Asian Economic and Financial Review
ISSN(e): 2222-6737
ISSN(p): 2305-2147
DOI: 10.55493/5002.v13i3.4739
Vol. 13, No. 3, 180-191.

URL: www.aessweb.com

Evidence of COVID-19's financial epidemiology on the ASEAN-5 stock indices

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Article History
Received: 29 August 2022
Revised: 18 January 2023
Accepted: 8 February 2023
Published: 2 March 2023

Keywords
ASEAN-5
COVID-19
Financial epidemiology
Spectrogram
Stock index
Wavelet.

JEL Classification:
G14; G15.

ABSTRACT

Little research has been done to determine whether the pandemic's impact is strong enough to innovate all of the ASEAN-5 stock indices. The traditional studies of financial epidemiology in regional equities mainly focus on the major global stock markets. This paper utilizes the conventional t-test and the advanced computational power of the Wavelet Power Energy Spectrum (WPES) to investigate the magnitude of the significance of the COVID-19 impacts on the ASEAN-5 stock indices. Our t-test confirms that the pandemic has caused significant changes to the overall stock index activities. Further, the WPES analysis yielded notable results based on the spectrogram plots. First, based on the spectral analysis, during pandemic, the ASEAN-5 stock indices experienced episodes of innovation in terms of market activities. It was also observed that the regional stock indices experienced phases of volatility persistence, volatility clustering and long memory of up to four months. We conclude that, due to the impact of the pandemic, trend-following investors can't dominate the market as they react quickly and efficiently to new information. It is suggested that asset allocation strategists particularly should regularly review and conduct climate tests on their baskets to ensure their positions are durable and resistant to shocks. The results of this study offer significant insights for both institutional and retail investors, particularly in strategizing investment baskets during uncertainties.

Contribution/Originality: This paper reveals new information regarding the impacts of the COVID-19 pandemic on the ASEAN-5 stock indices by applying both parametric and non-parametric approaches to determine the innovation in stock market dynamics. While the t-test has statistically confirmed the significance difference of the pandemic's impact on stock index activities, the Wavelet Power Energy Spectrum (WPES) based on the continuous wavelet transform (CWT) specification reveals all patterns of market variations in spectrogram plots.

1. INTRODUCTION

The city of Wuhan was where the novel coronavirus was discovered for the first time in December 2019, and it has since spread around the world. At the beginning of 2020, the World Health Organization (WHO) made the official announcement that COVID-19 had reached pandemic proportions (Giwa & Desai, 2020). Since then, lockdowns, social distancing, and travel bans have been implemented in nearly all countries. These stringent regulations had an unprecedented effect on the economic and financial landscape of a great number of countries. It clearly shows that the pandemic, which was previously a global health crisis, has now become a global financial crisis (Mensi, Vo, & Kang, 2021).

A country's stock market index can generally be used to gauge its economic and financial well-being, which is why it is frequently referred to as a good national economic barometer (Okodua & Ewetan, 2013). The stock markets in the Association of Southeast Asian Nations (ASEAN) regions are more prone to the pandemic's impact as they are geographically closer to China. However, Choi (2014) points out that the neighboring financial markets may react differently even though they have been impacted by a similar magnitude and intensity of geo-economic shocks. Among other studies that agree with the heterogeneity of market response, Ashraf, (2020); Ibrahim, Kamaludin, & Sundarasen (2020) postulated that when COVID-19 cases spiked, investors in ASEAN countries, such as Malaysia, Indonesia, and Singapore, were more efficient in reacting to the news than investors in Thailand and the Philippines. However, the literature is yet to showcase evidence of significance differences in ASEAN regional market innovations impacted by the COVID-19 pandemic prior to the investors' reactions. While this gives us a strong motivation to investigate the neglected area of research, we are more inspired to highlight the pandemic's impact on stock market innovations through parametric and non-parametric approaches to address the areas that have so far received less attention.

In this paper, we examine the daily closing prices of five ASEAN countries (ASEAN-5), which are Malaysia (Kuala Lumpur Stock Exchange Composite Index: KLSE CI), Indonesia (Jakarta Stock Exchange Composite Index: JCI), Thailand (Stock Exchange of Thailand Index: SET), Singapore (Straits Times Index: STI) and the Philippines (Philippines Stock Exchange Index: PSEi). The data is divided into two partitions for the t-test procedure. The mean difference of the pre-pandemic period (January 2018 to December 2019) is compared with the pandemic period (January 2020 to October 2021). The t-test results yield evidence of significant differences in market activities and overall behavior. A spectral analysis was then conducted using the Wavelet Power Energy Spectrum (WPES) to observe any evolutionary episodes of market innovations due to the pandemic. In our opinion, the paramount issue is to determine the significance of the impacts due to the pandemic outbreak before further research can be carried out. Then, stock market behavior should be observed in time evolution settings to spot any differences or market innovations caused by the pandemic.

