



Interdependencies of COVID-19 and Financial Equity Markets: A Case of Five Most Affected COVID-19 Countries—A Wavelet Transformed Coherence Approach

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Accepted: 16 July 2024

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Abstract

This study applied novel wavelet techniques to daily stock returns and COVID-19 case data from January 22, 2020, to March 31, 2022, for the five most COVID-affected countries (US, India, Brazil, France, and Turkey). We discovered that pandemic cases have a negative effect on stock returns across all nations. All countries except Turkey's equity market returns and COVID-19 cases exhibit specific short-run and consistent long-run coherence. This study contributes to the existing literature about the financial implications of the pandemic. The current study empirically examine the positive/negative, long/short-run, and leading/lagging dependence of COVID-19 and financial equity markets of the top 5 COVID-19 affected countries. The current findings reveal particularized short-run and consistent long-run coherence among COVID-19 cases and equity market returns of all the sample countries except Turkey, and specified short-run and consistent long-run coherence of USA COVID-19 cases with Brazil, France, India, and Turkey stock markets returns, respectively. Furthermore, this study will augment the knowledge of the policy maker to ward off crises created by any future pandemic by their understanding of the stock market reaction to such unwarranted situations. This study will also guide the investment professional in making the right decision to mitigate risks arising from the pandemic.

Keywords COVID-19 · Pandemic · Financial Markets · Wavelet · Stock Returns

1 Introduction

The COVID-19 outbreak has adversely influenced global financial markets. Stock markets have been highly volatile due to the pandemic's uncertain future. The COVID-19 epidemic has numerous implications, and its long-term effects on the economy, especially those on the financial markets, are unknown. Suddenly, the

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pandemic is acknowledged as a cause of climate change, economic crises, and material and global risk. As the European Commission stressed in its consultation on the RSFS (Renewed Sustainable Finance Strategy), the ongoing COVID-19 highlights the urgency to reduce and manage environmental and climate risks, which can be compatible with the solutions offered by sustainable finance. According to Doni and Johannsdottir (2021), the insurance sector observes that possible measures will be required to reduce the consequences of events caused by extreme weather and associated repercussions on the global supply chain. Investment in renewable energy, green technology, and new sustainable sectors that are capable and can aid in the global economy's rapid transition towards decarbonisation (UNEP, 2020), investors can help countries and communities rebuild economies and societies in a more sustainable and resilient manner than they did before the crisis. The COVID-19 pandemic brings to light systemic risk (Johannsdottir & Cook, 2019; Thurm et al., 2018).

In the essence, sudden changes in supply and demand in the world have severely impacted the interdependencies of financial markets, which has hampered stock indices worldwide (Liu et al., 2020). In addition, the fall in the price of crude oil has also affected the world financial markets. The pandemic outbreak weakened oil price demand due to the global sluggishness of economic activities. World stock markets plummeted more than 10% due to fears created by the oil price war and news of daily deaths, especially in the US, India, Brazil, France and Turkey (Richardson, 2020). The unfortunate situation due to COVID-19 demands a comprehensive investigation of the impact of a pandemic on the stock markets of most affected countries, as volatility in the stock markets will have a spillover effect on other dependent markets as contemporary economies are strongly interconnected (He et al., 2020a, b). Furthermore, the current pandemic can create systematic risk. Therefore, its financial effects need to be studied. (Sharif et al., 2020).

The linear and non-linear causal linkage among international stock markets due to events like COVID-19 can be utilized to diversify the systematic market risk of a portfolio and hence are of utmost importance. This pronounced interest may be explained by two reasons. Firstly, in response to the expansion of cross-border commerce and trade, financial globalization has been marked by a flow in capital surges across markets. In response, investors search for global instead of national assets allocation. Meanwhile, modern financial theories i.e., CAPM (Capital Asset Pricing Model) and APT (Arbitrage-Pricing Theory) support the reflective influence of correlation patterns of risk and return magnitudes and thus of asset allocation and diversification strategies (Lintner, 1965; ROSS, 1976; Sharpe, 1964). So, to condense portfolio hazards by diversification, an accepted requirement is the lowest correlation coefficient among the returns of different assets. The favourable outcomes from an international portfolio are associated with the extent of correlation among the spotted assets. In order to create the most favorable portfolios, investors are hence prompted to comprehend and observe the possible correlations and linkages among international financial markets (Bessler & Yang, 2003; Forbes & Rigobon, 2001; Forbes & Rigobon, 2002; Kiviaho et al., 2014).

