure 3 shows the obtained findings. In each pair, the findings are shown in the first, second, and third rows when both series distributions were at the 5, 50, and 95% quantiles, respectively. The cross-quantilogram correlation is

represented on the vertical axis, while the time of the recursive window is represented on the horizontal axis. The blue lines depict time-varying cross-quantilogram correlation in recursive subsamples, while the red lines indicate a 95% confidence range for the null hypothesis of no predictability. A bootstrap process was used to compute the confidence interval. In this work, we employed 1000 bootstrap iterations. We chose a one-day lag because earlier research has shown that cross-correlations over one day are significant in most circumstances.

Figure 3 reports a time-varying picture of cross-dependence between the confirmed Covid-19 cases and G7 stock returns. Over the sample period analysed, the cross-quantile correlation between Covid-19 and US stock returns shows a positive association, with a modest fall and volatility in early 2021. The cross-quantile correlation will predominantly transition from negative to positive in the remaining nations until 2021, especially in the UK, France, Japan, and Canada, before dropping, demonstrating that Covid-19's influence on these stock markets is time-varying. For example, at the start of 2020, the cross-quantile correlations of Covid-19 with stock returns in Canada, Italy, France, and Germany for the 0.5 quantiles were negative, implying that stock markets in these countries were unstable. This is big news for Canadian, Italian, French, and German investors. Furthermore, of the entire sample, there was only a weak (nearly zero) connection in the lowest quantile and positive correlations throughout the upper quantile periods. A broader examination of the graphical results reveals a negative lead-lag relationship between different quantiles of the confirmed Covid-19 cases and the G7 stock markets. The overall findings of the recursive analysis show that the influence of confirmed Covid-19 cases on the G7 varies with time, with some heterogeneity across the variables studied. Our results are generally in line with prior studies showing that Covid-19 has a negative impact on stock markets (Liu et al. 2021, Rahman et al. 2021, Sun et al. 2021, Zaremba et al. 2020).

Robustness checks

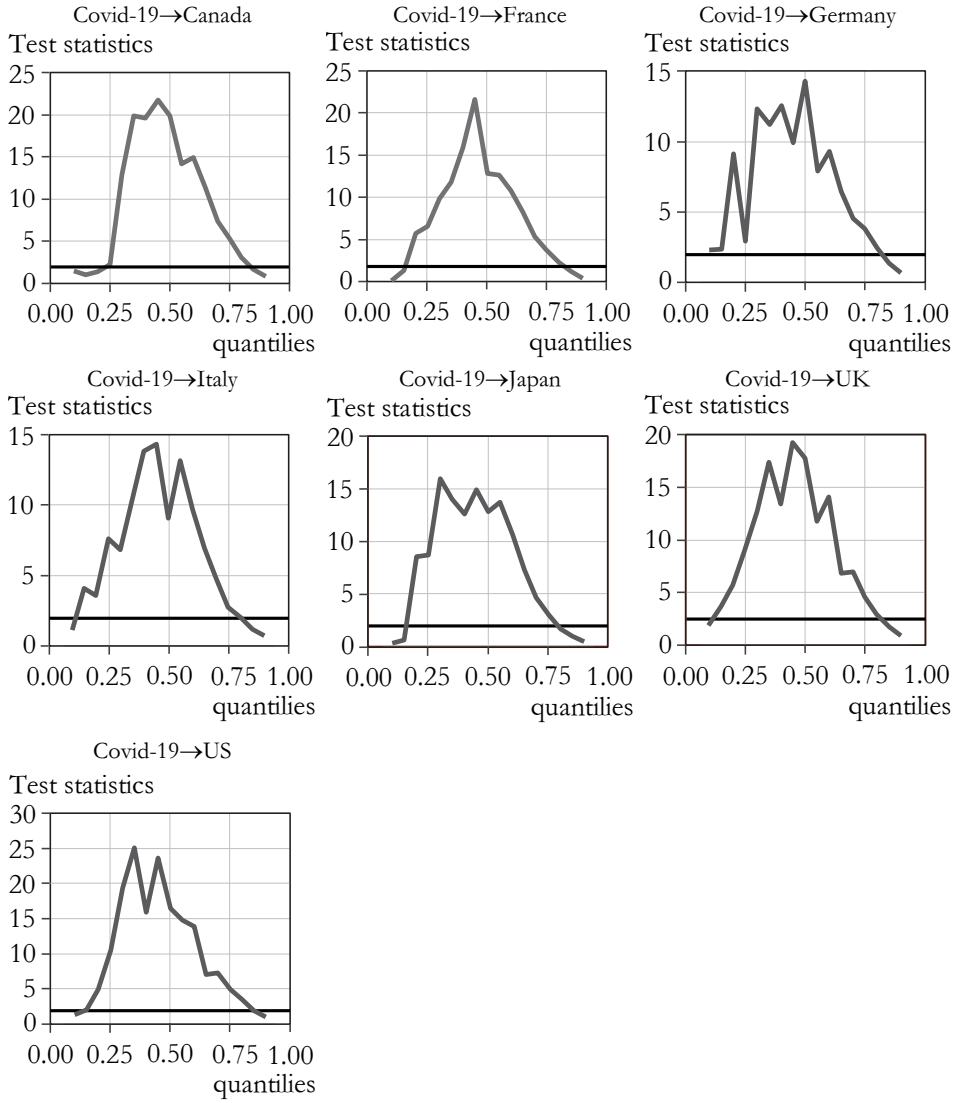
This section contains the results of the above-mentioned robustness analyses, as shown in Figure 4.

