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Covid-19 Effect on Community Mobility and Stock Market of Malaysia

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ABSTRACT

Physical distancing is believed to contain the spread of COVID-19 virus. With data provided by COVID-19 Community Mobility Reports from Google, this study examines the mobility patterns at different stages of Movement Control Order (MCO) and investigates whether lower mobility reduces the number of new cases, death cases, and recovery rate. This research also covers the time spent in places such as i) retail and recreation, ii) grocery and pharmacy, iii) parks, iv) transit stations, v) the workplace, and vi) residential areas. As each of these types of places has distinct epidemiological characteristics, they may spread transmission differently. This study also correlates the stock market with mobility patterns of Malaysians in order to evaluate the effectiveness of lockdowns on COVID-19 incidents and its impact on the stock market, in this case; Kuala Lumpur Composite Index (KLCI). Findings of this study highlight the effects of pandemic COVID-19 on stock market daily performance by utilizing prospect and uncertainty theory in predicting the short-term impacts of the epidemic.

Keywords: COVID-19; Malaysia; MCO; mobility; KLCI

Introduction

Covid-19 has resulted in a global pandemic with severe effects on human, social, and financial costs. To mitigate the spread of new cases, governments in many countries all over the world have implemented a multi-level approach involving social distancing, business closures, and movement restrictions. The implementation of these approaches can be very strict (e.g., Asia and Southern Europe) or relaxed (e.g., Sweden). As of mid-2021, the policy landscape continues to change rapidly depending on the pandemic situation that kept changing. At the same time, the benefits and costs of the various policy options continue to be the topic of debate in press and policy discussions. Existing empirical evidence demonstrates a clear impact of the reduction in human mobility on the virus growth rates (Soucy et al. 2020; Fang et al. 2020; Prem et al. 2020). There is also a growing literature which studied on how different social distancing policies affect mobility, most of which is based on the US data (see for example Engle et al. 2020; Brzezinski et al. 2020; Maloney & Taskin 2020). It has been hypothesized that these restrictions would have a deleterious effect on the global financial system. For example, the Dow Jones Industrial Average (DJIA) and the S&P 500 recorded the worse plunge in their stock market history, where they fell 33% and 29% respectively, even more than during the Global Financial Crisis. Such drastic fall in the financial markets requires a more comprehensive study.

Although the implementation of lockdown was successful in containing the spread of disease initially (Kraemer et al. 2020; Wilder-Smith & Freedman 2020; Wu & McGoogan 2020), recent studies have cast doubts on its long-term effectiveness, particularly when the economic sector is reeling from the effect of the policy. As the pandemic shows no sign of abating due to the emergence of new variants, it is imminent that this study closely examines the impact on the policies on human as well as economy. Additionally, developing markets seem to have a higher compliance with the movement restrictions (Chowdhury & Jomo 2020)

While movement restriction seems like the go-to method in containing the spread of disease, its efficacy is still debatable. Does a lockdown which is aimed at reducing community mobility really reduce the number of new cases and death rate? And at what cost? How does this harsh measure impact the economy, particularly the stock market? Studying the relationship between community activity, cases, and stock market during a period of time may help in understanding the efficacy and impact of these policy implementation on the country.

Therefore, the objective of this paper is to examine how different stages of movement restriction affect the population mobility patterns in Malaysia. Thereafter, this study also aims to investigate whether low mobility patterns affect the daily incidence of COVID-19 and the stock market. Understanding the effectiveness of the movement restrictions is important as policy makers and the society at large seek to achieve an optimal outcome in the fight against the pandemic at the lowest economic cost.

We argue that Malaysia is an interesting sample to study as the country was successful in controlling the pandemic in the first movement restriction but unfortunately not the second one. Therefore, it may be interesting to learn details about what causes the different results. As an emerging country, Malaysia's level of compliance towards movement restrictions might also differ between the two extremities of U.S. and China. This is due to the difference in the level of submission to the government, freedom of individual rights, and differences in culture. Studies like Alfano and Ercolano (2021) have also reiterated that the effectiveness of lockdown measures may depend on how citizens perceive the capacity of government to set up and implement sound policies. All countries are different in many aspects such as institutional quality, social capital, compliance to authority, and social trust. These aspects will impact the community mobility and stock price differently. Therefore, in our opinion, research focusing on a single country will provide a cleaner result to be interpreted. The sample chosen is a developing country, a less researched area as of to-date. Additionally, studies like Barnett-Howell and Mobarak (2020), Loayza (2020), and Subramanian and Vandewalle (2020) have also raised concern on whether lockdown should be the goal in developing countries as well. As an emerging country, Malaysia's level of compliance towards movement restrictions might also differ between the two extremities of U.S. and China. This is due to the difference in the level of submission to the government, freedom of individual rights, and differences in culture.

