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Coherence Wavelet Method and Wavelet-Granger Causality Tests to Measure COVID-19 Pandemic-Induced Uncertainties

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ABSTRACT

Covid-19 outbreak has caused economic policy uncertainties. The first COVID-19 case was reported in Wuhan, China at the end of 2019. The virus spread escalated in volume during the Chinese New Year festival. World Health Organisation declared a global health emergency on January 30, 2020. The global financial market was badly hit when oil price slumped to over 30% and oil price war also occurred between Saudi and Russia. The stock market, too displayed signs of being impacted by the virus outbreak. It is very important to determine if COVID-19 has affected economic uncertainty and oil prices or the oil price fall has affected the economic instability and stock market volatility Three models were used in this study to analyse the relationship between the recent spread of COVID-19 in Malaysia, Malaysia stock market, oil prices in Malaysia and Global Economic Policy Uncertainty (GEPU) in time-frequency domain. The coherence wavelet methods were used to analyse the movement of each variable and to evaluate the interactions between the selected variables from January 25, 2020 to May 25, 2020. The Wavelet-based Granger Causality were applied to test the robustness of the coherence wavelets. Three main conclusions from this study were i) oil prices were influenced by stock market and GEPU index, ii) stock markets and GEPU index had interactions with the pandemic and iii) short term effects existed between the pandemic and oil prices. More accurate results concerning the volatility of GEPU, stock market and oil price, can be obtained in future research works in this area if Malaysia Economic Policy Uncertainty index is used.

Keywords: *COVID-19; economic policy uncertainty; oil prices; stock market; wavelet*

1. INTRODUCTION

World Health Organization (WHO) reported the first COVID-19 case in Wuhan China on December 31, 2019 [1]. The volume of cases that have spread to other provinces exploded during the Chinese New Year festival. WHO declared a global health emergency on January 30, 2020 [2].

Stock prices fell substantively, local trading was affected and stocks became more volatile. As a result, industries were less stable [2]. Two months into the pandemic, oil price slumped over 30% when Saudi authorities suggested oil prices per barrel discount from 6 to 8 dollars to their

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main customers in USA, Europe and Asia [3]. Overall, the global financial market was badly hit.

An oil price war occurred between Russia and Saudi Arabia when Russia walked out on a production cut agreement. Supply of discounted oil was in excess [4]. Demand shock occurred when global demand declined over 33% [5]. Many countries instituted a lockdown and restriction movement. Travelling within cities and across the globe was also grounded to a halt. All these cause-and-effect factors acted as the catalysts for this study.

Oil prices were assumed to be affected by COVID-19 pandemic, GEPU index and stock market. GEPU index itself was assumed to correlate with the stock market. The volatility of the stock market, oil prices and economic policy uncertainty are always predictable. However, the COVID-19 outbreak has caused the stock market to respond with increasing worrying volatility, economic policy uncertainty, and oil price crash. Did COVID-19 pandemic affect economic uncertainty and oil price? Did the oil price fall contribute to the economic instability and stock market volatility? Therefore, it is imperative for this study to analyse and define the relationship between all these factors and oil price in Malaysia.

2. LITERATURE REVIEW

This sector describes different approaches from previous related studies and their findings. The first method is a study from [3], coherence wavelet methods and Wavelet-Based Granger Causality (WGC) test. The coherence wavelet method and the WGC test applied to USA recent data aimed to expose the impact of oil price slumps and COVID-19 on the stock market volatility as well as the economic policy uncertainty. The data (January 21 2020 to March 29 2020) included daily confirmed new COVID-19 cases, economic policy uncertainty index, oil prices and stock price index [3]. Malaysia is currently facing the same problems which are the outbreak of COVID-19 pandemic and oil price slumps. Therefore, this study was conducted to determine the relationship between GEPU, oil prices, the number of daily cases of COVID-19 pandemic and stock markets in Malaysia. The research from [3] has the same objective with the current study.