In the discussed context, very few studies are available on the nature of the stock market response due to the pandemic. However, few studies have attempted

to determine the impact of COVID-19 in the context of the environment, cryptocurrency, oil price, temperature, and financial markets. However, the literature confirms the unprecedented financial and economic impact and dramatic increase in market risk because of the recent pandemic (Zhang et al., 2020). For example, (Sharma et al., 2021) investigated coherence among COVID-19 cases and exchange rates of highly affected countries from COVID-19 in the frequency-time domain by employing data for three and a half months, i.e., February to Mid of May 2020. For instance, Sharif et al. (2020) examined the impact of COVID-19 on the US stock market. Khan et al. (2020) found that stock returns of sample countries were negatively related to weekly infections of COVID-19. In addition, several empirical studies have confirmed the pandemic's negative impact (Alber, 2020; Anh & Gan, 2020; Ashraf, 2020; Rahman et al., 2021).

The quickly growing literature on the possible impact of the pandemic has few limitations related to the available data set. First, these studies report long-run coherence between the studied variables despite using a short data span. In contrast, the methodology used cannot observe the long-run dynamics. For equity returns, stochastic features should be dealt with adequately with a long testing memory. Otherwise, it is impossible to draw reliable conclusions (Berg & Lyhagen, 1998). Second, to interpret the phases, the arrows of the wavelet plot indicate positive (arrow towards the right side), negative (arrow towards the left side), first series leading (upward arrow) and first series lagging (downward arrow) trends between the series (Vacha & Barunik, 2012). In contrast, the empirical literature employing wavelet methods discusses leading and lagging trends among the series and right and left dependence without arrow visualizations. Thus, further work is required to utilize the current prolonged data, and wavelet-transformed coherence to investigate better the relationship between several deaths and stock markets of most COVID-19-affected countries.

The objective of the current study is to examine the interdependencies of COVID-19 deaths and equity markets in the five most COVID-19-affected countries by applying the wavelet method to daily data on the number of deaths from January 2020 to July 2021 daily stock return. Our sample countries are geographically widespread on the world map and represent four continents- Asia, Europe, and North and South America. Furthermore, the study sample includes the US, the biggest economy in the world, whose markets have spillover effects worldwide (Syriopoulos et al., 2015). It is established that sensitive countries' commodity-price changes are correlated with the US bullish and bearish markets (Aloui et al., 2011). Oil price shocks due to COVID-19 have severely hit global financial markets. The most significant slump in oil prices since the Gulf War and traumatic news of patient deaths from the US, Brazil, India, France, and Turkey triggered the free fall of world stock markets. India and USA are two major world oil importers with large stock markets. Therefore, the impact of COVID-19 on the financial markets of these countries will provide insights, particularly for the countries which heavily depend on oil imports. Brazil and Turkey are emerging economies severely affected by the pandemic, which requires a comprehensive analysis of COVID-19 impacts on their stock markets. Including one advanced European economy in the sample represents a region severely affected by the pandemic since its emergence.

European stock markets are strongly correlated; therefore, the findings of this study is equally applicable to the whole region. We are confident that the result obtained in this study help in framing policies for other developed and developing economies of the region and elsewhere in the world. Furthermore, this paper is essential for policymakers and investors because they conceive COVID-19 as a risk for stock market behaviour. Second, the current study captures the lead-lag relationship between the variables with respect of time and frequencies. The current investigation helps understanding two research questions: 1) The nature of cyclical behavior between the studied time series; 2) The type of causality among the variables. On the other hand, the traditional method states the simple average relations over time (ul Husnain & Khan, 2021). Finally, instead of using several daily deaths as standard practice in COVID-19-related studies, we focus on daily cases as stock market returns are more sensitive to COVID-19 cases than deaths (Alber, 2020).

In the discussed context, objective of the current study attempts to empirically investigate the dependence pattern of the COVID-19 pandemic and financial equity markets of the top 5 COVID-19 affected countries by applying a novel wavelet technique to daily stock returns and COVID-19 cases. The current study contributes to the existing literature about the financial implications of the COVID-19 pandemic by presenting positive/negative, long/short-run, and leading/lagging dependence of COVID-19 and financial equity markets of the top 5 COVID-19-affected countries. We exposed a negative impact of COVID-19 cases on the stock returns of all the selected nations with specific short-run and consistent long-run coherences.

2 Literature Review

The literature about the impact of COVID-19 on financial institutions, especially the stock market, is quickly growing. The massive losses incurred by COVID-19 to financial markets have recently attracted researchers' interest in studying its impact on stock markets (Liu et al., 2020) as stock markets are a strong predictor of the economy as they can predict the unique future of a firm. Decision-making in the financial markets strongly depends on risk and uncertainty. Capital accumulation in the financial sector is negatively associated with bad news in stock markets, which can be avoided by reducing the number of transactions in the stock market, especially when the risk is global (Ashraf, 2020). According to the Efficiency Market Hypothesis (EMH), stock prices quickly reserve all available information. At the same time, in behavioral finance, psychological biases may force investors to take irrational decisions by exaggerating information (Rahman et al., 2021). According to (Goodell, 2020), financial markets are correlated with several economic aspects of COVID-19. Using the coherence wavelet method, Sharif et al. (2020) studied the connectedness between the current pandemic and macroeconomic variables in the US over the low-frequency bands. They reported an unprecedented sensitivity of the US stock market. Salman and Ali (2021) examined the impact of COVID-19 on the stock markets of GCC (Gulf Cooperation Council) using a non-parametric Mann–Whitney test. They concluded that COVID-19 negatively

affects GCC stock markets in the short run. However, GCC stocks were relatively less affected compared to the impacts witnessed in global stock markets. However, due to fluctuations in the Chinese stock market, bidirectional spillover effects were observed in the GCC stock markets.

