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COVID-19 pandemic waves and global financial markets: Evidence from wavelet coherence analysis

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ABSTRACT

This paper investigates the connectedness between the COVID-19 outbreak and major financial markets within a time-frequency framework. Wavelet coherency analysis unveils perceptual differences between the short-term and longer-term markets' reactions. In the short-run, we find strong co-movements during the first and second waves of the pandemic. During the first wave, longer-term investors were driven by the belief of future pandemic demise. They make use of time diversification that results in positive returns. The US being the new coronavirus epicenter, we also find that the US COVID-19 fear spills over into the international markets. Gold, SSE, and cryptocurrencies seem safer investments.

1. Introduction

Coronavirus (COVID-19) is one of the most severe pandemics throughout human history. The pandemic first broke out in China. While the disease propagation has gradually reduced in its birthplace, it has continued spreading to other countries causing unprecedented deterioration in global financial markets. As financial markets react to any “black swan” risk, fluctuations in one stock market might adversely influence back on others due to the breadth and depth of interdependence among contemporary economies. In the United States (US), the number of new infection cases has risen dramatically since March 2020. As a result, the broader SP500 index fell into a bear market, falling 20% from a prior high. The European markets suffered similar slumps, with exchanges in Paris and Frankfurt dropping by more than 12% and London’s FTSE index losing nearly 11%. At the time of writing this article, the US ranks first worldwide in the number of new COVID-19 cases and confirmed deaths. Being the largest international equity market, US market local fear may understandably spill over into the international financial markets.

A new stream of research emerged in the literature examining the effects of the COVID-19 outbreak on the financial markets. Limited to the first wave of the pandemic, this literature gives mixed results. Albulescu (2020) and Baker et al. (2020) showed that the COVID-19 pandemic significantly deteriorates the US market stability and drives the tremendous recent surge in stock volatility, the third-highest recorded peak since 1900. Ashraf (2020), using data from 64 countries, found that stock markets responded negatively to

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1 Refers to highly unpredictable events with severe effects on stock markets, money markets, and the general economy (Taleb, 2010).
the growth in COVID-19 new cases. Likewise, Ali et al. (2020) found that even safer commodities like gold are negatively related to COVID-19 deaths. They also assert that the Chinese market recovered very quickly as the virus spread to other parts of the globe. Contrary to them, Al-Awadhi et al. (2020) showed that COVID-19 has significant negative effects on all Chinese stock returns for the same period. Ji et al. (2020) demonstrated that commodity returns increased during this pandemic and that gold remained robust as a safe haven asset. Goodell and Goutte (2020) highlighted that the COVID-19 levels caused a rise in Bitcoin prices, whilst Corbet et al. (2020) found that Bitcoin does not act as a hedge or safe haven.

Further, given the interconnectedness of financial markets, another issue treated by the literature is the contagion effects caused by the COVID-19 uncertainty. Evidence has been amassed to support the existence of strong volatility spillovers, which rise sharply and abruptly during periods of stress triggered by the COVID-19 (Adekoya and Oliyide, 2020; Akhtaruzzaman et al., 2020; Bissoon-Doyal-Bheenick et al., 2020; Corbet et al., 2020). Besides, it is well-established in the financial literature that international investors holding diversified portfolios are responsible for the return and volatility spillovers among the international markets. Through the portfolio-rebalancing channel, any information in one market, altering the volatility in that market, will be transferred to other markets (Fleming et al., 1998). Along the same line of reasoning, as the pandemic epicenter moved from China to the US, the US market COVID-19 related fear could result in portfolio rebalancing and may understandably spill over into the international financial markets. Bai et al. (2021) show that Infectious Disease Equity Market Volatility Tracker (EMVID) has significant positive impacts on the volatility of international stock markets.

Based on the above rationale, we aim in this paper to examine: first, how the COVID-19 impacted the international financial markets during the first and second waves. Second, how did the US financial market local fear spread to the other markets. Similar to Zaremba et al. (2020) and Goodell and Goutte (2020), we employ the wavelet spectrum approach, which provides insights on the analyzed markets volatility and their connectedness to COVID-19 outbreak in the time-frequency domains.