The second method is ANOVA and Distributed Lag Non-linear Model (DLNM). The ANOVA and DLNM were employed to detect if the H7N9 epidemics in China has a negative effect on stock markets in China. The data (February 19, 2013 to March 31, 2013) includes the number of confirmed cases of H7N9, stock market index, closing and opening price information of the Overall Market Index as well as related sector indices. The indices involved were Chinese Traditional Medicine Sector Index, Avian Influenza Sector Index, Biomedicine Sector Index and Biological Product Sector Index [6]. Since Malaysia is currently facing an outbreak of COVID-19, this study adapted the current situation of COVID-19 to the H7N9 epidemics.

The third approach is from [7]. Event-study and regression-based methodology were used to estimate the effect of Ebola epidemic outbreaks (January 2014 to June 2016) on stock returns and to examine the role of geographic proximity of information. [7] evaluated the outbreak based on news from mass media and WHO alerts, and observed the effect on companies' stock returns. This research work revolved around stock prices and information geographic proximity affected by Ebola pandemics. The current study analysed how COVID-19 affected stock prices emphasis were not given on any geographic proximity information.

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The last method is Factor augmented vector auto-regression VAR (FAVAR). FAVAR approach is used to analyse the impacts of global economic uncertainty, oil price and geopolitical risk on stock price in Malaysia [8]. The method is employed in data collection involving all sectors in the Malaysian stock market, GEPU, oil price and geopolitical risk. Although the objective of the study by [8] was slightly similar to the current study, this study did not use any pandemic data as done by the present study.

After conducting a comparative analysis of these research works, the present study used the wavelet methods by [3]. It has to be noted that the objective of the study and the data used were similar in nature to the present study. The study in [7] used variables that were different such as mass media news. The study by [8] was also not appropriate because it did not use any pandemic data.

3. METHODOLOGY

To achieve the objective of this study, the researchers employed method by [3] which are Continuous Wavelet Transform (CWT) to describe the movement of each variable within a time-frequency, Wavelet Coherence (WC) to evaluate the interactions of selected variables and WGC Test to test the robustness of CWT and WC.

Phase 1 started with defining the problem statements and objectives of this study. The general purpose of this study is to analyse the relationship between COVID-19 confirmed cases, GEPU index, stock market index and oil prices in Malaysia. Phase 2 involved data collection. This study used secondary data of reported cases of COVID-19 in Malaysia, oil prices in Malaysia, and GEPU index.

The duration for data collection was from January 25, 2020 to May 25, 2020. The data were collected as follows:

i) data on the spread of COVID-19 from the Ministry of Health of Malaysia,
ii) data on the Malaysia stock price index as measured by the Dow Jones Malaysia Historical data from https://www.investing.com/indices/dj-malaysia-historical-data
iii) data on the GEPU index from https://www.policyuncertainty.com/, and
iv) data on oil prices from https://www.comparehero.my/transportation/articles/latest-petrol-price-ron95-ron97-diesel.

For Phase 3, the researcher adapted the model in [3]. The current work employed the coherence wavelet method and WGC test on data collected during the current COVID-19 pandemic in Malaysia. Lastly, Phase 4 involved finding solutions and discussions to the problem.

3.1 Continuous Wavelet Transform (CWT)

A wavelet (ψ) is a complex-valued square that can be integrated by functions of the form [9]:

$$\psi_{u,v}(t) = \frac{\psi\left(\frac{t-u}{v}\right)}{\sqrt{v}} \tag{1}$$

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The CWT $N_p(u,v)$ projects a wavelet $\psi(.)$ In contrast to the time series a $(t)\epsilon K^2(R)$:

$$N_p(u,v) = \int_{-\infty}^{\infty} p(t) \frac{1}{\sqrt{v}} \psi\left(\frac{\overline{t-u}}{M}\right) dt \tag{2}$$

This technique has the ability to decompose consequently and logically recreate a time series $(t)\epsilon K^2(R)$:

$$p(t) = \frac{1}{c_\psi} \int_0^{\infty} \left[\int_{-\infty}^{\infty} N_p(u,v) \psi_{u,v}(t) du \right] \frac{dv}{M^2}, M > 0 \tag{3}$$

This method also conserves the power of the time series observed time:

$$\|p\|^2 = \frac{1}{c_\psi} \int_0^{\infty} \left[\int_{-\infty}^{\infty} \left| N_p(u,v) \right|^2 du \right] \frac{dv}{M^2} \tag{4}$$

The wavelet coherence counts the successiveness of a bivariate model between two-time sequences [3].

