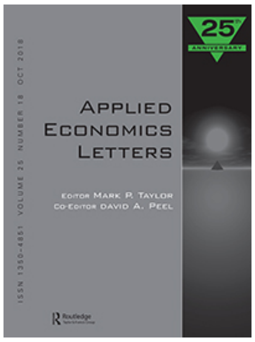

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Time-frequency dynamics of financial market stress and global economic uncertainties: evidence from the COVID-19 pandemic

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ABSTRACT
Given the negative effects of the COVID-19 pandemic on world economies, uncertainties are expected to increase during this period. To this end, we examine the time-frequency dynamics of financial market stress and economic uncertainties. We apply in-sample and out-sample namely; bivariate wavelet and quantile causality to accentuate the importance of economic uncertainties and market stress during COVID-19. We find that both in-sample and out-sample for economic uncertainty drive and pose a high risk to the financial market during COVID-19.

JEL CLASSIFICATION
financial market stress; economic uncertainties; wavelet coherence; COVID-19; quantile causality

KEYWORDS
E60; G10; G18

I. Introduction

The harmful and infectious effects of the invasive coronavirus have had a major impact on the dynamics of the world financial market in recent years (Goldstein et al. 2021). The rapid spread of the virus has resulted in the isolation of people around the world, and other regulations put in place to subvert the spread of COVID-19 and mitigate the associated hardship during the pandemic period contributed to the synchronous collapse of economic activity, thus exacerbating market stress (Armah, Amewu and Bossman 2022). The authors asserted that the effects of the COVID-19 pandemic, which led to a bizarre and unprecedented financial market collapse, exceeded the difficulties of the GFC period. To ease the acceptance of policy measures to combat the disastrous effects of the pandemic and stimulate economic recovery, the crucial role of financial market uncertainty is underscored. During GFC, co-movement in interest rates increases leading to a stress in the financial markets (Chatziantoniou, Gabauer, and Stenfors 2020). This period was associated with significant interest rate changes, promoted by rising risk premia, and accommodating to monetary policy decisions by the central bank to reduce market friction (Chatziantoniou, Gabauer, and Stenfors 2021). Given its macroeconomic predictability, Armah, Amewu, and Bossman (2022) asserted that financial market stress plays a central role in economic activities. Compared to policy uncertainty, which has become a predictive factor in assessing financial market stress (Xiong, Liu, and Liu 2022; Sun, Yao, and Wang 2017), financial uncertainties such as volatility index (VIX) and cryptocurrency volatility (VCRIX), could play a leading role in financial market uncertainty (Yarovaya, Brzeszczyski, and Lau 2016). The adverse impact of the pandemic on market complexity, market uncertainty, and financial market stress during COVID-19 has received little attention in the global literature. It is worth mentioning that the heterogeneity of the financial market during the crisis period is mainly attributed to investor sentiment (Armah, Amewu, and Bossman 2022). This suggests why in the high-risk and system crisis periods, determining how various classes of assets respond to risk pressure on various trading scales is essential for policymakers, risk managers, and investors.

The dynamism associated with the adverse impact of COVID-19 motivated us, to investigate the co-movement between market stress and global economic uncertainty during the COVID-19 pandemic. The GFC caused unprecedented volatility in the world's financial markets, and thus exacerbated the economic situation (Esparcia et al. 2022). However,

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the consequences and dynamism of the systemic risk caused by the recent COVID-19 pandemic are unique in terms of economic activity (Armah, Amewu, and Bossman 2022). Responses to market stress occasions by the GFC depend heavily on risk tolerance and trading horizons among economic and financial actors. Therefore, understanding a major move in financial markets during COVID-19 is crucial for policymakers, risk managers, and investors against the backdrop of the debate of market complexity and market uncertainty. We provide a quota of evidence from the embryonic debate on the time-frequency dynamics of the lead–lag relationship between market uncertainty and financial market stress during COVID-19.