The contribution of this paper is two-fold. First, it extends the scarce literature on the dynamic linkage of sentiment variables, such as fear, and the financial markets in the time-frequency framework. As our sample covers the two waves of the COVID-19 pandemic, our findings may help to understand the full extent of the crisis impact, and to provide better insights for investors, traders, and risk managers. Second, to the best of our knowledge, our paper is the first attempt to investigate the effects of COVID-19 financial contagion originated by the US stock market fear.

Our results prevail the presence of contagion effects between COVID-19 fear and all the considered markets. These effects vary through time and across investment horizons. For most assets, this contagion disappears in the long-run with the start of the second COVID-19 wave. Additionally, our results suggest that the US market acted as the new epicenter for the COVID-19 turmoil.

The remainder of this paper is as follows. Section 2 describes the data. Section 3 outlines the methodology. Section 4 reports and discusses the results. Section 5 concludes.

2. Data

To examine the impact of COVID-19 on financial stock markets, the following stock indices are chosen: the Nikkei 225 (Japan) and SSE (China) to represent Asia, the SP500 to represent the US; CAC40 (France), DAX (Germany), and FTSE (United Kingdom) to track the European market. We included oil (WTI spot) and gold as the most commonly traded commodities and Bitcoin and Ethereum as the two major cryptocurrencies. The global COVID-19 fear is proxied in this study by the daily confirmed COVID-19 deaths as in (Bissoon-Doyal-Bheenick et al., 2020), whilst the fear associated with COVID-19 in the US stock markets is measured by the EMVID index (Baker et al., 2020). The data are on daily frequency and cover the entire pandemic period from January 22, 2020 to January 13, 2021 when assets are traded. Data on cryptocurrencies, oil, gold, and EMVID index are sourced from Federal Reserve Economic Database (fred.stlouisfed.org) whilst COVID-19 deaths data comes from the website of the Johns Hopkins University Center for Systems Science and Engineering data repository. The remaining data are obtained from and Yahoo Finance website (finance.yahoo.com). For each data series, daily returns (r_t) are calculated as $Ln(P_t/P_{t-1}) \times 100$, where $P_t$ is the daily closing price and the COVID-19 deaths are transformed into change rates. Descriptive statistics are reported in Table 1.

3. Methodology

We use the wavelet method to examine the individual volatilities of the selected assets and to determine their co-movements with the COVID-19 pandemic. Firstly, to illustrate the local volatility of the return series in both time and frequency domains, we use the wavelet power spectrum (WPS) plots technique:

The WPS is defined as:

$$WPS_X(\tau, s) = |W_X(\tau, s)|^2$$

(1)

2 Several studies showed that global measures as worldwide daily deaths better assess the COVID fear rather than local measures (Lyöcsa et al., 2020; Albulescu, 2020).

3 https://github.com/CSSEGISandData/COVID-19

4 Since financial markets operate with different holidays, we synchronize the COVID-19 daily deaths and the EMVID with the data of each analyzed asset.
Table 1
Descriptive Statistics.

| Variable     | Mean  | Min   | Max   | Std. Dev. | Skewness | Kurtosis | Jarque-Bera | Obs.  |
|--------------|-------|-------|-------|-----------|----------|----------|-------------|-------|
| COVID death rate | 0.00047 | 0.000178 | 0.2153 | 0.0727 | 4.6097 | 30.538 | 3817.8 | 356 |
| EMVEID       | 12.073 | 0.000000 | 11.239 | 16.69 | 1.5527 | 6.8328 | 134.17 | 357 |
| Bitcoin      | 0.00412 | -0.46862 | 1.36644 | 0.04277 | -3.35246 | 44.349 | 95.47 | 356 |
| Ethereum     | 0.00537 | -0.56378 | 2.4049 | 0.5704 | -2.5427 | 30.914 | 944.08 | 356 |
| Gold         | 0.00068 | -0.05401 | 0.6790 | 0.06221 | 0.03240 | 8.0879 | 264.78 | 255 |
| WTI          | -0.00022 | -0.42588 | 0.42583 | 0.07601 | -0.11991 | 15.377 | 1266.9 | 255 |
| SP500        | 0.00054 | -0.12765 | 0.09686 | 0.02180 | -0.85759 | 11.507 | 618.79 | 255 |
|CAC40        | -0.00024 | -0.13098 | 0.08056 | 0.02087 | -1.1102 | 11.008 | 598.39 | 250 |
| FTSE         | -0.00047 | -0.11512 | 0.08667 | 0.01900 | -0.95488 | 10.304 | 556.31 | 247 |
| DAX          | 0.00013 | -0.13055 | 0.10414 | 0.02120 | -0.86195 | 11.291 | 642.46 | 247 |
| Nikkei       | 0.00069 | -0.06274 | 0.77731 | 0.01632 | -1.6323 | 7.2349 | 171.38 | 245 |
| S$\$            | 0.00069 | -0.09803 | 0.05554 | 0.01335 | -1.0015 | 9.8774 | 504.55 | 236 |