Following Balcilar et al. (2017), quantile Granger causality tests were performed to investigate the cross-quantile dependence between confirmed Covid-19 cases and G7 stock markets further. We considered the causality-in-quantiles test. This nonlinear model is flexible and allows testing causality in the joint distribution of the variables, including the tails (Adekoya–Oliyide 2021, Balcilar et al. 2017). The black line in individual plot represents the critical values at the 5% significance level. When Covid-19 was used as the causal variable, most spillover series at the lower and higher quantiles showed significance at 5%. Overall, Granger causality from confirmed

Covid-19 cases to G7 stock markets is significantly evident. These findings are in line with the cross-quantilogram empirical evidence presented in the previous section.

Figure 4

Causality in quantiles between Covid-19 and G7 stock returns



Notes: This figure summarizes the quantile Granger causality test statistics. The x-axis shows the quantiles and the y-axis shows the test statistics for a specific pair of assets.

Methodologically, by minimizing a weighted sum of absolute value of residuals, Koenker–Bassett (1978) proposed using the quantile regression technique to model

conditional quantiles as a function of predictors. As a result, for each quantile regression, the coefficients calculation was based on the weighted complete sample data, not simply the datapoints at those quantiles. The cross-quantilogram technique allows us to represent the response variable's entire conditional distribution features, detect heterogeneous covariate effects at multiple quantiles of the outcome, and provide more robust estimates when outliers and long tails exist. This study utilized the cross-quantilogram model to shed light on quantile dependence between the Covid-19 confirmed cases and G7 stock returns. This approach allows us to focus on the lowest tails of the distribution rather than the whole distribution. Past studies have measured the direction and strength of shock spillovers in the stock markets, relying on traditional average-based estimators that can only estimate the system of average shocks (Bouri et al. 2021). Nevertheless, systemic shocks are not necessarily equal to average shocks but can be much larger, indicating the need to consider potential heterogeneous effects across the size distribution of shocks. Compared to conventional methodologies, the cross-quantilogram is based on quantile hits and accommodates a large number of quantiles and lags, which provide information on the direction, magnitude, and duration of the dependence between time series across a wide range of quantiles (upper tail, lower tail, and median). As a result, the cross-quantilogram model can more completely depict the association between variables under investigation (Naeem et al. 2021, Uddin et al. 2019, Shahzad et al. 2019, Liu et al. 2020, Han et al. 2016, Rehman et al. 2021).

In general, our findings shed light on the significant impacts of global confirmed Covid-19 cases on G7 stock markets. Hence, we draw several policy implications. First, politicians should pay greater attention to the dynamics of stock markets and the number of confirmed Covid-19 cases in their countries. In this sense, authorities should figure out how to assist the market quickly and effectively when the number of confirmed Covid-19 cases is high. In severe instances, the risk of a market crash can be mitigated by doing so.