We intend to go beyond the extant literature in the following areas. First, to the best of our knowledge, this paper is the first to use the wavelet method to analyze the impact of the pandemic on the market activity of the ASEAN-5 stock indices. Current literature, among others, Sadiq, Hsu, Zhang, and Chien (2021) analyze the regional ASEAN stock exchanges using the Smooth Transition and Heterogenous Autoregressive model (ST-HAR), a type of Bayesian posterior model which focuses on individual industry sectors listed on the stock exchange. We, on the other hand, take both parametric and non-parametric approaches to observe the possible innovations on the stock market dynamics. The two tests were conducted to guarantee the robust validity of the findings. Second, the WPES analysis was employed based on the Continuous Wavelet Transform (CWT) framework to magnify the evolution of the pandemic's impact in two dimensions – time and frequency. The CWT is the top wavelet application in the finance area. Based on Gallegati (2008), Gallegati (2012) and Gallegati and Gallegati (2007), the original purpose of the wavelet method is to measure the levels of seismic waves in geospatial analysis. Hereto, the application of wavelets in our study provides a detailed analysis of the pandemic's impact as the graphical plot illustrates the magnitude and intensity of the impacts along the observation period. Furthermore, research that is based on wavelets sheds light on the spectral dispersion of economic shocks that occur across multiple timescales. It is possible to use the wavelet method to find hidden patterns in the changes that occur in the stock market because this method transforms time series data into frequency signals, provides meaningful information, and does so without losing any time information (Cărăuşu, Filip, Cigu, & Toderaşcu, 2018).

The findings from our study extend the research by Sharma (2020) and Nguyen and Nguyen (2022) as these works of literature use volatility models to examine the impacts of the pandemic. Finally, current literature has documented a lot in studying the pandemic's impact on stock market connectedness, among others, (Behera & Rath, 2022; Kamaludin, Sundarasen, & Ibrahim, 2021). We, on the other hand, focus on analyzing each of the ASEAN-5

stock markets. We are of the opinion that analyzing the pandemic's impact on each of the stock indices is equally as importance as studying regional markets.

The results from the t-tests and wavelet analyses on the ASEAN-5 stock markets are consistent in that the pandemic's impact has innovated the market behavior and dynamics. Further, the multiscale analysis shows that the pandemic's impact has caused market shocks that last up to 128 days or around four months. The scalogram from the wavelet computation plots the possible volatility persistence and long memories in 2020 and 2021. Such findings provide evidence that COVID-19 triggered financial epidemiology across the ASEAN-5 stock markets.

The rest of this paper is organized as follows: Section 2 contains a brief literature review; Section 3 discusses how the chosen empirical research methodologies will assist in achieving the study objectives; Section 4 explains the empirical design of the study; Section 5 presents the findings and discusses them in relation to existing literature; Section 6 explains how the results of this study link to previous studies; and Section 7 comprises the important lessons from our findings and recommendations for future studies.

2. LITERATURE REVIEW

Fear of an epidemic could truncate the global economy, particularly if it originates from China, the world's second-largest economy. The current global economic trajectory has shifted as a result of the prolonged COVID-19 pandemic that has afflicted the world's economies since January 2020. For investors, the threat of a pandemic began with the spread of fear. The term "fear spillover" refers to the impact of non-economic events on financial markets (Sarwar & Khan, 2019). Numerous empirical studies have examined the effects of global medical emergencies on financial markets. For instance, Hai, Zhao, Wang, and Hou (2004) pointed out that the outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003 had the greatest impact on Chinese tourism. China's economy lost USD 25.3 billion in total, and the national gross domestic product (GDP) slowed by 2% from its projected growth rate. Furthermore, Beijing expressed its concern to its ASEAN neighbors. Fortunately, data from the affected countries show that the magnitude of the effects on their macroeconomics is well contained (Keogh-Brown & Smith, 2008). Having said that, investors tend to overreact to certain macro-thematic events (De Bondt & Thaler, 1985).