Several studies investigated the pre-pandemic, after pandemic, and the global influence of COVID-19 on financial markets (Ali et al., 2020; Alzyadat & Asfoura, 2021; Ashraf, 2020; Bora & Basistha, 2021; Chang et al., 2020; Chowdhury et al., 2022; Cox et al., 2020; Goodell, 2020; Xu & Lien, 2022; Yousfi et al., 2021; Zaremba et al., 2021). Alzyadat and Asfoura (2021) evaluated the impact of COVID-19 on the Saudi Arabian stock market using daily data on pandemic infection from March 15, 2020, to August 10, 2020. Utilizing the Vector Auto-Regressive (VAR) and Autoregressive Conditional Heteroscedasticity (ARCH) models, they discovered a negative correlation between stock market performance and the recent epidemic.

The universality of the current pandemic is causing significant losses to financial markets, and all countries have designed various strategies to mitigate the impact of the pandemic (Aslam et al., 2020). The stock market's behavior did not react, though it might look insane, irrational, and random at first glance (Capelle-Blancard & Desroziers, 2020). Cox et al. (2020) described stock market movements during COVID-19 as "more reflective of sentiment than substance." Using data from the US, China, France, Italy, Japan, South Korea, Germany, and Spain on daily returns and stock markets, He et al. (2020a, b) showed the negative impact of COVID-19 on stock markets of all countries in the short run. Pakistan's stock return responded positively during the pandemic due to the timely and effective intervention of the concerned authorities, which saved investors' gains (Waheed et al., 2020). Chinese stock market returns showed high volatility during the pandemic compared to France, Russia, India, Brazil, the US, South Korea, Thailand, Singapore, Hong Kong, and Australia. However, the different impacts of COVID-19 were reported across different stock markets (Khanthavit, 2021). In emerging markets, the negative impact of COVID-19 first falls and then gradually tapers off because of the size of the stimulus package and the timely response of governments to mitigate pandemic effects (Topcu & Gulal, 2020). Growth in infections and deaths in the USA and six other pandemic-affected countries is not negatively associated with US market return. When global markets were free-falling, the Chinese market was stabilizing, especially in the latter stage of the pandemic (Ali et al., 2020). In their findings, ALAM et al. (2020) showed that the Indian stock market reacted positively to the lockdown period, whereas in the pre-lockdown period, panic engulfed investors. Gormsen and Koijen (2020) find that there is no or very low association in the case of Chinese and European Union stock markets. Khan et al. (2020) reported that in the early days of the pandemic, no reaction was witnessed between media news of COVID-19 and the stock markets of 16 countries. Investors' confidence in the Shanghai stock exchange was restored by the Chinese government's timely intervention to curb the pandemic's spread.

Yousef (2020) revealed that stock markets in G7 countries were more volatile during a pandemic. The pandemic observed high volatility in India, Japan, Hong Kong, Singapore, Russia, and South Korea stock markets (Bora & Basistha, 2021; Sharma, 2020). In the case of 67 countries worldwide, Zaremba et al. (2021)

unearthed an increase in stock volatility as a response to government measures to curb the pandemic. Likewise, Baek et al. (2020) showed high fluctuations in the USA stock market due to both negative and positive news impacts of COVID-19, with stronger effects of the earlier. European stock markets are susceptible to the changes in the news of the pandemic (Ambros et al., 2020), and similar behavior was identified in Nigerian stock markets (Jelilov et al., 2020). Engelhardt et al. (2021) revealed increased volatility in global financial markets due to increased announcements of pandemic infection.

Stock prices have shown a strong relationship with COVID-19 (P. He et al., 2020a, 2020b). The pandemic's noteworthy impact on the stock prices of important Chinese sectors, including electricity, mining, and transportation. On the other hand, sectors like health, education, and manufacturing grew during the pandemic. In the Egyptian stock market, sectoral indices were highly sensitive to the cumulative mortality indicators compared to daily health cases and newly infected cases (Elsayed & Abdelrhim, 2020). Mazur et al. (2021) revealed that high positive returns were observed in the US sectors like healthcare, gas, software, and natural gas, while stock values of hospitality, entertainment, real estate and petroleum sectors saw a significant fall. Huo and Qiu, (2020) and Baker et al., (2020) stated that COVID-19 surpassed the previous outbreaks, including Spanish flue, in terms of negative effect on the US stock market due to social distancing and restrictions on business activity to curb measures imposed to check the spread of the pandemic. In the Turkish stock market, share prices of banking, insurance, machinery, and supports sectors were devastatingly affected by COVID-19. In contrast, retail trade, food-beverage and real estate investment sector were less affected by the pandemic (Öztürk et al., 2020). In Indonesia, Saputra et al. (2021) found a significant difference in average trading frequency and trading volume activity in pharmaceutical stocks. In China, stocks with lower institutional ownership were more reactive to pandemics.