Second, investors are likely to be sensitive to both local and worldwide news (for example, G7 domestic infected cases or deaths). As a result, clear and timely communication on the Covid-19 pandemic could lead to better market forecasting. Specifically, when the number of confirmed Covid-19 cases rises considerably, both investors and regulators should be warier about the potential of stock market co-movements. Then, as recommended by earlier studies, hedging or safe haven measures could be used (Rahman et al. 2021, Gao et al. 2021).

Finally, our findings provide recommendations to risk regulators, who should build a daily monitoring method for financial risk transmission across international boundaries to improve early risk warning systems. They should implement management methods that illustrate the use of benefits, prudent risk prevention, and risk management. Countries should also develop a comprehensive assessment index system covering a wide range of markets and industries that is completely transparent,

with frequent data updates. Furthermore, it is crucial for enhancing international coordination among financial authorities. In the context of economic globalization, stock markets are a complex economic ecosystem, thus it is vital to increase international management information exchange related to financial risk contagion.

Conclusions

Using the outbreak of Covid-19 as the shock event, this study empirically investigated the effects of the total daily global confirmed cases of Covid-19 on the stock markets of G7 countries. As opposed to earlier works mostly based on linear correlation or causality modelling, we employed cross-cross-quantilogram proposed by Han et al. (2016) to detect and determine the nature of dependence impacts of Covid-19 on the selected stock returns. This method employs a model-free measure of the correlation between two variables across the quantiles of each distribution and investigates the dependence in specific market conditions and investment horizons, thereby providing fresh insights into the stock markets of G7 countries during the Covid-19 period.

The empirical findings reveal that the cross-quantile dependence between the confirmed Covid-19 cases and G7 stock returns is the most significant in the short and medium run. The interlinkage weakens as the lag period lengthens. These findings suggest that the stock markets of G7 countries reacted negatively and overwhelmingly to the increase in the number of daily confirmed Covid-19 cases in the short and medium term. However, the dependence structures between the two variables dissipate in the long run. Besides, cross-quantile correlations calculated from recursive subsamples uncover that cross-quantile correlations change over time, especially in low and medium quantiles, suggesting that they are prone to jumps and discontinuities in the dependence structures. This means that the Covid-stock relationship experiences strong moves in the tail distributions at divergent periods, showing interrelatedness during the Covid-19 crisis, and directional predictability is time-varying. As a result, common policy instruments could serve as effective stabilization tools for all G7 economies.

Investors and policymakers should be aware of the correlation between Covid-19 and stock market results when diversifying their portfolios. The cross-quantile correlations aids in the understanding of asset co-movement, which aids portfolio diversification and investing decisions. During the Covid-19 crisis, investors should reconsider their asset allocation if they have significant, positive dependencies. Liberalizing trade and investment policies have improved the Covid-stock relationship, and market flows into G7 economies have risen significantly over time. Understanding the underlying dependencies of these movements can help enhance asset allocation and risk-adjusted portfolios. Furthermore, a better understanding of the net recipients and net transmitters of Covid-19 or stock movements at various stages could aid policymakers and regulators in developing a surveillance system for

addressing market interdependence effects connected to the impact of Covid-19 changes in these markets.

REFERENCES

ADEKOYA, O. B.–OLIYIDE, J. A. (2021): How Covid-19 drives connectedness among commodity and financial markets: Evidence from TVP-VAR and causality-in-quantiles techniques *Resources Policy* 70: 101898. https://doi.org/10.1016/j.resourpol.2020.101898

AHMED, F.–SYED, A. A.–KAMAL, M. A.–DE LAS NIEVES LOPEZ-GARCÍA, M.–RAMOS-REQUENA, J. P.–GUPTA, S. (2021): Assessing the impact of Covid-19 pandemic on the stock and commodity markets performance and sustainability: A comparative analysis of South Asian Countries *Sustainability* 13 (10): 5669. https://doi.org/10.3390/su13105669

ALBULESCU, C. T. (2021): Covid-19 and the United States financial markets' volatility *Finance Research Letters* 38: 101699. https://doi.org/10.1016/j.frl.2020.101699

ANTALÓCZY, K.–BIRIZDÓ, I.–SASS, M. (2022): Local investment promotion in a Hungarian medium-sized town and the implications of the Covid pandemic *Regional Statistics* 12 (1): 27–50. https://doi.org/10.15196/RS120104