From a financial perspective, the COVID-19 outbreak has triggered financial epidemiology. The term 'financial epidemiology' was introduced by Peckham (2013) to explain when an infectious disease is disastrous and destructive to financial markets. The quantile regression analysis carried out by Rahadian and Nurfitriani (2022) showed that the sporadic effects of the pandemic's impact on the stock indices are channeled by media hype, fake news, country sentiment, and the infodemic risk index. Investors' responses to new information are visible through the volatile behavior of the markets (Engelhardt, Krause, Neukirchen, & Posch, 2021; Li et al., 2022). Although Choi (2014) mentions that the event impacts are heterogenous, we can expect that the stock indices are vulnerable to the pandemic's impact. The regional financial markets are cointegrated, so the ASEAN-5 stock indices may experience volatility clustering (Zhang & Fang, 2021), volatility persistence (Nguyen, Phan, & Ming, 2021) and long memory (Yousef, 2020).

The crux of issue is whether the ASEAN-5 stock market investors, who reacted to the outbreak, are able to innovate the stock market behavior through their responses. We recognize that much less attention has been paid to emerging markets, especially for the ASEAN-5 regional stock indices. In addition, to date, no empirical research has applied the wavelet method to verify and confirm the COVID-19 impact on each of ASEAN-5 stock markets. Previous studies use the wavelet method exclusively to analyze the pandemic's impact on ASEAN-5 connectedness in terms of regional stock market association (Aziz, Ahmad, Zichu, & Nor, 2022), the co-movement of developed and emerging stock indices (Kamaludin et al., 2021), and exchange rates (Shahrier, 2022). To the best of our knowledge, this is the first empirical study to use the continuous wavelet transform (CWT) approach to investigate the shocks caused by the COVID-19 pandemic throughout the ASEAN-5 stock markets with both time and frequency settings.

3. THE BASICS OF WAVELET ANALYSIS

The wavelet analysis approach has been enjoying patronage from financial researchers due to its ability to simultaneously illustrate time series data in the time-frequency domain (Armah, Amewu, & Bossman, 2022; Karamti & Belhassine, 2022). Wavelet means 'small waves', and the dynamic pattern of wavelets can provide a meaningful interpretation of the time series dataset in a spectral representation (In & Kim, 2012). Due to its powerful computational ability, the wavelet method is preferred by financial researchers to analyze the financial market through a multiscale analysis in a single presentation window.

The mechanics of wavelet computation in the CWT involves two important steps. First, the wavelet formulation converts the financial time series data into signals. Here, the researchers have the flexibility to decide on the discretization of signals. Then the set of signals make up sequenced data in oscillation patterns readable in the time-frequency scale. There are three merits of using the wavelet method to study financial data that has been affected by a financial crisis compared to other conventional approaches. First, if we assume there is a structural break, the wavelet method finds the point of discontinuity and represents it in a continuous pattern, allowing for a more accurate observation and analysis. Second, the wavelet method does not require the data to comply with stringent statistical requirements such as stationarity and normality. The wavelet method itself is a non-parametric approach, thus it captures the details of patterns for all types of data behavior, including outliers. Last, time series data slicing is not used for wavelet analysis. The CWT parameterization is continuous in nature, it converts the financial time series data into sets of meaningful signals so that a multiscale analysis can be conducted without manual interference in the empirical procedure.

The overall aim is to observe the turmoil that occurred in the ASEAN-5 economies due to the COVID-19 outbreak. We believe that the application of the CWT as the primary empirical research procedure will extract the most details from the data.

4. EMPIRICAL DESIGN

This study examines the daily closing prices of the stock indices in five ASEAN countries from January 2018 to October 2021. We use daily data instead of weekly or monthly periods as the event impacts may last for only a few days (Huo & Ahmed, 2017). Beginning with the t-test as a preliminary procedure, the raw data, which are the daily closing prices in each market, were split into two groups, before and after January 1, 2020. This date was selected as it reflects when the Chinese government warned the WHO about the virus outbreak (Xiao & Torok, 2020), signifying the beginning of the COVID-19 pandemic. The t-test results are expected to furnish the parametric analysis in determining the significant differences in market behavior by comparing the phases of the periods before and after the pandemic. The multiscale and time-varying analyses are then performed based on the spectrograms generated by the CWT graphical plots.

4.1. Two-Sample T-Test

Before conducting the wavelet analysis, we examine the original set of the data to determine the significant differences of the time series for two observation periods. A two-sample t-test will be applied in this study to answer the hypotheses below:

H1: There is a significant difference in the closing prices for Malaysia's stock index before and after January 1, 2020.

H2: There is a significant difference in the closing prices for the Indonesia stock index before and after January 1, 2020.

H3: There is a significant difference in the closing prices for the Thai stock index before and after January 1, 2020.

H4: There is a significant difference in the closing prices for the Singapore stock index before and after January 1, 2020.

H5: There is a significant difference in the closing prices for the Philippine stock index before and after January 1, 2020.