II. Methodology

We employed the wavelet technique to assess the time-frequency co-movement and the lead/lag relationship between market stress and economic uncertainty.

Fundamental wavelet tools comprise location (i) and scale (s) expressed as

$$\Psi_{is}(t) = \sqrt{s}^{-1}\Psi(t-i)\left(s^{-1}\right), \Psi(\cdot) \in L^2(R) \quad (1)$$

Where $\sqrt{s}^{-1}$ represents the normalization factor, ensuring that the unit variance of the wavelet$||\Psi||_{i,s}{}^2 = 1$, i represents the precise location of the wavelets, and s is the scale illustrating the stretched nature of the wavelet. The Morlet wavelet is represented as follows;

$$\psi_o(\eta) = \pi^{-1/4} e^{i\omega_0 \eta} e^{-\eta^{2/2}} \quad (2)$$

Where ω_o is a non-dimensional frequency taken to 6 to satisfy the admissibility condition.

A time series x(t) based on a selected mother wavelet can be discomposed as follows:

$$W_{x(\tau,s)} = \int_{-\infty}^{+\infty} x(t)\psi^*_{\tau,s}(t)dt = \frac{1}{\sqrt{s}}\int_{-\infty}^{+\infty} x(t)\psi\left(\frac{t-\tau}{s}\right)dt \quad (3)$$

where * represents the complex conjugate. To recover the original time series $x(t)$ from the original wavelet transformation, the inverse wavelet transformation is presented as follows.

$$x(t) = \frac{1}{c_\psi}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \left|w_{x(\tau s)}\right|^2 \frac{dt\, ds}{s^2} \quad (4)$$

The square of the absolute value of a wavelet cross-spectrum normalization to the single spectrum of wavelet power is known as wavelet transform coherence. This is represented as follows:

$$W_n^2(i,s) = \frac{\left|S\left(s^{-1}W_n^{xy}(i,s)\right)\right|^2}{\left|S\left(s^{-1}W_n^{x}(i,s)\right)\right|^2 . \left|S\left(s^{-1}W_n^{y}(i,s)\right)\right|^2} \quad (5)$$

Where S is the smooth factor that ensures a balance in resolution and the resulting value of the square of the wavelet coefficients, W_n^2 is such that $0 \leq W_n^2(s) \leq 1$. By interpretation, weak relationships are indicated by values approaching 0, whereas strong relationships are indicated by values approaching 1.

To gain a deeper insight into the lead–lag relation between the variables, the study applies the wavelet coherence phase difference as follows:

$$\varphi_{xy}(i,s) = tan^{-1}\left(\frac{\boldsymbol{I}\left(S\left(s^{-1}W^{xy}(i,s)\right)\right)}{\boldsymbol{R}\left(S\left(s^{-1}W^{xy}(i,s)\right)\right)}\right) \quad \varphi_{xy} \in [-\pi, \pi] \quad (6)$$

where $\boldsymbol{I}$ and $\mathbf{R}$ are, respectively, the imaginary and real parts of the smoothed CWT. Wavelet coherence is defined by the dimensional phase pattern, and the varying phase patterns are distinguished by using dimensional arrows. The series moves in phases if $\varphi_{xy} \in \left[0, \frac{\pi}{2}\right]$, when x is led by series y. if $\varphi_{xy} \in \left[-\frac{\pi}{2}, 0\right]$, then x is considered to be leading. There is antiphase if the phase difference of π or $(-\pi)$ connotes that $\varphi_{xy} \in \left[-\frac{\pi}{2}, \pi\right] \cup \left[-\pi, \frac{\pi}{2}\right]$. If $\varphi_{xy} \in \left[\frac{\pi}{2}, \pi\right]$ in this case, x is leading, and the series y is leading if If $\varphi_{xy} \in \left[-\pi, -\frac{\pi}{2},\right]$

Data source

The data considered in the study were daily data for the US financial stress index (USFSI), EPU VIX, VCRIX, and OVXCLS. The data for EPU, VIX and OVXCLS were gleaned from FRED, Federal Reserve Bank of St. Louis,[1] while the data for USFSI were gleaned from the Office of Financial Research

[1]www.Fred.stlouisfed.org.