ARIF, M.–NAEEM, M. A.–HASAN, M.–M ALAWI, S.–TAGHIZADEH-HESARY, F. (2021): Pandemic crisis versus global financial crisis: Are Islamic stocks a safe-haven for G7 markets? *Economic Research-Ekonomska Istraživanja* 35 (1): 1707–1733. https://doi.org/10.1080/1331677X.2021.1910532

ARITENANG, A. F. (2022): The impact of urban characteristics on the spread of Covid-19 in 2020: The case of Java Island cities, Indonesia *Regional Statistics* 12 (3): 3–17. https://doi.org/10.15196/RS120301

ASHRAF, B. N. (2020): Stock markets' reaction to Covid-19: Cases or fatalities? *Research in International Business and Finance* 54: 101249. https://doi.org/10.1016/j.ribaf.2020.101249

BAKER, S. R.–BLOOM, N.–DAVIS, S. J.–KOST, K.–SAMMON, M.–VIRATYOSIN, T. (2020): The unprecedented stock market reaction to Covid-19 *Review of Asset Pricing Studies* 10 (4): 742–758.

BALCILAR, M.–BEKIROS, S.–GUPTA, R. (2017): The role of news-based uncertainty indices in predicting oil markets: a hybrid nonparametric quantile causality method Empirical Economics 53: 879–889. https://doi.org/10.1007/s00181-016-1150-0

BOURI, E.–SAEED, T.–VO, X. V.–ROUBAUD, D. (2021): Quantile connectedness in the cryptocurrency market *Journal of International Financial Markets, Institutions and Money* 71: 101302. https://doi.org/10.1016/j.intfin.2021.101302

BULUT, V.–KORUKOGLU, S. (2022): Surface curvature analysis of bivariate normal distribution: A Covid-19 data application on Turkey *Regional Statistics* 12 (4): 3–26. https://doi.org/10.15196/RS120401

CHEN, X.–WANG, Z.–LI, X.–LIU, Z.–LI, K. (2021): The Impact of Covid-19 on the Securities Market: Evidence from Chinese Stock and Bond Markets *Procedia Computer Science* 187: 294–299. https://doi.org/10.1016/j.procs.2021.04.065

CHOWDHURY, E. K.–KHAN, I. I.–DHAR, B. K. (2021): Catastrophic impact of Covid-19 on the global stock markets and economic activities *Business and Society Review* 127 (2): 437–460. https://doi.org/10.1111/basr.12219

FITRIANI, R.–DARMANTO, D.–PUSDIKTASARI, Z. F. (2022): A dynamic-time dependent spatial autocorrelation detection for East Java's Covid-19 regional percent of cases, March 2020–March 2021 (Indonesia) *Regional Statistics* 12 (3): 18–53. https://doi.org/10.15196/RS120302

GAO, X.–REN, Y.–UMAR, M. (2021): To what extent does Covid-19 drive stock market volatility? A comparison between the US and China *Economic Research-Ekonomska Istraživanja* 35 (1): 1686–1706. https://doi.org/10.1080/1331677X.2021.1906730

HAN, H.–LINTON, O.–OKA, T.–WHANG, Y. J. (2016): The cross-quantilogram: Measuring quantile dependence and testing directional predictability between time series *Journal of Econometrics* 193 (1): 251–270. https://doi.org/10.1016/j.jeconom.2016.03.001

HUNG, N. T. (2020a): Dynamic spillover effects between oil prices and stock markets: New evidence from pre and during Covid-19 outbreak *Aims Energy* 8 (5): 819–834. https://doi.org/10.3934/energy.2020.5.819

HUNG, N. T. (2020b): Volatility spillovers and time-frequency correlations between Chinese and African stock markets *Regional Statistics* 10 (2): 63–82. http://dx.doi.org/10.15196/RS100203

HUNG, N. T. (2021): Oil prices and agricultural commodity markets: evidence from pre and during Covid-19 outbreak *Resources Policy* 73: 102236. https://doi.org/10.1016/j.resourpol.2021.102236

HUNG, N. T.–VO, X. V. (2021): Directional spillover effects and time-frequency nexus between oil, gold and stock markets: Evidence from pre and during Covid-19 outbreak *International Review of Financial Analysis* 76: 101730. https://doi.org/10.1016/j.irfa.2021.101730