After confirming the significant differences in the ASEAN-5 stock markets, the wavelet procedure is applied. For this type of analysis, the raw daily closing data is converted into natural log form to make it unit free (Mensi, 2019). The equation can be instantiated as follows:

$$r_t = ln\left(\frac{p_t}{p_{t-1}}\right) \tag{1}$$

Equation 1 presents the return on spot and futures at time t in logarithmic form of the difference between the closing prices at times t and t-1 .

4.2. Wavelet Power and Energy Spectrum (WPES)

Basically, wavelet computation transforms time series data into signals by integrating the time series in a frequency domain without losing any time information. Because a wavelet is a 'small wave', it can grow and decay in a finite period of time (Osu, Okonkwo, Uzoma, & Akpanibah, 2020).

The WPES plays a main role in the methodology for this study as it deals with the distribution of time series energy. Conversely, it plots the volatility, volatility persistence, volatility clustering and the energy decays of the time series throughout the observation domain. Mathematically, the WPES is based on the CWT settings and it can be illustrated as the total energy contained in a given signal $x(t)$, which is the transformed time series, and is given as the integral of the square of its absolute value.

$$E = \int_{-\infty}^{\infty} |x(t)|^2 dt = \|x(t)\|^2 \tag{2}$$

In Equation 2, E is the energy, the relative contribution of the signal energy contained at a specific u scale, and the scale's (s) location is given by the WPES in Equation 3, which is the absolute square of the wavelet transform.

$$WPES_x(s,\tau) = |W_x(u,s)|^2 \tag{3}$$

The plot of $WPES_x(u,s)$ is also known as a scalogram. The WPES depicts and measures the local variance of a signal at various scales, s, by giving information on the relative power (energy) at a particular time and scale (frequency) (Addison, 2017). Hence, the local wavelet power spectrum is the absolute square of the wavelet transform as follows:

$$WPES_x(s,\tau) = \left|W_{x,\psi}(u,\tau)\right|^2 \tag{4}$$

The spectrogram illustrates the volatility across the observations as a final step in the process of demonstrating how events have impacted a single financial time series by using the CWT as a medium. The spectrogram is computed by the R software using the code retrieved from the Comprehensive R Archive Network (CRAN), namely 'biwavelet', written by Gouhier, Grinsted, Simko, Gouhier, and Rcpp (2013). The market behavior is color-coded from blue to red, representing calm to agile market activity.

5. RESULTS AND DISCUSSION

We conduct the t-test to verify that there are significant differences in the ASEAN-5 stock market data. Based on the results in Table 1, there are significant differences in the closing prices for the ASEAN-5 stock indices (KLSE CI, JCI, SET, STI, and PSEi) before and after January 1, 2020. Hence, the occurrence of financial epidemiology in the ASEAN regional stock indices can be confirmed.

Table 1. Two sample t-tests.

Stock index	Levene's test for equality of variances	t-test for equality of means			
	F	t	df	Sig. (2-tailed)	Mean difference
KLSE CI	43.007***	28.990	932.000	0.000	165.062
		29.207	922.352	0.000	165.062
JCI	575.013***	17.368	905.000	0.000	536.009
		17.103	572.728	0.000	536.009
SET	371.649***	31.040	928.000	0.000	235.120
		30.090	618.632	0.000	235.120
STI	384.185***	26.889	958.000	0.000	382.994
		26.292	698.681	0.000	382.994
PSEi	94.390***	37.915	931.000	0.000	1277.918
		37.381	784.971	0.000	1277.918

Note: *** indicates statistical significance at 1%.

Table 2 presents a summary of the descriptive statistics for the daily returns in all ASEAN-5 countries' stock markets before and after January 1, 2020. The standard deviation values in each market show that the daily returns after January 1, 2020, are more spread compared to before January 1, 2020. This reveals that the price agility in all markets was agile, but the levelness cannot be traced by only depending on this output.

Table 2. Descriptive statistics of daily stock index returns.

Stock index	Before January 1, 2020		After January 1, 2020	
	Mean	Standard deviation	Mean	Standard deviation
KLSE CI	-0.000220	0.005963	0.000021	0.010187
JCI	-0.000023	0.008649	0.000175	0.013891
SET	-0.000220	0.006797	0.000176	0.014888
SCI	-0.000097	0.007439	0.000060	0.012048
PSEi	-0.000175	0.010231	-0.000043	0.017384

From the standard deviation values in Table 2, we now know that the ASEAN-5 stock indices may experience volatility persistence, volatility clustering and long memory. The three typical conditions of volatility can be defined as when today's price return has a large effect on the unconditional variance of many periods in the future (Mandelbrot, 1963; Mandelbrot, 1971). Pertaining to the aforesaid, we conduct the wavelet analysis through the multiscale examination based on the WPES.