3.2 Wavelet Coherence (WC)

WC was used to examine the interaction between all data over time scales. The cross wavelet can be explained by two-time sequence $p(t)$ and $q(t)$ [3]:

$$N_{pq}(u,v) = N_p(u,v) N^*_q(u,v) \tag{5}$$

where, $N_p(u,v)$ and $N_q(u,v)$ are continuous transforms of $p(t)$ and $q(t)$ respectively. u shows the location index and q is the measure. The composite conjugate is shown by (*).

Sharif, et al. [3] defines the equation of the coefficient of adjusted WC as:

$$W^2(u,v) = \frac{\left| M\left(M^{-1} N_{pq}(u,v) \right) \right|^2}{M\left(M^{-1} \left| N_p(u,v) \right|^2 \right) M\left(M^{-1} \left| N_q(u,v) \right|^2 \right)} \tag{6}$$

where M is the smoothing mechanism.

Here, $0 \leq W^2(p,q) \leq 1$ shows the scale of the squared coherence coefficient. A value closer to 0 indicates a zero correlation while a value near to 1 (unity) implies a high correlation between variables. The graphic W^2 allows to find the areas of co-movement between time series because the value cannot differentiate between negative and positive correlation [10].

3.3 Wavelet-Based Granger Causality (WGC) Test

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WGC test is employed to determine the robustness of WC and CWT analysis [3]. The traditional Granger causality test was designed to identify linear causality [11]. The Granger test in two-variable cases includes the estimation of the bivariate VAR model [12]:

$$X_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{j=1}^{q} \beta_j Y_{t-j} + \varepsilon X, t \tag{7}$$

$$Y_t = \beta_0 + \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{j=1}^{q} \beta_j Y_{t-j} + \varepsilon_{y,t} \tag{8}$$

where X and Y are stationary variables and n and q are the lag length of X and Y respectively.

Hypothesis in the Granger causality test:

$$H_0: \beta_1 = \cdots \beta_q = 0 \tag{9}$$

$$H_1: \beta_1 \neq 0 \text{ for at least one } j \tag{10}$$

The test statistics has a standard F distribution with degrees of freedom, $(T - n - q - 1)$, where T is the number of observations [12].

4. RESULTS AND DISCUSSION

In brief, the main objective of this study was to analyse the relationship between the GEPU, confirmed cases of COVID-19, stock market, and oil price in Malaysia. Three mathematical models were adapted to solve three specific objectives, namley CWT, WC and WGC.

CWT plots were drawn up for all variables, namely GEPU index, COVID-19, Stock Price Index, Oil Prices (RON 95), Oil Prices (RON 97), and Oil Prices (Diesel). The thick black contour represents the 5% significance level against the red noise.

Table 1 provides the interpretation for the CWT Plots.

Table 1: Interpretation for the CWT Plots

Figure of WC	Interpretation
Warmer colour (yellow)	Regions with significant interrelation
Colder colour (blue)	Lower dependence between the series
Cold regions beyond the significant areas	Time and frequencies with no dependence in the series

Figure 1 shows the CWT plot for the GEPU index.

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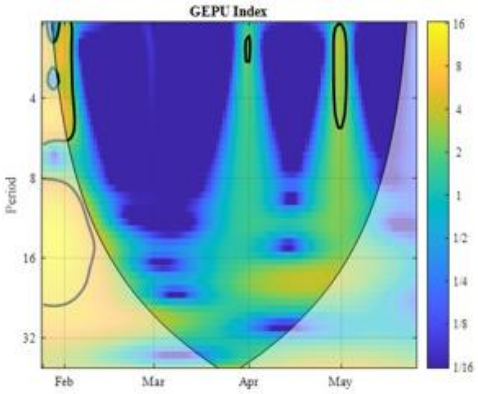

Figure 1: CWT Plot for GEPU Index

In the CWT plot for GEPU index, there were two islands of high volatility for the 1 to 32 day-frequency bands beginning from the start point of sample period. This may be caused by the bad news related to the new infectious disease in China. There were sudden effects at the beginning of April and May.

Similar plots were drawn for the other variables. Table 2 presents the interpretation for CWT Plot for each variable.