We use the data provided by COVID-19 Community Mobility Reports from Google to help us track the movement of people in the country when movement restrictions were implemented and how this affects the stock market. The mobility data provide us with an accurate representative of the current state of community movement and activity. The data also provide invaluable information as to whether people are actively reducing their exposure to COVID-19 by reducing distances travelled and avoiding social contact and by how much.

We show that lockdown restricted the community mobilities, particularly in the retail and recreational sector. Furthermore, mobility patterns such as retail and recreation, parks, transit stations and workplace mobilities have dropped within 24 days after the number of new cases started to rise. However, it took more than 2 months (>70 days) to see eased of restriction due to the drop of new COVID-19 cases. We further find increased trading activity in volume and KLCI index associated with the increase of mobility to retail and recreation, and grocery and pharmacy.

In this study, the understanding and conjecture are based on the prospect theory which was developed by Kahneman and Tversky (1979). In the prospect theory, investors value gains and losses differently and when presented with a choice, both equal, will choose the one presented in terms of potential gains. Prospect theory is also known as the loss-aversion theory. During the COVID-19 pandemic, investors are postulated to be very risk-averse due to the high uncertainty caused by the reduced community mobility and high COVID-19 cases.

Our study relates closely to a growing literature on the dynamics of stock prices, economic activity, and policy actions during the COVID-19 pandemic (e.g., Caballero & Simsek 2021; Cox et al. 2020; Deb et al. 2020; Giglio et al. 2020; Germen & Koijen 2020; Landier & Thesmar 2020; Zarembra et al. 2020). To the best of our knowledge, none of the extant past studies investigate the effect of COVID-19 cases on community mobility and the stock market in the same breath. The current study fills this gap in the literature by examining these relationships using a cross-correlation of lagged time. This enables us to track how the increase of death cases is influenced by the number of new cases. Similarly, we look at how increase in community mobility correlates with the number of new cases. Relative to these literatures, we contribute in several ways.

The main contributions of the paper are as follows. First, we link policy implementations to mobility patterns by examining not only the impact of these policies on mobility patterns but also on the incidence of COVID-19. Our research also covers the time spent in places such as i) retail and recreation, ii) grocery and pharmacy, iii) parks, iv) transit stations, v) the workplace, and vi) residential areas. Each of these types of places has distinct epidemiological characteristics, thus, they may spread transmission differently. Second, we show that movement restriction is very effective in the first lockdown in controlling the community mobility and daily incidence of COVID-19 in Malaysia. Therefore, this provides evidence on the compliance level when lockdown policies were implemented in Malaysia. Third, we link community mobility to the stock market of Malaysia by examining daily movements in KLCI. Hence, our study provides evidence on the distinctive character of an emerging country's stock market reaction to the pandemic and highlights the contrasts to countries like U.S. and China, whose market size and characteristics are different than Malaysia.

These findings are important to investors as they provide evidence that in developing country like Malaysia, stock market is affected by the number of COVID-19 cases and the community mobility. These findings are beneficial for policymakers because it could guide them to implement policies that are not too restrictive on community mobility as tighter rules will have an adverse effect on the stock market. Societies can learn about the impact of lockdown on stock market because although stricter lockdown brings down COVID-19 cases, the negative impact that it has on the economy will be felt in terms of higher unemployment in the near future. The findings of this study can be generalized to future periods of pandemic or crisis of similar size and effect.

Literature Review

COMMUNITY MOBILITY AND INCIDENCE OF COVID-19 DURING LOCKDOWN

Most countries enforced the lockdown policies when the number of COVID-19 cases soar. Malaysia too adopted this approach. However, the effect of lockdown is not homogenous for every country. For example, Jarvis et al. (2020) found that in UK, lockdown policies reduced the average number of daily contacts by 73 percent, while Singh and Adhikari (2020) showed that lockdown policies in India were unlikely to be effective if applied for 3 weeks or less. Gao et al. (2020) showed that in many countries in which mobility restrictions were only recommended but not imposed, mobility did not decrease. Study by Engle et al. (2020) found that official confinement orders lead to a mobility reduction of less than 8 percent in the United States. Huber & Langen (2020) found that a relatively later exposure to lockdown entails higher cumulative hospitalization and death rates based on the data from Germany and Switzerland.