Xu and Lien (2022) examined the implications of COVID-19 pandemic for dependence of foreign exchange in case of Russia, Brazil, China, India and South Africa (BRICS) economies. With supposition of a long-run association among variables, Chowdhury et al. (2022) concluded more exposition of the US stock market to COVID-19 relative to the rest of the world. Garcin et al. (2023) used several statistics with divergence, and determined the TVD (Time-Varying Density) by employing different stock indices, and observed a strong impact of COVID-19 pandemic on financial market of US while weak impact on financial market of China with a weak recovery in the European financial markets.

3 Data and Methodology

The COVID-19 infection due to coronavirus (SARS-CoV-2) significantly damaged the world financial stock markets and the global economy (Chang et al., 2020). Consequently, global financial markets face significant uncertainty, extreme volatility, and fear. In the essence of the newly emerged interrelation between the COVID-19 pandemic and financial equity markets, the key objective of the current study is to empirically examine the long/short-run, positive/negative and leading/lagging

Table 1 Sample description.
Source: Yahoo Finance and our world in data

| Country | Equity stock exchange | Stock returns symbol | COVID cases symbol |
|-------------------------|-----------------------|----------------------|--------------------|
| United State of America | NYSE | UR | UC |
| India | NIFTY-50 | IR | IC |
| Brazil | IBOVESPA | BR | BC |
| France | FCHI CAC-40 | FR | FC |
| Turkey | BIST-100 | TR | TC |

dependence of COVID-19 and financial equity markets of the top 5 COVID-19 affected countries (i.e., USA, India, Brazil, France, and Turkey) by using a novel method of wavelet transformed coherence (WTC). Equity returns daily data from NYSE, NIFTY-50, IBOVESPA, FCHI CAC-40 and BIST-100 were obtained, while country-wise COVID-19 daily death data were collected from “our world in data” from January 22, 2020, to March 31, 2022. For detail of the top 5 most affected countries by COVID-19, their respective equity markets and stock return and COVID- 19 symbols, see Table 1.

4 Wavelet Transformed Coherence

To achieve the purpose of the study, this paper adopts an innovative bivariate technique to wavelet transform coherence (WTC) with its unique ability to handle short/long run, positive/negative, and leading/lagging dependent patterns of the time series. WTC is getting significant attention, as the linear (traditional) correlation model normally provides spurious results by avoiding the large and small realization of the time series (Poon et al., 2003), while WTC has unique characteristics of coping with time/frequency domain simultaneously (Gençay et al., 2001). Moreover, the wavelet methodology is an advancement of the Fourier series (Fourier work, 1807), who first introduced a novel approach to studying a time series. In continuation, (Haar et al., 2009) explored a time series’ time and frequency domains through a wavelet framework for the first time, while C Torrence and Compo (1998) added quantitative efficacy to the model. In addition, wavelet application gives a defined and valuable revelation of an event unconditional to the supposition of stationarity (Mallat, 1989). Thus, to avoid the spurious results and stationarity reservation of traditional models, Bodart and Candelon (2009) recommend a useful and novel application, i.e., a wavelet framework. Most recently, Goodell and Goutte (2021) used the wavelet framework to assess the co-movement of Bitcoin and COVID-19.

Wavelet is the most suitable framework for unveiling the emerging linkages between COVID-19 and financial equity markets. Ranta (2010) quoted that naturally financial time series data is the belief of multi-scale attributes like a financial time series that contains several compositions where each arising from a different time

range. The wavelet method has the property to decompose the series into different sub-series that may be linked to a particular time scale. He further quoted that Wavelet method works with these differentiated time-series that otherwise might not be notable. Wavelet methodology is more relevant to noise than competing frameworks (Graham et al., 2012).¹ To obtain the significance of the dependence supported by AR (0) and AR (1), we use Monte-Carlo simulations as used by (ul Husnain & Khan, 2021). A mother wavelet is decomposed into minute (small) waves² to represent time and position scales in the wavelet framework.

$$\Psi_{t, s(m)} = \frac{1}{\sqrt{m}} \Psi \frac{m-t}{s} \tag{1}$$

The normalisation factor is represented by $\frac{1}{\sqrt{m}}$, while t represents translation and scale parameters.