Table 2: Interpretation of CWT Plot for Each Variable

Variables	Interpretation
COVID-19	Significant island of high volatility over the short-run which was on 1 to 4 days' frequency bands on the middle of March until April.
Stock Market Index	Increased activity in the 1 to 8 days-frequency bands at the end of January which was the inception of sample periods. There were also sudden changes in stock price index which were detected around March.
Oil Prices (RON 95, RON 97 and Diesel)	The oil prices of RON 95, RON 97 and Diesel were affected for 1 until 32 days-frequency bands at the beginning of sample. The oil prices again showed signs of instability around March until April.

The present study found that variables with high volatility at the beginning of the sample period were GEPU, oil prices and stock market, in which oil prices were in the long-run effect. They probably reacted to the early news of the spread of COVID-19 pandemic. Next, variables with high volatility at the middle of the sample period were COVID-19, the price of oil and stock price index. Oil prices and stock price index were in high volatility probably because of the sudden increase of COVID-19 cases in Malaysia. Therefore, the first objective to describe the movement of each variable by using CWT was achieved. In order to further analyse the interactions between variables, WC plots were drawn between

i. COVID-19 and GEPU Index,
ii. COVID-19 and Stock Market,
iii. COVID-19 and Oil Prices (RON 95),
iv. COVID-19 and Oil Prices (RON 97),
v. COVID-19 and Oil Prices (Diesel),
vi. GEPU Index and Stock Market,

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vii. GEPU Index and Oil Prices (RON 95),
viii. GEPU Index and Oil Prices (RON 97),
ix. GEPU Index and Oil Prices (Diesel),
x. Stock Market and Oil Prices (RON 95),
xi. Stock Market and Oil Prices (RON 97), and
xii. Stock Market and Oil Prices (Diesel).

Table 3 provides an interpretation for WC Plots for the selected variables.

Table 3: Interpretion for WC Plots

Arrows in WC Plot	Interpretation
No arrows	Zero-phase • Two time series move together on a particular scale
Point to the right	Time series are in phase • Two time series move in the same direction
Point to the left	Time series are in anti-phase • Two time series move in the opposite direction
Point to the right-down or left-up	The first variable is leading
Point to the right-up or left-down	The second variable is leading

Figure 2 displays the WC plot between COVID-19 and GEPU index.

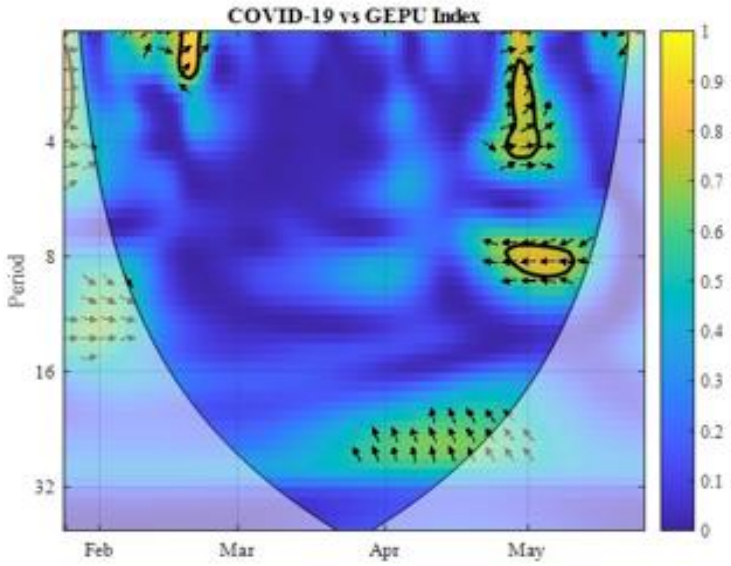

Figure 2: WC Plot Between COVID-19 and GEPU Index

From the plot, there were strong dependence at the beginning of the sample period, which is in the middle of February and end of April until early May over 4 to 8 days-frequency bands. An island is located in the beginning of the sample period from mid-February to May for 4 days-frequency bands showed strong correlation. The series were in phase where GEPU index led. However, a high correlation located at the end of April and beginning of May on 8 days-frequency indicated the time series is an anti-phase.