Malaysia enforced a few types of lockdowns, where some are stricter than others. The movement control order (MCO) is considered the strictest lockdown, followed by the conditional movement control order (CMCO), and recovery movement control order (RMCO). All these phases specify the sectors that are allowed to operate. FIGURE 1 shows the timeline of Malaysia's lockdown. As showed in the graph, each stage of MCO provided different SOPs for different sectors and community mobility restrictions. A deep look into the community mobility throughout the MCO stages was done to identify the patterns behind the COVID-19 cases. Initially, community mobility was found to be more random, some low effect during lockdown and possibly not always positive towards the number of COVID-19 cases (Rajendran K. et al. 2021). The study found that Retail and Recreation have low mobility, but the Grocery, Pharmacy and Transit Stations have higher mobility. In our neighbouring country, Indonesia, the Grocery and Pharmacy is reported to be the highest (4.12%) in predicting COVID-19 dynamics (Nanda R.O. 2022).

As a global pandemic respond to the COVID-19, mobile operating system providers, such as Google (Android) and Apple (IOS) have provided open-source anonymous mobility tracking of the mobile users to important sites (Agarwal et al. 2020; Yilmazkuday 2021). Through their subsidiary applications and softwares (i.e., Google Location Services and Apple Maps), the companies have provided the aggregated and anonymized mobility data for the public to analyze (Apple 2021; Google LLC 2021). This provided opportunity for contagious disease experts to track disease spreading of COVID-19 and economist to predict economic fallout due to the mobility restrictions of the communities (Agarwal et al. 2020; Leung et al. 2021; Lin & Meissner 2020; Ma & Lipsitch 2021). In Malaysia, most mobile phone users are divided into two major providers: Google Android (75%) and Apple IOS (24%) (Statcounter 2021; Statista 2021). Google Mobility provided six major mobility sites (Google LLC 2021), while Apple only provided two mobility types: Walking and Driving (Apple 2021). Furthermore, Apple had 3 missing days throughout the MCO period (11-12 May 2021 and 22 March 2021), while Google Mobility had none. Thus, with bigger market share and detailed database, Google Mobility is often used to track community activities during the COVID-29 pandemic (Agarwal et al. 2020; Leung et al. 2021; Lin & Meissner 2020; Ma & Lipsitch 2021).

Initially, Malaysia was considered as one of the most successful countries in containing the virus, through the strict MCO implementation (Tang 2020). However, after the relaxation of lockdown and a local election, cases started to increase again. And even though lockdown measures (CMCO, MCO2, MCO3, FMCO) were enforced, the situation was different from the first MCO stage. On 23 May 2021, Malaysia surged past India to record one of South East Asia's highest COVID-19 infection rates, with deaths per capita exceeding India and neighbouring Indonesia. Since then, the numbers have only grown, despite the nation being in a state of emergency for seven months and in lockdown since June 2021. Malaysia reported a high record of 22 242 daily cases on 18 August 2021, with a total of 1.47 million cases and 13 302 deaths during the pandemic (as of 30 June 2021).[1]

One of the reasons for the unsuccessful containment in the second lockdown could be due to the government's inconsistent lockdown measures. For example, the government allowed 18 manufacturing sectors to operate at 60 percent capacity, thus causing outbreaks at factories and workers' dormitories. Woon (2021) further corroborated that the community mobility was higher during the second lockdown compared to the first. For example, while the average decline in mobility during first lockdown was 75 percent, it was only 50 percent in the second lockdown.

Though the efficacy of lockdown could be decreasing, nonetheless, it is still a good way to reduce community mobility among the people. Therefore, we hypothesize that a reduced community mobility due to the lockdowns will decrease the COVID-19 incidence in Malaysia. There are three COVID-19 incidences examined in this study which are the number of new cases, the number of death cases, and the recovery rate. The three hypotheses are stated as below:

H_{1a} A reduced community mobility due to lockdown will have a negative relationship the number of new cases on average, *ceteris paribus.*

H_{1b} A reduced community mobility due to lockdown will have a negative relationship the number of death cases on average, *ceteris paribus.*

H_{1c} A reduced community mobility due to lockdown will have a positive relationship the rate of recovery on average, *ceteris paribus*.