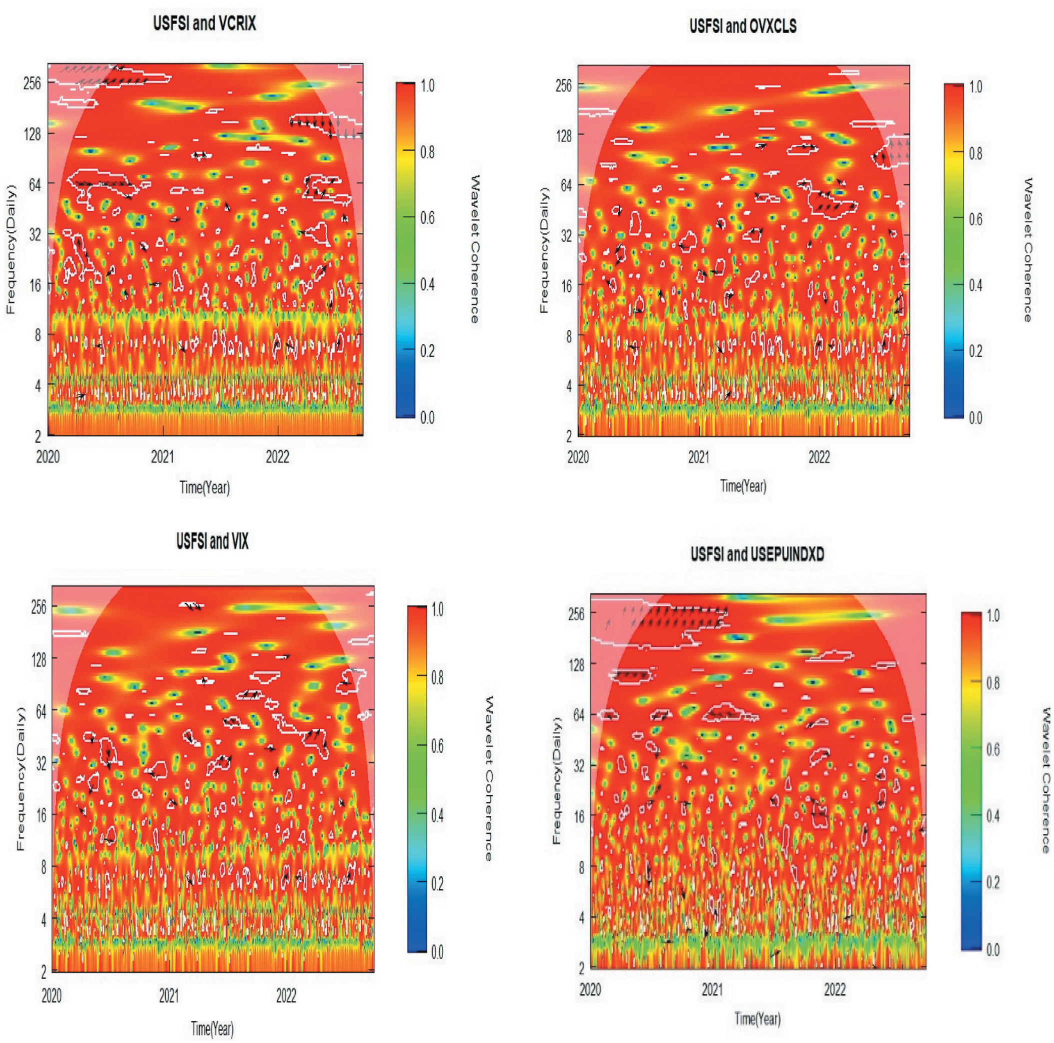

Figure 1. Wavelet coherence for market stress and global economic uncertainty.