CVT (continuous wavelet transform) for a specific time series $f(r)$ regarding $\Psi(k)$ would take the following form;

$$\Psi_{t, s(m)} = \frac{1}{\sqrt{s}} \int_{-\infty}^{+\infty} f(m) \Psi^* \left[\frac{m-t}{s} \right] dm \tag{2}$$

Wavelet power spectrum (WPS) byC Torrence and Compo (1998) indicates the interdependences among any two-time series, i.e., TR_1 and TR_2 . It can be written as $|W_{i(t,s)}|^2$. At the same time, WTC indicates leading/lagging and reciprocal relationships among the two series both in the domains of time and frequency (Christopher Torrence & Webster, 1999). Wavelet transformed (WT) in case of any two series such as COVID-19 and equity stock market [i.e., $WT_1(t,s)$ and $TW_2(t,s)$] is given as;

$$W_{1,2}(t, s) = \frac{|V((m^{-1}W1, 2(t, s))|^2}{V(m^{-1}|Wi(t, s)|^2) * M(m^{-1}|W2(t, s)|^2)} \tag{3}$$

where t represents translation, s represents the scale, and V represents smoothing parameters, 1 and 2 indicate time series 1(stock market equity) and time series 2 (COVID-19). Graphical representation of the esteem model can be as follow;



¹ For further details, see Tiwari (2012) work.

² For a detailed understanding of mother wavelet decomposition and wavelet framework, see the work of Grinsted et al. (2004).

Table 2 Descriptive statistics

| Variable | Mean | Std Dev | Minimum | Maximum |
|----------|------------|------------|----------|-----------|
| UC | 14,328,983 | 12,443,432 | 1 | 3,364,746 |
| UR | 0.000600 | 0.0123233 | -0.11834 | 0.1003649 |
| IC | 7,647,635 | 7,843,256 | 1 | 2,987,674 |
| IR | 0.000903 | 0.013454 | -0.1298 | 0.0876321 |
| BC | 6,645,826 | 5,435,678 | 1 | 1,797,373 |
| BR | 0.001232 | 0.012343 | -0.0512 | 0.0308932 |
| FC | 1,974,636 | 2,435,678 | 2 | 5,998,765 |
| FR | 0.000432 | 0.01439 | -0.12277 | 0.0838948 |
| TC | 1,563,536 | 1,543,654 | 1 | 5,673,546 |
| TR | -0.00232 | 0.053454 | -0.98997 | 0.0598247 |

The table presents arithmetic mean, standard deviation, minimum and maximum values of COVID-19 cases and financial equity market returns for the top 5 countries affected by COVID-19

5 Results and Discussion

Table 2 represents descriptive statistics of COVID-19 total cases and equity stock market returns for the 5 top affected countries from COVID-19. Based on the observed COVID-19 cases, the USA is at the top. At the same time, India, Brazil, France, and Turkey are at 2nd, 3rd, 4th and 5th positions, respectively.

After observing data attributes (descriptive statistics) of total COVID-19 cases and equity market returns, the results of the Pearson correlation coefficient are available in Table 3. The table reports that France's total COVID-19 cases are significantly related to France's equity market return with a coefficient of -0.123 . The table further reports that Indian and Turkish equity returns are significantly related to the USA's total COVID-19 cases with coefficients of -0.130 and 0.021 , respectively.

After correlation estimates, to examine short/long run, positive–negative, and leading/lagging linkages among COVID-19 cases and equity market returns and to avoid spurious results of traditional linear regression, WTC is applied. Figure 1a–e show wavelet coherence for COVID-19 cases and equity stock market returns of USA, India, Brazil, France, and Turkey, respectively. Figure 1a–e reveal particularized short-run and consistent long-run coherence among COVID-19 cases and equity market returns of all the sample countries except Turkey. The most significant and notable islands in the short run (4–16 days) can be observed in Fig. 1a, indicating the rapid reaction of the US stock market to the early news of the COVID-19 pandemic. Overall, we observed small, particularised islands in the short run (i.e., 4–16 days) from the beginning to end, indicating the stock market's reaction to the incoming news (COVID-19 pandemic) from Wuhan city. Which is referred to coherence by (Al Shugaa & Masih, 2014; Albulescu et al., 2013; Forbes & Rigobon, 2001; Ftiti et al., 2014). As the Covid-19 cases emerged and accelerated with time, USA, India, and France stock indices tended to react to the bad news in the long run as well negatively (i.e., 32 to 128 days). In contrast,

Table 3 Linear correlations

| Pearson correlation coefficients | | | | | | | | | | |
|----------------------------------|--------|----------|----------|-----------|----------|----------|---------|----------|--------|----|
| | BR | BC | FR | FC | IR | IC | TR | TC | UR | UC |
| BR | 1 | | | | | | | | | |
| BC | -0.022 | 1 | | | | | | | | |
| FR | 0.029 | -0.034 | 1 | | | | | | | |
| FC | -0.034 | 0.054 | -0.123** | 1 | | | | | | |
| IR | 0.032 | -0.023 | 0.145** | -0.043 | 1 | | | | | |
| IC | -0.090 | 0.098 | -0.054 | 0.543*** | -0.130 | 1 | | | | |
| TR | 0.034 | 0.005 | 0.134** | -0.024 | -0.001 | -0.003 | 1 | | | |
| TC | 0.043 | 0.237*** | -0.009 | 0.055 | -0.031 | -0.020 | 0.045 | 1 | | |
| UR | 0.028 | 0.000 | 0.405 | -0.197*** | -0.132** | -0.110** | 0.145** | -0.010 | 1 | |
| UC | -0.090 | 0.069 | -0.097 | 0.453*** | -0.130** | 0.139** | 0.021* | 0.260*** | -0.056 | 1 |