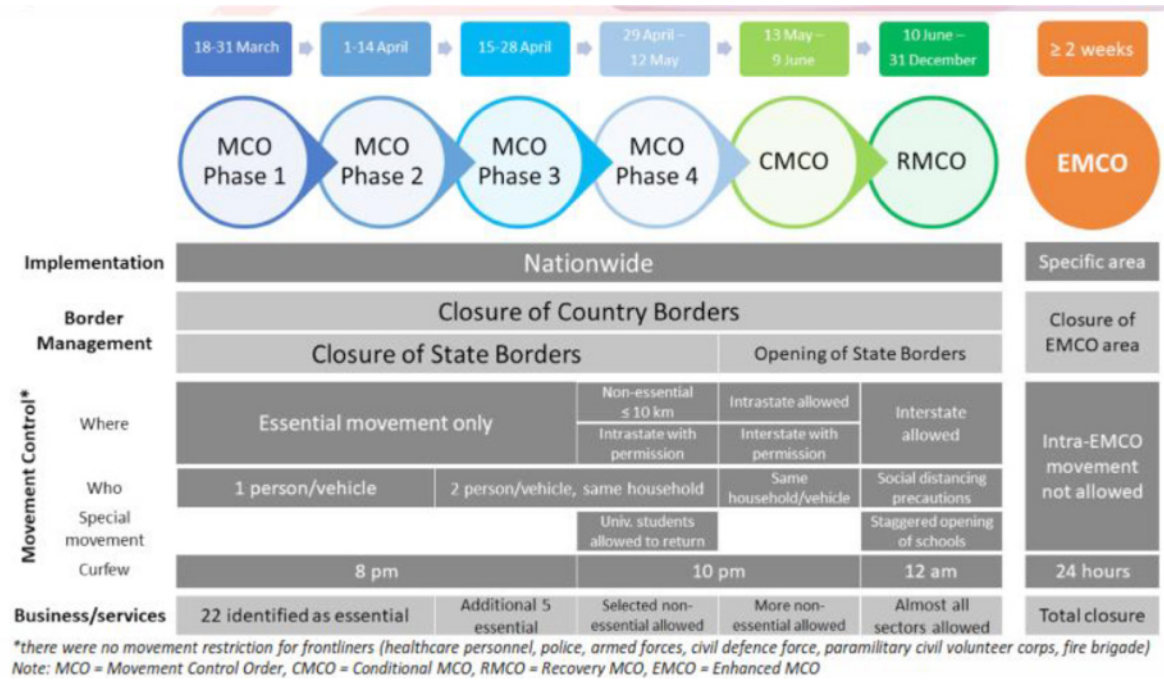

FIGURE 1. Lockdown phases in Malaysia.
Source: WHO Malaysia (www.who.int)

COMMUNITY MOBILITY AND STOCK MARKET

Historically, events that capture worldwide attention tend to receive a lot of coverage from the media (Blendon et al. 2004; Mairal 2011; Young et al. 2013). As COVID-19 is a worldwide pandemic, it naturally overshadows all other concurrent events. The immense media coverage can cause anxiety and panic among investors, which eventually affects their investment decisions (Ederington & Lee 1996; Klibanoff et al. 1998; Tetlock 2007). For example, Beirne et al. (2020) provided evidence that financial markets around the world were affected during the COVID-19 pandemic. However, stock market in emerging countries in Asia and Europe were more severely affected as compared to advanced economies due to the intense outflow of capitals.

The financial market also reacts towards the government's response during pandemic. For example, the implementation of lockdown policies can increase investor's anxiety as restrictive government policies could force them to reconstruct their portfolio and engage in unusual transactions which eventually disrupts the market (Zaremba et al. 2020; Blau et al. 2014). Ru et al. (2020a) and Ru et al. (2020b) provided evidence that countries that have quicker response policies during the SARS epidemic in 2003 resulted in quicker stock market reactions. Baker et al. (2020) also concluded that the stronger government response to COVID-19 drove the observed strong market volatility in the U.S. Meanwhile, Baig *et al.* (2020) found that government-induced lockdown due to COVID-19 caused a decline in the United States' market stability and liquidity. Eleftheriou and Patsoulis (2020) also investigated similar issue on the stock market indexes of 45 nations and found a negative relationship between the lockdown and the performance of international stock markets. However, Ichev and Marinč (2018) showed that certain sectors like pharmaceutical, biotechnology, healthcare supplies, and food and beverage industries are positively connected to a pandemic.