(OFR).[2] Data for VCRIX were obtained from the website(https://data.thecrix.de/data/vcrix.csv). We employ four uncertainty indices that include the EPU index (USEPUINDXD), proposed by (Baker, Bloom, and Davis 2016). Furthermore, cryptocurrency volatility (VCRIX) is used in our study due to its crashes that spread contagion and weaken the financial system (Yarovaya, Brzeszczyski, and Lau 2016). VIX represents investor fear and expectations in the financial market and finally, we include OVXCLS as an important risk factor in the financial market (Armah, Amewu, and Bossman 2022).

The daily data span from 31 December 2019 to 30 September 2022, yielding a total of 1006 observations. The suggested time frame is chosen to cover the COVID-19 pandemic. The daily returns for the uncertainties were transformed by taking the logarithmic difference between the consecutive prices given by $R_t = [In(p_t) - In(p_{t-1})] * 100$

III. Results and discussion

Time-frequency domain

Following the standard practice of literature, the right-pointing arrows upward and the left-pointing arrow downward indicate that the first series is leading, whereas the left-pointing arrow upward and the right-pointing arrow downward indicate the second series leading. The cone of influence (COI) within the

[2]https://www.financialresearch.gov/financial-stress-index.

wavelet plots indicates the region of significance bounded by white contours with phase arrows indicating the directionality of coherence. Hotter colours, such as yellow and red signify a high coherence, whereas warmer colours such as blue and green indicate a low coherence. The horizontal axis shows the time, while the vertical axis gives a frequency band that varies from low to high frequency.

In Figure 1, we observed a co-movement and lead-lag relationship between USFSI and VIX in the frequency band of 32–64 daily in mid-2020 with VIX driving USFSI downward. This period marks the emergency of COVID-19 when the level of market stress was high. This implies that an increase or decrease in USFSI is highly alternated with the VIX and therefore amplifies financial market stress. The interdependence between VIX and USFSI augments the financial instability hypothesis of (Keen 1995). Positioning arrows (↗) and (↙) indicate that USFSI led co-movement with OVXCLS. This implies that the market stress dynamics was driven by OVXVLS in the frequency band of 32–64 daily between the early stages of the pandemic period and the outbreak of new variant detection. Turning our focus to USFSI and VCRIX, we observe that there is a lead/lag relationship at the higher frequency band of 128–256 daily. We also observe a lead–lag relationship between the series with non-homogeneous interconnection at a lower and medium frequency (12–48) daily in late 2020, with USFSI leading at the frequency band of 48 daily. Positioning arrows (↗) at the high frequency of 256 daily signify that USFSI led USEPUINDXD by $\pi/2$ which partly communicates the driving role of USEPUINDXD at the highest scale concerted at 128–256 daily in the early part of 2020. This suggests that changes in USEPUINDXD may be a short-term predictor of changes in USFSI. These findings are consistent with the work of (Liow, Liao, and Huang 2018).