*, **, and *** represent significant at 90%, 95% and 99% respectively

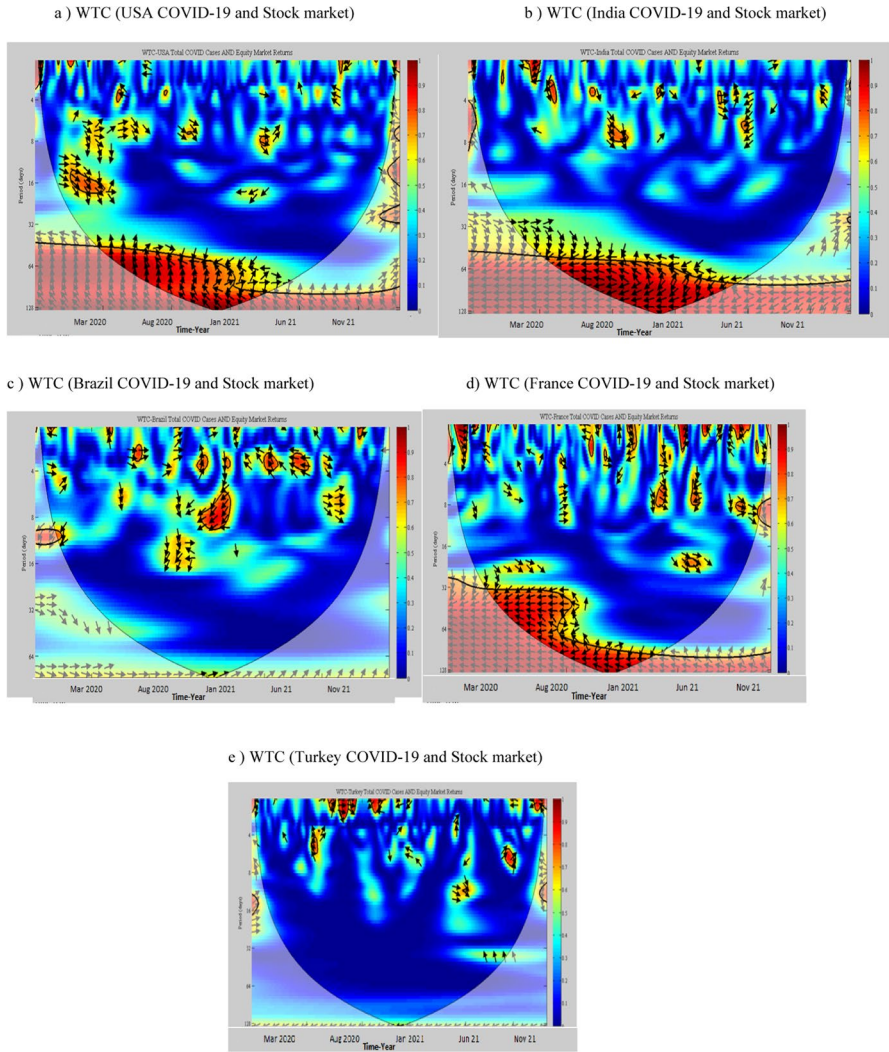
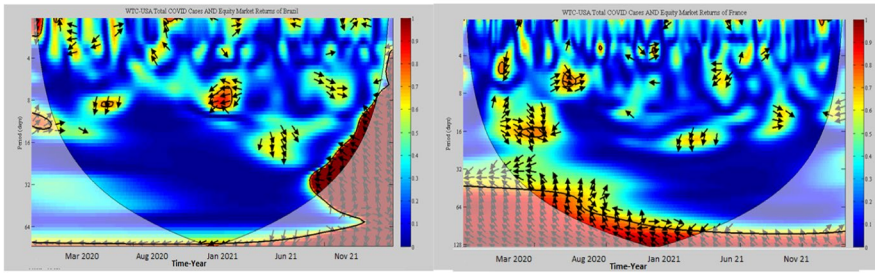