In Malaysia, the stock market experienced a period of instability and panic selling when government-induced lockdown was announced. FIGURE 2 provides a graphical illustration on how the Kuala Lumpur Composite Index (KLCI) fell when lockdown measures was introduced. As the lockdown affected the earnings recovery for many companies, particularly those in the services sector, the stock market continued to be bearish. Studies like Keh and Tan (2021), Mustaffa et al. (2021) and Song et al. (2021) also provided evidence on the effect of lockdown on the Malaysian stock market. Recently, Yi Xie and Lingke Zhou (2022) highlighted the effect of lockdown on Malaysian healthcare companies stock market. The study found that the most significant negative impacts of lockdown on the stock market occured during the first event. This is further supported by uncertainty theory (J.C. Mao 1969) where investors became worried at the moments of uncertainty. In this study, this situation occured during the first lockdown where panic spread quickly to the whole stock market. Following international and local evidence from the effect of lockdown on the stock market, we state the below hypotheses:

H_{2a} A reduced community mobility due to lockdown will have a negative relationship with the stock market on average, *ceteris paribus.*

H_{2b} An increased community mobility due to easing of lockdown will have a positive relationship with the stock market on average, *ceteris paribus.*

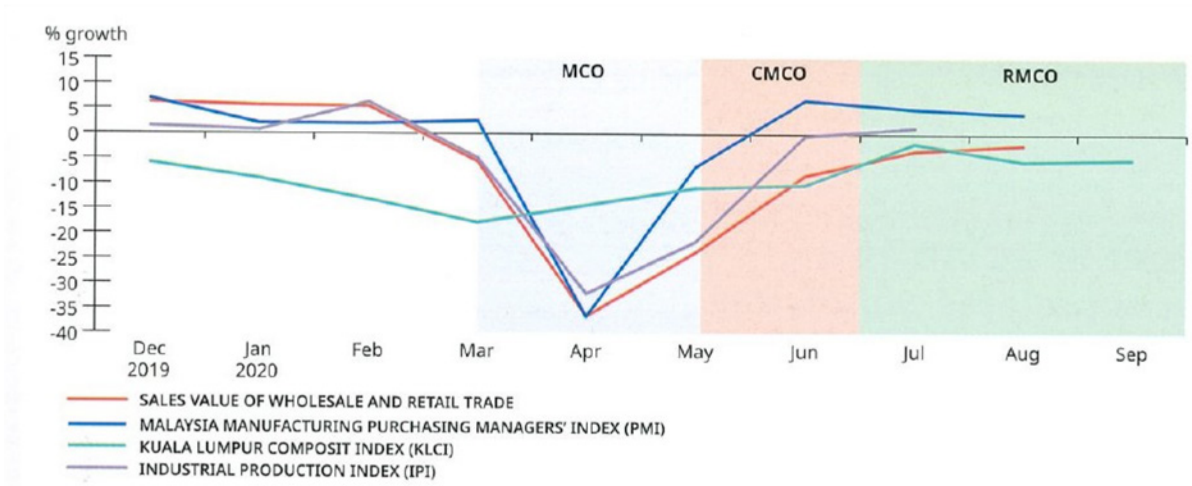

FIGURE 2. Macroeconomic indicators on the effect of lockdown.
Source: Adapted from the department of statistics Malaysia, Bloomberg and IHS market

Data And Methodology

SAMPLE PERIOD

The sample period is for the year 2020 and 2021 due to the implementation of lockdowns in Malaysia. Table 1 states the different stages of lockdowns. MCO is the harshest form of lockdown followed by CMCO and RMCO. The first and last day of lockdown and the number of days of each lockdown implementation are also stated in Table 1.

TABLE 1. Details of the MCO stages, days, number of cases, and periods of implementation.