\[
W_X(t, s) = \int_{-\infty}^{\infty} x(t) \psi_s(t - \tau) dt, \quad s, \tau \in \mathbb{R}, \quad s \neq 0
\]  

(2)

\[
WSC = R_{XY}^2(t, s) = \frac{|S(s^{-1}W_{XY}(t, s))|^2}{S(s^{-1}|W_X(t, s)|^2)S(s^{-1}|W_Y(t, s)|^2)}
\]  

(3)

where $S$ is a smoothing operator in both time and scale. $W_{XY}$ is the cross-wavelet power (XWP) which captures the local covariance between the two time series at each scale. The WSC closely resembles a traditional correlation coefficient with $0 \leq R_{XY}^2(t, s) \leq 1$. As the WSC is restricted to positive values, we use the phase differences, $\phi_{XY}$, determining the lead-lag relationships:

\[
\phi_{XY} = \tan^{-1}\left(\frac{\text{Im}\{S(s^{-1}W_{XY}(s))\}}{\text{Re}\{S(s^{-1}W_{XY}(s))\}}\right) \quad \text{with} \quad \phi_{XY} \in [-\pi, \pi]
\]  

(4)

where $\text{Im}$ and $\text{Re}$ are the imaginary and real parts of the smoothed XWP, respectively. Phases $\phi_{XY}$ are indicated by arrows on the WSC plots and reveal the causal direction (lead-lag) relationships between two series. Arrows pointed to the right (left) imply that two time-series move in-phase (out of phase) or are positively (negatively) correlated. Up-right and down-left pointing arrows indicate that the first time series leads the second, otherwise, the second time series is leading.

4. Results and discussion

4.1. Local volatility and COVID-19 fear contagion

Fig. 1 illustrates the WPS of each considered asset, showing its local variance intensity during the COVID-19 pandemic. The time scale is presented on the horizontal axis, while the frequency scale is represented by the vertical axis. This ranges from high-frequency (2–4 days) to low-frequency (32–64 days) bands. The intensity of the spectra is color-coded (blue to red color; low to high intensity). The WPS significance level of 5% is represented by the black contour.

All the analyzed indices exhibit very high and significant volatilities in the first wave of the pandemic (February-March 2020), with big islands of dark colors scattered along the 2–32 days bands. An exception is the SSE index with higher power taking place in July-August 2020 and coinciding with the fear of a new coronavirus outbreak linked to Beijing’s largest wholesale market. Gold, and at a lesser extent Ethereum, show additional power at 4–16 days scale in the August-September period, the mid of the COVID-19 second wave.