Fig. 1 WTC COVID-19 and Equity Stock Market Returns. **a** and **b** Combinations for dependence patterns for COVID-19 and equity stock market returns of the USA and India, respectively. Both the figures reveal specified ties between COVID-19 cases and financial equity markets in the short run. Furthermore, both the figures highlight significant negative coherence among COVID-19 and equity market returns in the long run, i.e., in the frequency domain of 32 to 64 days. **c** and **d** Mixtures of association for COVID-19 cases and Brazil and France’s equity stock market returns, respectively. A short-run specified mixture of dependence may be observed in the case of both countries. Furthermore, France’s COVID-19 cases negatively correlate to France’s equity market returns in the long run. In contrast, Brazil COVID-19 cases remain insignificant to Brazil’s equity market returns in the long run, i.e., in the frequency domain of 32 to 64 days. **e** Highlights the dependence pattern of Turkey’s COVID-19 cases and Turkey’s stock market returns. The figure shows coherence in the short run while there is no significant coherence in the long run

a) WTC (USA COVID-19 and Brazil Stock market) b) WTC (USA COVID-19 and France Stock market)



c)WTC (USA COVID-19 and India Stock market)

d) WTC (USA COVID-19 and Turkey Stock market)

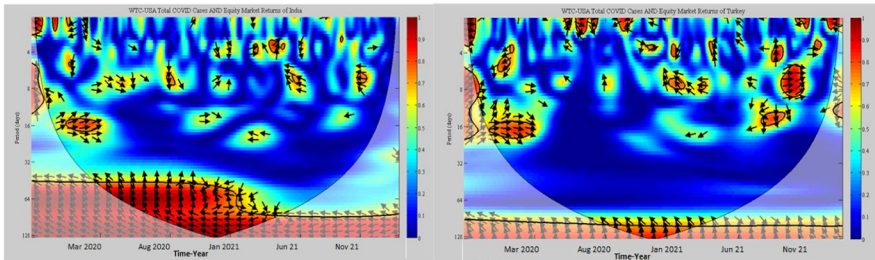


Fig. 2 Wavelet Transform C USA COVID-19 Cases with Brazil, France, India, and Turkey Equity returns. After observing the significant correlation coefficient of USA COVID-19 cases with India and Turkey equity market returns, the study presents wavelet coherence for USA COVID-19 cases with Brazil, France, India and Turkey in Figures a–d. **a** and **b** Coherence of USA COVID-19 cases with Brazil and France's equity stock market returns, respectively. Both the stock markets show particularised coherence with USA COVID-19 cases in the short run and a consistent negative coherence in the long run. **c** and **d** Coherence of USA COVID-19 cases with equity stock market returns of India and Turkey, respectively. Both the stock market indices show a particularized mixture of coherence with USA COVID-19 cases in the short run and a significant negative dependence in the long run, i.e., in the frequency domain of 32 to 64 days

Brazil and Turkey stock indices showed no long run coherence with COVID-19 bad news.

Furthermore, the study presents wavelet coherence for USA COVID-19 cases with Brazil, France, India, and Turkey stock indices in Fig. 2a–d. As the bad news of COVID-19 emerged, Brazil, France, India, and Turkey's stock market indices were implicated in the USA COVID-19 cases, as were their domestic equity market returns. Figure 2a–d show specified short-run and consistent long-run coherence of USA COVID-19 cases with Brazil, France, India, and Turkey stock markets returns, respectively. (Al Shugaa & Masih, 2014; Forbes & Rigobon, 2001) referred these short-term co-movements to contagion and further stated that these can only be observed in the time of financial distress i.e., sovereign debt crises and global financial crises etc.

Based on the research objective, the current study empirically investigates the dependence pattern of COVID-19 pandemic and financial equity markets of the top 5 COVID-19 affected countries by applying a novel wavelet technique to daily stock

returns and COVID-19 cases. The current findings exposed negative consequences of COVID-19 cases for the equity markets of all the five selected countries. The obtained patterns between financial equity markets and COVID-19 cases has also some theoretical implications. First of all, by clarifying the complex relationship between a public health crisis and economic indicators, the obtained findings extend our understanding of complex systems and market forces. By offering short/long run and empirically presented coherence patterns for understanding the relationships between the pandemic and equity market behavior, the current study can benefit prolong the domains of economics, epidemiology, and multidisciplinary studies. The obtained results also provide insights into how human conduct and the equity markets are interrelated and can effect each other's. Furthermore, the current findings advance our current theoretical knowledge of how societies respond to crises and adjust to changing conditions by looking at the societal ramifications of these interactions, such as international collaboration, investment decisions, resource allocation, and risk management. Overall, the current study enriches theoretical understanding by spanning disciplinary boundaries and providing fresh insights into the interactions between health, pandemic, global health crises and equity market.

6 Discussion

The pandemic has caused much suffering for humanity, which needs to be ascertained. The economy has been hard hit, and the global financial market has also witnessed its worst performance since the pandemic's start. The current study applies the wavelet methods to demonstrate interdependencies between COVID-19 and equity markets of the five most affected COVID-19 countries using data on daily cases and daily stock returns. A strong negative relationship is observed between COVID-19 cases and stock markets. The negative influence of COVID-19 cases and equity market returns are consistent with the previous findings by Chien et al. (2021) and Yousfi et al. (2021). DeLisle (2003) estimated the cost of the 2003 SARS outbreak to Asian financial markets to equal \$3 trillion and \$2 trillion in terms of GDP and financial markets equity. Nippani and Washer (2004) reported a negative impact of SARS on the stock market of China and Vietnam.