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The WC Plot for other selected variables were drawn by using MATLAB software. Table 4 presents the interpretations of WC plots for selected variables.

Interpretations were also made for plots of several other variables. For example, the WC Plot between COVID-19 and GEPU Index displayed strong dependence at the beginning of sample period, in the middle of February and at the end of April until early May over 4 to 8 days-frequency bands. The island located in the beginning of the sample period in the middle of February and May for 4 days-frequency bands showed strong correlation. The series were in phase where GEPU index led. However, a high correlation located at the end of April and beginning of May on 8 days-frequency indicated the time series is an anti-phase.

To summarize the findings, COVID-19 confirmed cases displayed a higher correlation with stock market than with GEPU index. There were also high coherences between GEPU index with oil prices and stock market. Stock market also had high coherency with oil prices. The results also indicated that there was a relationship between oil prices and COVID-19 cases. Therefore, the second objective, which is to evaluate the interactions between the selected variables by using WC was accomplished.

The last objective of the study was to check the robustness of the WC and CWT analysis by using WGC test. The test was operated for seven frequency domains D1 to D7.

Table 4: Interpretation of WC Plots for Selected Variables

Selected Variables	Interpretation
COVID-19 and Stock Market	• A huge island of high coherency on 4 to 16 days-frequency was reported for the whole sample period. • Small islands of strong dependence between the two variables were revealed on March and at the end of sample period.
COVID-19 and Oil Prices (RON 95, RON 97 and Diesel)	• A higher dependence between COVID-19 cases and all oil prices at the end of January until the middle of February. • A very small island indicated a strong coherency between variables for all oil prices located at the end of February. • A strong correlation of variables for RON 95 and RON 97 located in March. • High correlation located during the whole period was detected in WC between COVID-19 and RON 95 and RON 97.
GEPU Index and Stock Market	• Two strong dependency at the beginning and at the end of sample period in anti-phase where GEPU index led the stock market. • An island indicated a strong coherency existing in May in which stock market was leading the GEPU index.
GEPU Index and Oil Prices (RON 95, RON 97 and Diesel	• All three plots showed quite similar configuration in terms of islands of strong coherencies. • There were yellow islands recognised at the beginning of the sample period until March and at the end of sample period. • Islands at the beginning of sample period were moved in anti-phase.
Stock Market and Oil Prices (RON 95, RON 97 and Diesel)	• At the beginning of the sample period and in March, strong correlations were in phase. • There was also an anti-phase strong coherency in March for RON 95 and RON 97. • Strong correlation for all oil prices at the end of sample period where stock market led the oil prices.

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Table 5 and Table 6 present the value of F and F critical value of GWC tests for data of COVID-19 reported cases, oil prices, stock market in Malaysia and GEPU index. Table 5 for independents variables stock market, COVID-19 and GEPU, while Table 6 for independent variable oil prices. The bolded values (COVID-19 against SPI and GEPU for D1 until D7; oil prices against SPI and GEPU for D1 until D7; SPI against GEPU for D2 and D3; COVID-19 against Oil Prices for D2 until D5) emphasize that F value is greater than F critical value. This means that independent variable does Granger-cause dependent variable.

The researchers observed that wavelet-based causality was transitioning from COVID-19 pandemic to the Malaysia stock market and the GEPU for the whole selected frequency domain. Furthermore, the stock market affected oil prices for all selected frequencies while oil prices did not have granger causality impact on stock market. Next, a significant impact of the COVID-19 confirmed cases was spotted on the oil prices for D1, D3, D6 and D7 frequency domain. As for the GEPU, causality was strongly influencing the oil prices for all selected frequencies while granger causality effect between GEPU and stock market were on D1-D3 and D6-D7. Besides, stock market affected GEPU index only for D4 and D5. Furthermore, there were no granger causality between oil prices and stock, and oil prices and GEPU index.

Findings indicate that oil prices were affected by stock market, GEPU index and COVID-19 confirmed cases. There was also a degree of correlation between oil prices and COVID-19 confirmed cases. On the other hand, COVID-19 was strongly influenced by stock market and GEPU index. Besides, GEPU index have some influence for the stock market. Therefore, the third objective was also successfully realised.