IQBAL, N.–FAREED, Z.–WAN, G.–SHAHZAD, F. (2021): Asymmetric nexus between Covid-19 outbreak in the world and cryptocurrency market *International Review of Financial Analysis* 73: 101613. https://doi.org/10.1016/j.irfa.2020.101613

IZZELDIN, M.–MURADOĞLU, Y. G.–PAPPAS, V.–SIVAPRASAD, S. (2021): The impact of Covid-19 on G7 stock markets volatility: Evidence from a ST-HAR model *International Review of Financial Analysis* 74: 101671. https://doi.org/10.1016/j.irfa.2021.101671

JERIBI, A.–FAKHFEKH, M. (2020): Determinants of G7 and Chinese stock market returns during Covid-19 outbreak *Business Excellence and Management* 10 (5): 256–266. http://dx.doi.org/10.24818/beman/2020.S.I.1-20

JIANG, Y.–TIAN, G.–MO, B. (2020): Spillover and quantile linkage between oil price shocks and stock returns: new evidence from G7 countries *Financial Innovation* 6: 42. https://doi.org/10.1186/s40854-020-00208-y

KAPÁS, J. (2022): Has Covid-19 caused a change in the dynamics of the unemployment rate? The case of North America and continental Europe *Regional Statistics* 12 (1): 3–26. https://doi.org/10.15196/RS120107

KINCSES, Á.–TÓTH, G. (2020): How coronavirus spread in Europe over time: national probabilities based on migration networks *Regional Statistics* 10 (2): 228–231. http://dx.doi.org/10.15196/RS100210

KOENKER, R.–BASSETT JR, G. (1978): Regression quantiles *Econometrica: Journal of the Econometric Society* 46 (1): 33–50. https://doi.org/10.2307/1913643

LE, T. H.–DO, H. X.–NGUYEN, D. K.–SENSOY, A. (2021): Covid-19 pandemic and tail-dependency networks of financial assets *Finance Research Letters* 38: 101800. https://doi.org/10.1016/j.frl.2020.101800

LINTON, O.–WHANG, Y. J. (2007): The quantilogram: With an application to evaluating directional predictability *Journal of Econometrics* 141 (1): 250–282. https://doi.org/10.1016/j.jeconom.2007.01.004

LIU, Z.–HUYNH, T. L. D.–DAI, P. F. (2021): The impact of Covid-19 on the stock market crash risk in China *Research in International Business and Finance* 57: 101419. https://doi.org/10.1016/j.ribaf.2021.101419

LIU, C.–NAEEM, M. A.–REHMAN, M. U.–FARID, S.–SHAHZAD, S. J. H. (2020): Oil as hedge, safe-haven, and diversifier for conventional currencies *Energies* 13 (17): 4354. https://doi.org/10.3390/en13174354

MATOS, P.–COSTA, A.–DA SILVA, C. (2021): Covid-19, stock market and sectoral contagion in US: a time-frequency analysis *Research in International Business and Finance* 57: 101400. https://doi.org/10.1016/j.ribaf.2021.101400

NAEEM, M. A.–NGUYEN, T. T. H.–NEPAL, R.–NGO, Q. T.–TAGHIZADEH–HESARY, F. (2021): Asymmetric relationship between green bonds and commodities: Evidence from extreme quantile approach *Finance Research Letters* 43: 101983. https://doi.org/10.1016/j.frl.2021.101983

NYIKOS, G.–SOHA, B.–BÉRES, A. (2021): Entrepreneurial resilience and firm performance during the Covid-19 crisis – Evidence from Hungary *Regional Statistics* 11 (3): 29–59. https://doi.org/10.15196/RS110307

O'DONNELL, N.–SHANNON, D.–SHEEHAN, B. (2021): Immune or at-risk? Stock markets and the significance of the Covid-19 pandemic *Journal of Behavioral and Experimental Finance* 30: 100477. https://doi.org/10.1016/j.jbef.2021.100477

PHAM, L. (2021a): Frequency connectedness and cross-quantile dependence between green bond and green equity markets *Energy Economics* 98: 105257. https://doi.org/10.1016/j.eneco.2021.105257