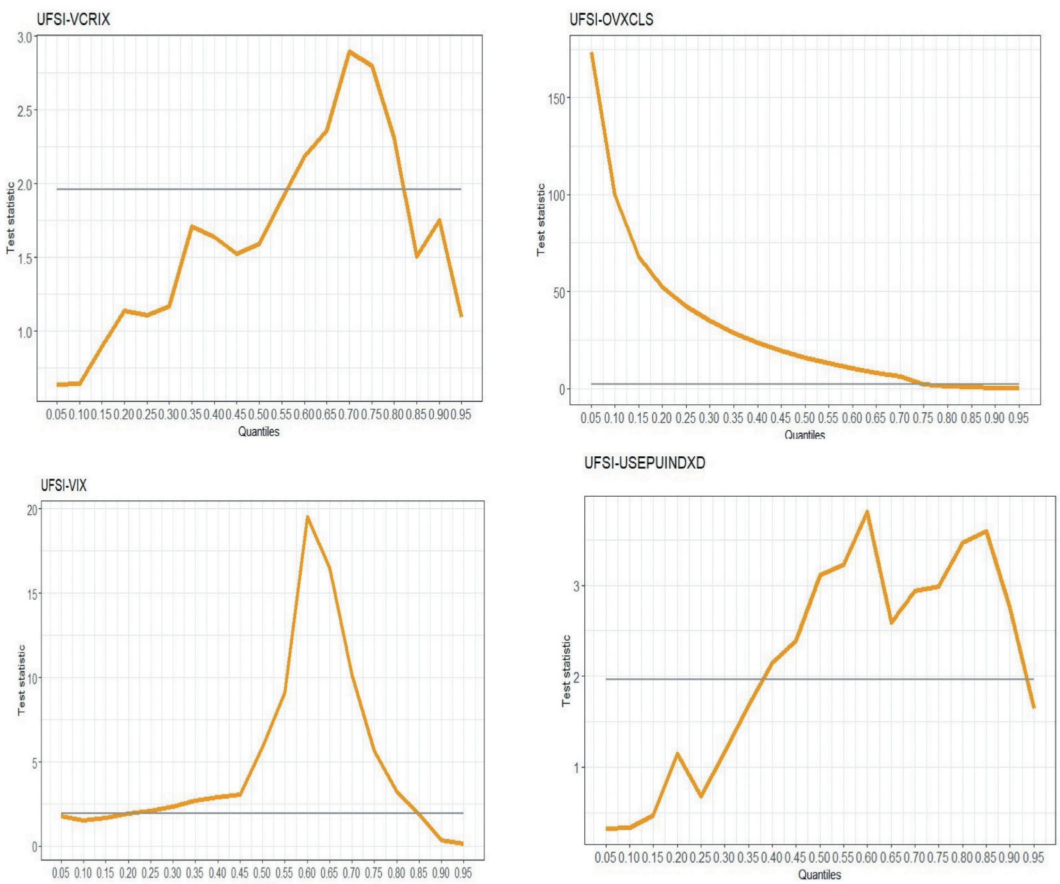

Figure 2. Test statistics for quantile causality-in-mean for market stress and global economic uncertainty.

Robustness check under quantile causality

We used the causality-in-quantile framework proposed by Jeong, Härdle, and Song (2012) to test the predictive ability of uncertainty and market stress during COVID-19. Figure 2 reports on the predictive ability of economic uncertainty and financial market stress. The horizontal line corresponds to the critical value of 1.96 at a significance level of 5%. The test statistics are shown on the vertical axis, and the matching quantiles are shown on the horizontal axis. The null hypothesis is rejected that a change in market uncertainty does not cause changes in market stress to be rejected ($p < 0.05$). We reject the null hypothesis below 0.25 and above 0.85 for VIX, and below 0.55 for VCRIX & USEPUINDXD and above 0.85 for USEPUINDXD. This suggests that global economic uncertainties have weak predictability of market stress in these quantiles and strong predictive power with the remaining quantiles. The predictability of OVXCLS covers the entire distribution, with some exceptions at the tail. This suggests that OVXCLS has strong predictive power information on market stress. Overall, our results suggest that economic uncertainties have predictive information about financial market stress during COVID-19.

IV. Conclusion policy and implications

We investigated the lead/lag co-movement between market stress and economic uncertainties using the wavelet technique. We also utilize quantile causality as an out-sample to check the robustness of the results to accentuate the importance of economic uncertainties on market stress during COVID-19. We find that both in-sample and out-sample for VIX, OVXCLS, VCRIX, and USEPUINDXD drive and pose a high risk to the financial market during COVID-19. Therefore, empirical observation warrants a deliberate policy effort to address market complexity during the crisis period. The essence of synchronizing global economic uncertainties is pivotal for portfolio management during the crisis period; therefore, policymakers should not disdain global economic uncertainties when formulating new measures for economic and trading operations during the crisis period.

Disclosure statement

No potential conflict of interest was reported by the authors.

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