In contrast, Macciocchi et al. (2016) showed a mild negative economic impact of the Zika virus outbreak in Argentina, Mexico, and Brazil. Furthermore, during the SARS outbreak, a steep decline was seen in Taiwanese hotel stocks' income and stock prices (Chen et al., 2007). Likewise, the negative impact of infectious diseases was observed on Taiwanese biotechnology stock (Wang et al., 2013).

During pandemics, stock markets show interdependence and close cross-market correlations. The study found that US COVID-19 cases are more associated with Brazil, France, India, and Turkey equity market returns. Chen et al. (2018) found the time-varying contagion effect of the Chinese market with Asian markets during the SARS epidemic. Using data from nine Asian markets, Chiang et al. (2007) found a high correlation between the daily stock returns of the sample countries during the crisis period. They reported strong integration of Southeast Asian financial markets

with China. The crisis in the financial market spreads to another due to the strong interdependence of global stock markets.

The findings reveal particularized short-run and consistent long-run coherence among COVID-19 cases and equity market returns of all the sample countries except Turkey. The consistent long-run coherence in the US, India and France stock indices may be attributed to the overall consequences of the COVID-19 pandemic worldwide. The findings (reliance of these stock indices on US COVID-19 cases) validate (Felmingham & Grüneberg, 2000), who indicate more association among financial markets during the crises.

The answer to why financial markets suffered due to COVID-19 lies in understanding the constraints faced by businesses and firms during the pandemic. First, enterprises become illiquid, forcing companies to resort to staff reduction or complete closure. Second, investors consider stock prices as a source of future earnings while they perceive pandemics as a threat to future revenue (Liu et al., 2020). Third, investors become pessimistic about investment prospects in a given market and resort to selling off the market's stock during the pandemic (Baker et al., 2012). In culturally susceptible countries, the role of investor sentiment in the context of the stock market is crucial (Donadelli et al., 2017).

The current findings on the investigation of the dependence patterns between financial markets and COVID-19 cases have great potential to benefit society in several ways. First, it can notify financial regulators and public health experts of impending virus waves or market volatility, acting as an early warning system. Using this information, policymakers can create well-balanced measures that reduce economic disturbance while slowing the virus's spread. Furthermore, realizing this connection improves public health messaging by emphasizing the economic effects of the epidemic and allows for more effective resource allocation and informed investment decisions. In addition, better risk management techniques can also help firms and data exchange and cooperative solutions can promote international cooperation. In the end, by detecting and correcting differences in the effects of COVID-19 cases on various societal sectors, this research may advance health equity.

7 Conclusion and Policy Suggestion

The situation caused by the pandemic requires a consolidated effort from all the stakeholders to ward off such a crisis, safeguard the economy, and mitigate financial risks. By uncovering the relationship between COVID-19 cases and stock returns in the 5 most-affected COVID19 economies, we provide insight for policy makers to intervene to protect stock markets from the future COVID-19 pandemic and similar outbreaks. The covid-19 spread control measures such as lockdowns and constrained economic activities caused supply chain disruptions, stock return fluctuations, and economic slowdown. Policymakers would tend to offset these effects along with containing the transmission of the virus (Huang et al., 2020). Collaborative action from central banks, government officials and investment regulators can tackle this challenge. Massive bailout packages and current rolling loans will ensure

sustainability and economic activity, especially to more vulnerable sectors like travel and tourism. Officials require a logical approach to contain the spread of the pandemic. For example, they can inform people how to behave during a pandemic without triggering uncertainty.

The current results regarding the five series identify various risk management signals regarding assets allocation theory and investment. The current results i.e., symmetric tail dependence of the five countries with their death rates and the US Stock returns have various policy implications for portfolio managers, international investors and risk managers as tail independence has no concerns with systematic risk during the highly turbulent eras. To get diversified portfolio, international investors may take a short position on investing in these stocks in order to overcome the extreme losses.

Our analysis presents perspectives for further research on the economic effects of COVID-19 to bolster investor confidence. A behavioral study of investors' attitudes toward the pandemic's uncertainty can aid in comprehending investors' apprehensions. In addition, the impact of health officials' announcements on investors' decisions could potentially be a fascinating issue for future study. Using the most current and extensive data sets, we can also extend our analysis by examining the regional effects of the pandemic on financial markets. The current study is not free from some caveats that can be addressed in future. The study focused on only on death rates of the affected countries, future studies can also take account of other economic and health related variables.

Funding No fund receives from any source.

Data Availability Data will be made available upon request.

Declarations

Conflict of interest I have no conflict of interest to disclose.

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