PHAM, L. (2021b): How integrated are regional green equity markets? Evidence from a cross-quantilogram approach *Journal of Risk and Financial Management* 14 (1): 39. https://doi.org/10.3390/jrfm14010039

QING, H.–JUNYI, L.–SIZHU, W.–JISHUANG, Y. (2020): The impact of Covid-19 on stock markets *Economic and Political Studies* 8 (3): 275–288. https://doi.org/10.1080/20954816.2020.1757570

RAHMAN, M. L.–AMIN, A.–AL MAMUN, M. A. (2021): The Covid-19 outbreak and stock market reactions: Evidence from Australia *Finance Research Letters* 38: 101832. https://doi.org/10.1016/j.frl.2020.101832

REHMAN, M. Z.–TIWARI, A. K.–SAMONTARAY, D. P. (2021): Directional predictability in foreign exchange rates of emerging markets: New evidence using a cross-quantilogram approach *Borsa Istanbul Review* 22 (1): 145–155. https://doi.org/10.1016/j.bir.2021.03.003

SEVEN, Ü.–YILMAZ, F. (2021): World equity markets and Covid-19: Immediate response and recovery prospects *Research in International Business and Finance* 56: 101349. https://doi.org/10.1016/j.ribaf.2020.101349

SHAHZAD, S. J. H.–BOURI, E.–ROUBAUD, D.–KRISTOUFEK, L.–LUCEY, B. (2019): Is Bitcoin a better safe-haven investment than gold and commodities? *International Review of Financial Analysis* 63: 322–330. https://doi.org/10.1016/j.irfa.2019.01.002

SHEN, D.–ZHANG, W. (2021): Stay-at-home stocks versus go-outside stocks: The impacts of Covid-19 on the Chinese stock market *Asia-Pacific Financial Markets* 28 (2): 305–318. https://doi.org/10.1007/s10690-020-09322-4

SUN, Y.–WU, M.–ZENG, X.–PENG, Z. (2021): The impact of Covid-19 on the Chinese stock market: Sentimental or substantial? *Finance Research Letters* 38: 101838. https://doi.org/10.1016/j.frl.2020.101838

SZCZYGIELSKI, J. J.–BWANYA, P. R.–CHARTERIS, A.–BRZESZCZYŃSKI, J. (2021): The only certainty is uncertainty: An analysis of the impact of Covid-19 uncertainty on regional stock markets *Finance Research Letters* 43: 101945. https://doi.org/10.1016/j.frl.2021.101945

THAKUR, D.–DAS, I. (2022): Statistical assessment of spatio-temporal impact of Covid-19 lockdown on air pollution using different modelling approaches in India, 2019–2020 *Regional Statistics* 12 (3): 54–84. https://doi.org/10.15196/RS120303

UDDIN, G. S–RAHMAN, M. L.–HEDSTRÖM, A.–AHMED, A. (2019): Cross-quantilogram-based correlation and dependence between renewable energy stock and other asset classes *Energy Economics* 80: 743–759. https://doi.org/10.1016/j.eneco.2019.02.014

WANG, Q. J.–CHEN, D.–CHANG, C. P. (2021): The impact of Covid-19 on stock prices of solar enterprises: A comprehensive evidence based on the government response and confirmed cases *International Journal of Green Energy* 18 (5): 443–456. https://doi.org/10.1080/15435075.2020.1865367

YI, X.–BAI, C.–LYU, S.–DAI, L. (2021): The impacts of the Covid-19 pandemic on China's green bond market *Finance Research Letters* 42: 101948. https://doi.org/10.1016/j.frl.2021.101948

YOUSFI, M.–ZAIED, Y. B.–CHEIKH, N. B.–LAHOUEL, B. B.–BOUZGARROU, H. (2021): Effects of the Covid-19 pandemic on the US stock market and uncertainty: A comparative assessment between the first and second waves *Technological Forecasting and Social Change* 167: 120710. https://doi.org/10.1016/j.techfore.2021.120710

ZAREMBA, A.–KIZYS, R.–AHARON, D. Y.–DEMIR, E. (2020): Infected markets: Novel coronavirus, government interventions, and stock return volatility around the globe *Finance Research Letters* 35: 101597. https://doi.org/10.1016/j.frl.2020.101597