Table 5: Results of WGC Test (Part 1)

Frequency Domains	Dependent Variables		Independent Variables					
			SPI		COVID-19		GEPU	
			F	Critical Value	F	Critical Value	F	Critical Value
D1	SPI		-	-	0.000	0.00619	0.593	0.00619
	COVID-19		65535	0.00619	-	-	52363.169	161.448
	GEPU		1.688	161.448	0.0000191	0.00619	-	-
	OIL	RON 95	20427.006	161.448	0.231	0.00619	12103.173	161.448
		RON 97	14253.867	161.448	0.161	0.00619	8445.536	161.448
		DIESEL	18595.951	161.448	0.210	0.00619	11018.258	161.448
D2	SPI		-	-	0.00000191	0.108	0.593	0.108
	COVID-19		522684.633	9.277	-	-	313387.610	9.277
	GEPU		1.686	9.277	0.00000319	0.108	-	-
	OIL	RON 95	20400.596	9.277	0.0386	0.108	12103.173	9.277
		RON 97	14235.438	9.277	0.0269	0.108	8445.536	9.277
		DIESEL	18571.909	9.277	0.0352	0.108	11018.258	9.277
D3	SPI		-	-	0.0000170	0.264	0.752	0.264
	COVID-19		58932.784	3.787	-	-	35571.382	3.787
	GEPU		1.330	3.787	0.0000281	0.264	-	-
	OIL	RON 95	20051.897	3.787	0.340	0.264	12103.173	3.787
		RON 97	14479.512	3.787	0.241	0.264	8582.860	3.787
		DIESEL	18254.467	3.787	0.310	0.264	11018.258	3.787
D4	SPI		-	-	0.00000521	0.416	1.018	2.403
	COVID-19		191794.149	2.403	-	-	58554.683	2.403
	GEPU		0.9828	0.416	0.0000171	0.416	-	-

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Frequency Domains	Dependent Variables		Independent Variables					
			SPI		COVID-19		GEPU	
			F	Critical Value	F	Critical Value	F	Critical Value
	OIL	RON 95	20521.272	2.403	0.3223	0.416	18872.312	2.403
		RON 97	15174.376	2.403	0.2353	0.416	13775.199	2.403
		DIESEL	19100.678	2.403	0.2966	0.416	17366.364	2.403
D5	SPI		-	-	0.000217	0.549	1.2389	1.822
	COVID-19		4603.401	1.822	-	-	148245.215	1.822
	GEPU		0.807	0.549	0.00000675	0.549	-	-
	OIL	RON 95	19890.349	1.822	0.155	0.549	22928.231	1.822
		RON 97	14866.640	1.822	0.115	0.549	17088.673	1.822
		DIESEL	18592.092	1.822	0.144	0.549	21347.449	1.822
D6	SPI		-	-	0.0983	0.659	1.750	1.518
	COVID-19		10.169	1.518	-	-	43.267	1.518
	GEPU		0.572	0.659	0.0231	0.659	-	-
	OIL	RON 95	23378.944	1.518	684.463	1.518	29614.829	1.518
		RON 97	16977.579	1.518	507.039	1.518	21938.158	1.518
		DIESEL	20259.053	1.518	618.728	1.518	26770.662	1.518
D7	SPI		-	-	0.0897	0.746	1.837	1.340
	COVID-19		11.153	1.340	-	-	20.963	1.340
	GEPU		0.544	0.746	0.0477	0.746	-	-
	OIL	RON 95	25884.841	1.340	2254.824	1.340	47266.870	1.340
		RON 97	18563.468	1.340	1612.520	1.340	33802.533	1.340
		DIESEL	22281.146	1.340	1935.294	1.340	40568.719	1.340

Table 6: Results of WGC Test (Part 2)