Panels of Fig. 2 display the results for the coherency and phase between the COVID-19 panic proxy and the studied assets. Overall, our results show that the connectedness between the global COVID fear and the international markets depends on the considered market and the investment horizons. At the 2–8 days frequency bands there is evidence of high correlation for all markets mostly in-phase. However, comparing the density of red spots, SSE and cryptocurrencies seem the least affected by COVID global fear. For the 8–32 days bands, red spots are almost absent for all assets. Only for cryptocurrencies and FTSE, we observe a significant high correlation in the July-August period, mostly anti-cyclical. In this same period, the correlation is positive (right-turn arrows) for the SSE. Moreover, despite being the first epicenter of the COVID-19 outbreak, the contagion is globally less perceived in the Chinese market as...
Fig. 1. Wavelet power spectra of analyzed assets' returns.
the epicenter moved to the US. For the 32–64 days bands, SSE, WTI, and Gold are no more affected by the pandemic fear, suggesting that these markets can act as safe haven in pandemic times. Cryptocurrencies and Nikkei display high in-phase coherency with the COVID-19 fear, disappearing after June-2020. Although counterintuitive, this positive coherency between COVID-19 deaths and financial markets in the long-run is in line with the findings of Goodell and Goutte (2020) and Sharif et al. (2020). The difference between the investment horizon findings reflects the perceptual differences between the short-term and longer-term investors. Several studies have acknowledged that risk can be considerably reduced if the asset is held over a longer period (Butler and Domian, 1991). In our case, longer-term investors seem to be insulated from short-term market fluctuations induced by the COVID-19 fear. Different from previous crises, during which investors have fled the markets, a common belief about the future possible demise of the COVID-19 pandemic drives the lower-frequency asset movements and results in positive returns. This optimism disappears as experts project an autumn surge in coronavirus cases.

4.2. Financial contagion among US COVID-19 fear and international markets

Fig. 3. shows coherency and phase-difference between the EMVID and the considered international markets. Overall, the degree of co-movements differs across the EMVID-financial market couples and varies among time and frequencies. For the high frequency (2–4 days) bands, there is evidence of strong co-movements between the EMVID and all the studied markets. Exceptions are
Fig. 2. Wavelet coherence and phase of COVID death index and analyzed assets’ returns.
Fig. 3. Wavelet coherence and phase of EMVID and analyzed assets' returns.
cryptocurrencies being the least affected by the EMVID. Thus, these assets could be considered the safest short-term investments in this crisis period. For the 4–32 days bands, gold and Nikkei are the least correlated with EMVID. However, all the remaining markets exhibit periods of high co-movements with the US fear index, especially around June and November 2020 coinciding with the beginning of the second and third waves in the US.\(^5\)

For bitcoin, we find large red islands with predominantly right-turn arrows during the first COVID-19 wave in the US. Around June, at the start of the second US wave, EMVID clearly leads the bitcoin market, suggesting that the more US-COVID-19 fear increases, the more investors ran to bitcoin, considered a safe haven for the US market. Finally, at lower frequencies (32–64 days) high co-movements with EMVID are perceived for the oil, the US, and the European markets. The Asian, gold, and cryptocurrency markets exhibit a high correlation that disappeared after Mai–June with the end of the first wave and the beginning of the second. Moreover, almost all arrows indicate negative correlations, with the EMVID leading the international markets. This result provides evidence of contagion effects as the US market fear caused by COVID-19 is spilling over and driving the financial markets. Sharif et al. (2020) also documented a negative relationship between economic and policy uncertainty and the US stock market in the lower frequencies in the COVID period.

5. Conclusion

In the present study, we used the wavelet approach to investigate the time-frequency connectedness between the COVID-19 outbreak and the major financial markets. Unlike all previous research, our sample covers the first and the second waves of the pandemic. Overall, our results demonstrate the existence of contagion effects between COVID-19 fear and the considered international markets. These effects vary through time and across investment horizons. Interestingly, during the first wave, a common belief of a possible future demise of the pandemic prompted the longer-term investors’ results in positive returns. For most assets, the contagion effects disappeared in the long-run with the end of the first COVID-19 wave. Additionally, our results suggest that fear in the US market spread to all the other markets at the longer investment horizons. Gold, SSE, and cryptocurrencies are notable exceptions and could be good candidates for developing US portfolio strategies. Our findings enrich COVID-19 contagion effects research and give insights to financial market investors and risk managers seeking to manage their portfolios in times of COVID-19.

CRediT authorship contribution statement

Chiraz Karamti: Conceptualization, Methodology, Software, Data curation, Validation, Writing – original draft, Writing – review & editing, Visualization. Olfa Belhassine: Conceptualization, Investigation, Validation, Writing - original draft, Writing – review & editing.

Declarations of interest

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