Figure 1 shows that KLSE CI was in a normal state (blue-orange) throughout the 4-day to 8-day frequency region from January 2018 to December 2019. In January 2020, the volatility became agile and lasted up to 32 days. From January 2020 until the early weeks of 2021, volatility clustering is apparent and shows that there was excessive volatility during the pandemic period. The pattern slowly returns to normal from April 2021 to the end of the sample period with a frequency region below 32 days. This behavior is a lot like what was seen before the pandemic, when volatility tended to cluster around the 4-day to 6-day frequency region.

Figure 2 shows that JCI is also in a normal state (blue-orange) through the 4-day to 8-day frequency region from January 2018 to December 2019. There is very little volatility clustering detected during this timeframe around the 32-day frequency region. Volatility began to rise in early January 2020, eventually going beyond the 32-day frequency region. As with the KLSE CI, volatility clustering is clearly visible from January 2020 until early 2021. The volatility slowly returns to normal from April 2021 until the end of the sample period. A small volatility cluster was detected around 16 days before May 2021.

The SET shows a normal state (blue-orange) through the 4-day to 8-day frequency region from January 2018 to December 2019 (see Figure 3). Starting from the end of 2019, excessive volatility and long-term memory volatility

that lasts up to 128 days are detected. This volatile and excessive episode ends at the beginning of 2021. After April 2021, the pattern of volatility goes back to normal and stays that way until the end of the study period.

The STI exhibits a similar pattern to the SET during the pandemic period (December 2019 to January 2021), indicating that volatility is excessive for up to 128 days. In addition, Figure 4 shows volatility clustering around the 32-day to 64-day frequency regions from the beginning to mid-2019 and after January to March 2021. The volatility pattern after January 2021 indicates a similar pattern to that before the pandemic period.

Figure 5 shows that the PSEi was in a normal state (blue-orange) from the beginning of 2018 to mid-2019. Concurrently, there are a few small volatility clusters with a frequency range greater than 16 days. The market became volatile and agile in the early part of January 2020, with a frequency of almost 64 days. From January 2020 to March 2021, the volatility clustering is apparent through the 64-day to 128-day frequency regions. From April 2021 until the end of the sample period, the market behavior slowly returns to normal.

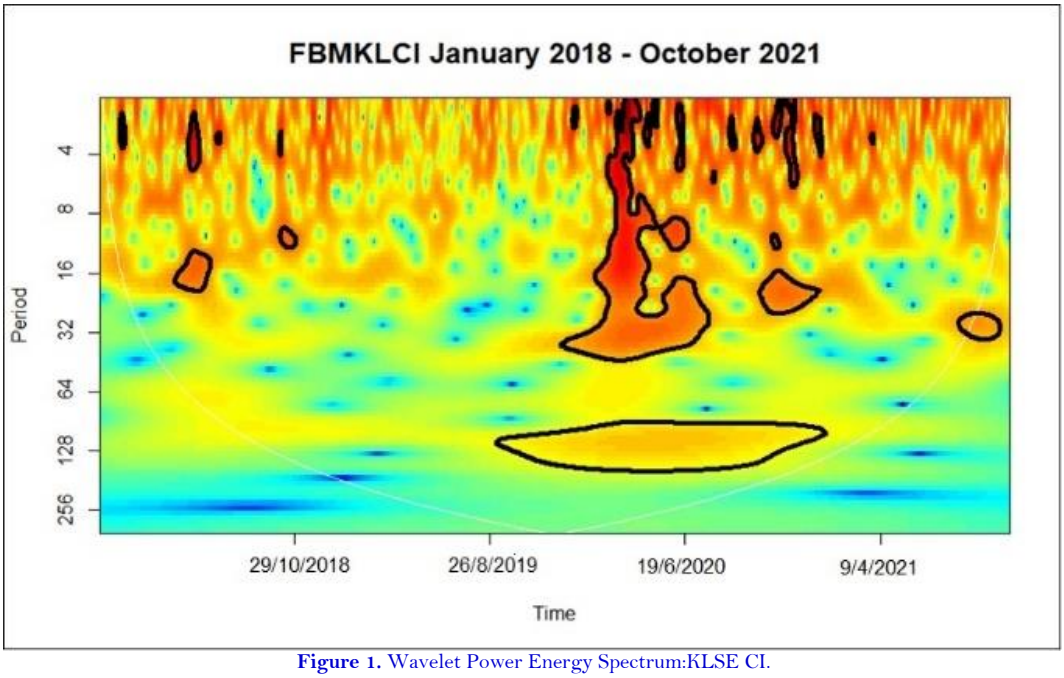

Figure 1. Wavelet Power Energy Spectrum:KLSE CI.