Frequency Domains	Dependent Variables		Independent Variables					
			OIL					
			RON 95		RON 97		DIESEL	
			F	Critical Value	F	Critical Value	F	Critical Value
D1	SPI		0.0000490	0.00619	0.0000702	0.00619	0.0000538	0.00619
	COVID-19		4.326	161.448	6.200	161.448	4.752	161.448
	GEPU		0.0000826	0.00619	0.000118	0.00619	0.0000908	0.00619
	OIL	RON 95	-	-	-	-	-	-
		RON 97	-	-	-	-	-	-
		DIESEL	-	-	-	-	-	-
D2	SPI		0.0000490	0.108	0.0000702	0.108	0.0000538	0.108
	COVID-19		25.893	9.277	37.107	9.277	28.443	9.277
	GEPU		0.0000826	0.108	0.000118	0.108	0.0000908	0.108
	OIL	RON 95	-	-	-	-	-	-
		RON 97	-	-	-	-	-	-
		DIESEL	-	-	-	-	-	-
D3	SPI		0.0000499	0.264	0.0000691	0.264	0.0000548	0.264
	COVID-19		2.939	3.787	4.144	3.787	3.228	3.79
	GEPU		0.0000826	0.264	0.000117	0.264	0.0000908	0.264
	OIL	RON 95	-	-	-	-	-	-
		RON 97	-	-	-	-	-	-
		DIESEL	-	-	-	-	-	-
D4	SPI		0.0000487	0.416	0.0000659	0.416	0.0000524	0.416
	COVID-19		3.103	2.403	4.251	2.403	3.371	2.403
	GEPU		0.0000530	0.416	0.0000726	0.416	0.0000576	0.416

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Frequency Domains	Dependent Variables		Independent Variables					
			OIL					
			RON 95		RON 97		DIESEL	
			F	Critical Value	F	Critical Value	F	Critical Value
	OIL	RON 95	-	-	-	-	-	-
		RON 97	-	-	-	-	-	-
		DIESEL	-	-	-	-	-	-
D5	SPI		0.0000503	0.549	0.0000673	0.549	0.0000538	0.549
	COVID-19		6.466	1.822	8.675	1.822	6.944	1.822
	GEPU		0.0000436	0.549	0.0000585	0.549	0.0000468	0.549
	OIL	RON 95	-	-	-	-	-	-
		RON 97	-	-	-	-	-	-
		DIESEL	-	-	-	-	-	-
D6	SPI		0.0000428	0.659	0.0000589	0.659	0.0000494	0.659
	COVID-19		0.00146	0.659	0.00197	0.659	0.00162	0.659
	GEPU		0.0000338	0.659	0.0000456	0.659	0.0000374	0.659
	OIL	RON 95	-	-	-	-	-	-
		RON 97	-	-	-	-	-	-
		DIESEL	-	-	-	-	-	-
D7	SPI		0.0000386	0.746	0.0000539	0.746	0.0000449	0.746
	COVID-19		0.000443	0.746	0.000620	0.746	0.000517	0.746
	GEPU		0.0000212	0.746	0.0000296	0.746	0.0000246	0.746
	OIL	RON 95	-	-	-	-	-	-
		RON 97	-	-	-	-	-	-
		DIESEL	-	-	-	-	-	-

5. CONCLUSIONS AND RECOMMENDATIONS

During the COVID-19 pandemic, the society was worried about the impact of this virus towards the economic and social costs. By implementing all three models, the researcher has established that oil prices were affected by GEPU index and stock market. Stock market and GEPU index also had some interactions with COVID-19 pandemic. There was also some short-term effect between COVID-19 confirmed cases and oil prices. Therefore, the researchers have attained the aim of the present study to analyse the connectivity of COVID-19 confirmed cases in Malaysia, GEPU index, stock market in Malaysia, and oil prices in Malaysia.

Firstly, to obtain precise results, it is recommended for future research to use the Economic Policy Uncertainty (EPU) of Malaysia instead of GEPU index. By using EPU index, the results of the study can be more specific and relatable with Malaysia's economic background. Future research are also advised to use more sample data to get more convincing results.

Secondly, investors who invest in stocks may need to be constantly aware on the GEPU index and COVID-19 cases. As identified in the analysis of this study, GEPU index affected the stock market. This study also reported that COVID-19 pandemic had a strong correlation with stock market and GEPU index.

Thirdly, oil and gas company should always be alert on the volatility of all factors investigated. It has been shown in the findings of this study that oil prices seemed to be affected by stock

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market, GEPU index and pandemic of COVID-19 where stock market and GEPU index influenced more than COVID-19 cases.

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