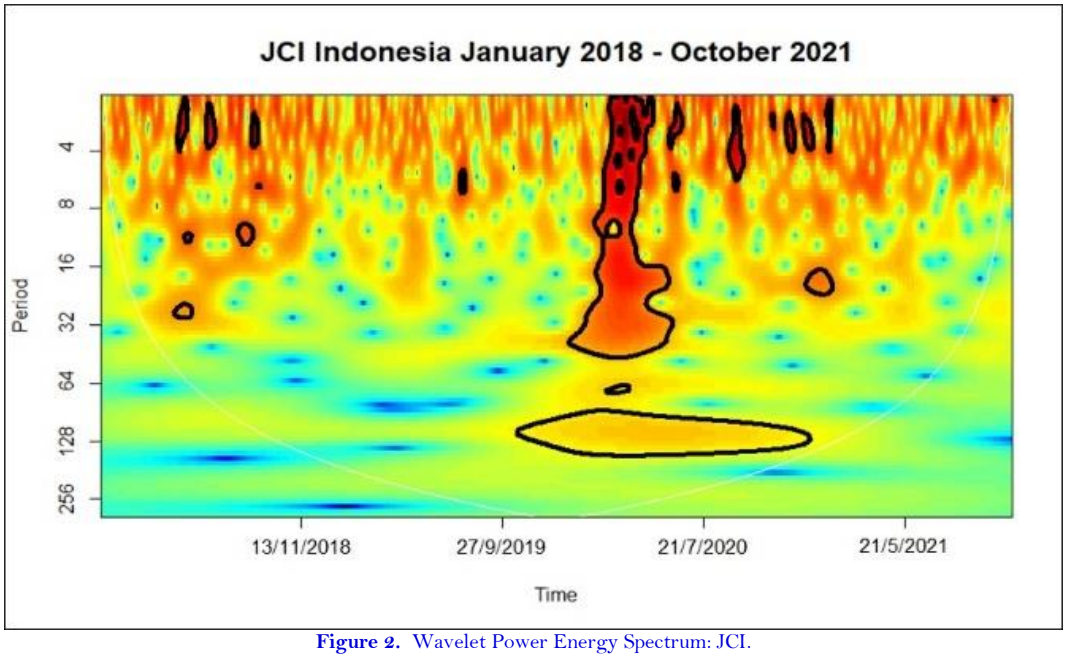

Figure 2. Wavelet Power Energy Spectrum: JCI.

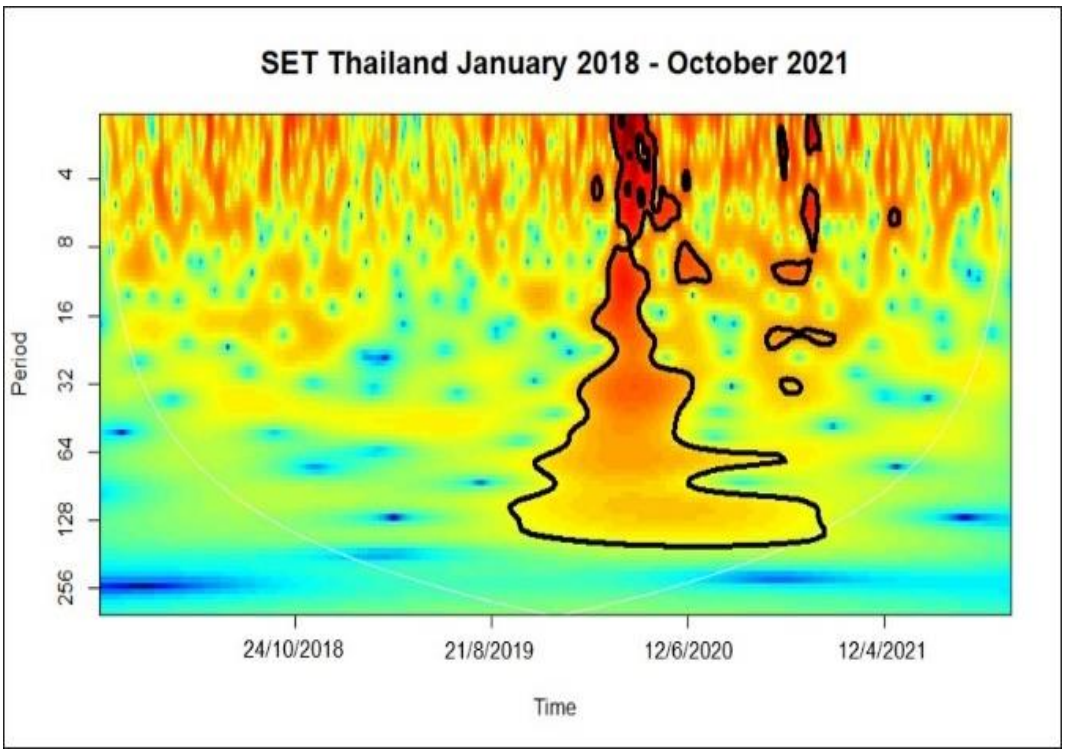

Figure 3. Wavelet Power Energy Spectrum: SET.

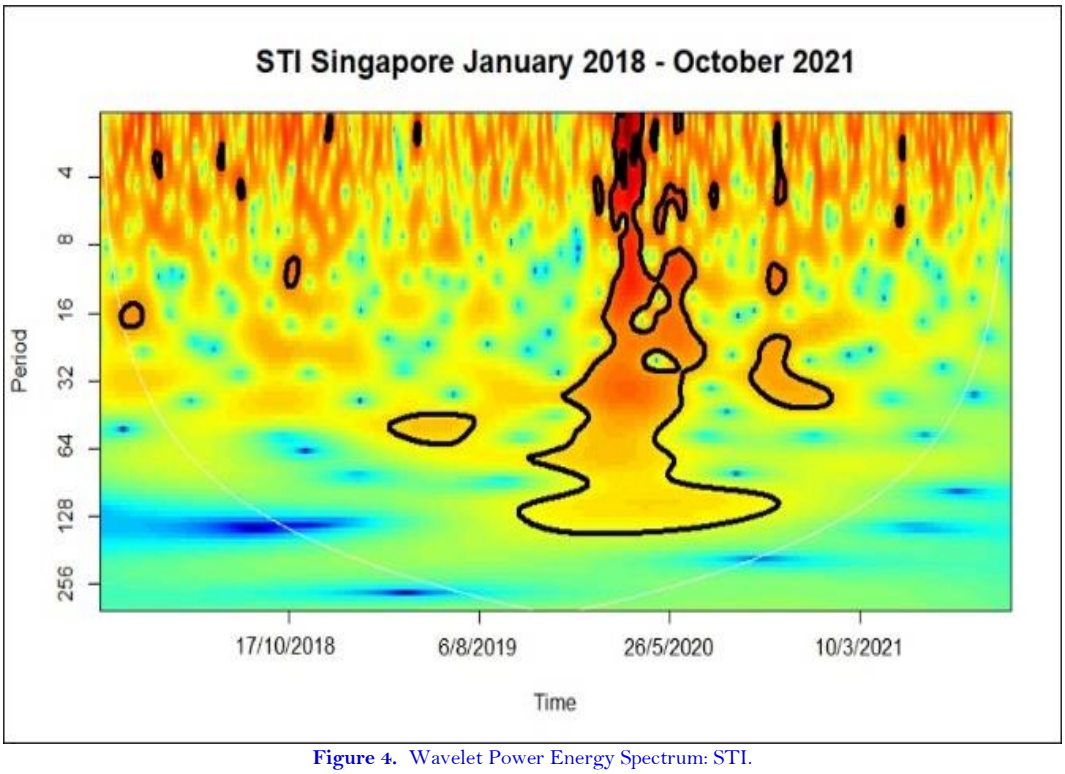

Figure 4. Wavelet Power Energy Spectrum: STI.

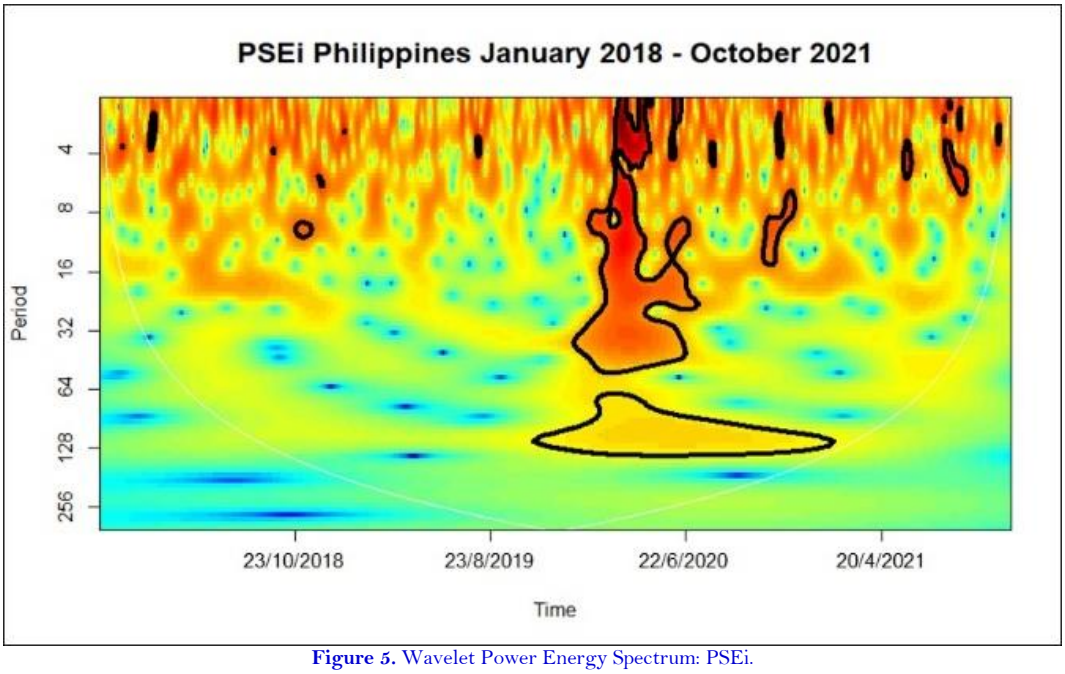

Figure 5. Wavelet Power Energy Spectrum: PSEi.

Through this wavelet analysis, market behavior abnormality can be observed from January 2020 for all ASEAN-5 stock markets. This excessive volatility episode lasts until the first quarter of 2021, with a frequency range of 32 to 128 days. Compared to the period before the pandemic, the volatility was in a normal state with a 4-day to 16-day frequency region. By looking at the market behavior after the excessive volatility episode, it was evident that the volatility slowly returned to its normal pattern from April 2021. Compared to the beginning of the pandemic, when investors were shocked by the sudden changes in the market, we can see that investors have already gotten used to the new market sentiment.

6. CONNECTION TO PREVIOUS WORKS

Our findings are somewhat mixed in comparison with previous literature on the pandemic's impact across the ASEAN-5 stock markets. The results are not in accordance with Resindra and Lubis (2022), who stated that only the investors in Thailand reacted to the pandemic's effects. The wavelet analysis clearly shows that the regional stock markets in this study experienced shocks due to the pandemic's impact in 2020. The results also disagree with Dias, Heliodoro, and Alexandre (2020) due to the fact that COVID-19 has had a noticeable prolonged impact on market volatility. The multiscale analysis shows that, overall, the ASEAN-5 stock markets suffered four months of unstable behavior before the markets reverted to their normal state. In a global context, our findings are consistent with Okorie and Lin (2021) and Topcu and Gulal (2020) on the note that the COVID-19 pandemic had fractal contagion effects on the stock markets and that the trails diminish over the medium- and long-term horizons. With the confirmation of financial contagion, our work can be further extended by applying the wavelet approach to conduct a correlation breakdown test among the regional ASEAN-5 stock markets. According to Bookstaber (1997), the correlations between two markets will change dramatically during major events.

7. CONCLUSION

Our key findings point to the conclusion that the COVID-19 pandemic has changed the dynamics of the ASEAN-5 stock indices. The pandemic has taken a toll from the very first period of global epidemiology, as our analysis has shown that investors have efficiently reacted to the shocks. This paper provides evidence of COVID-19's impact on the ASEAN-5 stock indices by applying both parametric and non-parametric approaches. The t-test shows that there is a significant difference in market behavior in the ASEAN-5 stock indices after the pandemic. Then we proceed to

apply the wavelet approach to analyze the market activity in time-frequency domain. The wavelet approach elicits two perspectives. First, based on the time-varying window, the plots strongly support the t-test results which show a clear difference in the market activity before and after the pandemic shock. Second, the multiscale analysis shows that the ASEAN-5 equities experienced volatility persistence, volatility clustering and long memory up to four months. Such market conditions suggest that neither the fundamental nor trend-following traders are able to dominate the market. The post-pandemic era claims more effort by the hedgers, fund managers and asset allocation strategists to frequently review their portfolios to optimize returns. Further research can be undertaken to determine the COVID-19 impact on the future of the ASEAN-5 stock indices, as it would be interesting to see the pandemic's impact on the future markets as a price risk mitigation mechanism.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.

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