No.	Stages	Full Name	Days	First Day	New Cases	Last Day	New Cases
1	MCO1	Movement Control Order 1	47	18-Mar-20	117	03-May-20	122
2	CMCO1	Conditional Movement Control Order 1	37	04-May-20	55	09-Jun-20	7
3	RMCO1	Recovery Movement Control Order 1	124	10-Jun-20	2	11-Oct-20	561
4	CMCO2	Conditional Movement Control Order 2	81	12-Oct-20	563	31-Dec-20	2525
5	RMCO2	Recovery Movement Control Order 2	12	01-Jan-21	2068	12-Jan-21	3309
6	MCO2	Movement Control Order 2	56	13-Jan-21	2985	09-Mar-21	1280
7	RMCO3	Recovery Movement Control Order 3	54	10-Mar-21	1448	02-May-21	3418
8	MCO3	Movement Control Order 3	29	03-May-21	2500	31-May-21	6824
9	FMCO	Full Movement Control Order	30	01-Jun-21	7105	30-Jun-21	6276

(Malaysian National Security Council, 2021)

COVID-19 REPORTED CASES

The cumulative number of total COVID-19 cases, active cases, recovery cases and death cases, were collected from the Ministry of Health Malaysia (MOHM) website. The daily reported new cases, daily recovery rate and daily death report of COVID-19 were calculated based on the cumulative data. The data were represented as number of individuals (Individual).

COMMUNITY MOBILITY REPORT

Community Mobility Report of Malaysia was obtained from Google database. The Mobility Report track are the movement of each user to specific locations based on six categories via Google Maps tags: retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential. The rate of visits of the categorized locations are compared with baseline days, which represents a "normal" value of that day of the week, between 3 January to 6 February 2020. The data were represented in percentage (%) change from the baseline traffic.

KUALA LUMPUR COMPOSITE INDEX (KLCI)

Daily Kuala Lumpur Composite Index (KLCI) closing values were obtained from Thompson Reuters Datastream. On days where there was no occurrence of trading, such as weekends and public holidays, average values of the nearest trading days (before and after) were used. This is to complete the continuous data for later statistical analyses (Jamshidian 2007).

STATISTICAL ANALYSES

The dataset of COVID-19 Reported Cases, Community Mobility Report and KLCI were appended and organized based on the MCO stages (STAGES) and dates (DATES) within the study period. The STAGES and DATES (the continuous date of which each individual data was published, 18-Mar-2020 to 30-Jun-2021) represent the independent variables (factors), while 10 dependent variables (New Cases, Recovery Rate, Death Rate, Community Mobility, Retail and Recreation, Grocery and Pharmacy, Parks, Transit Station, Workplace, Residential, KLCI) were focused for the statistical analyses. Since this study focuses on observing MCO stages (STAGES) on to the new COVID-19 cases, the economy (KLCI) and community mobility, the latter variables are identified as dependent variables.

$$NEWCASE = \beta_0 + \beta_1 MOBILITY + \beta_2 LOCKDOWNSTAGE + \varepsilon \quad (1)$$

$$RECOVERY = \beta_0 + \beta_1 MOBILITY + \beta_2 LOCKDOWNSTAGE + \varepsilon \quad (2)$$

$$DEATH = \beta_0 + \beta_1 MOBILITY + \beta_2 LOCKDOWNSTAGE + \varepsilon \quad (3)$$

$$KLCI = \beta_0 + \beta_1 MOBILITY + \beta_2 NEWCASE + \beta_3 RECOVERY + \beta_4 DEATH + \beta_5 LOCKDOWNSTAGE + \varepsilon \quad (4)$$

Tests of normality (Shapiro-Wilk test, SW) were conducted on the 10 dependent variables prior to test the differences among the MCO stages (STAGES) with COVID-19 Reported Cases, Community Mobility Report and KLCI. This is to explain whether the data are subjected to parametric (normally distributed) or non-parametric (not normally distributed) tests. This is followed by test of homoscedasticity (Fligner-Killeen test, FK) to check the equality of variance among groups of the dependent variables. The Brown-Forsythe (BF) tests were conducted to test and distinguish the difference of median among STAGES of dependent variables. Pairwise Wilcoxon test with Holm's (WH) correction post-hoc tests were conducted with dependent variables recorded significant difference among STAGES. This is to further distinguish the differences between STAGES for each dependent variable. The significance level of this study was set at α=0.050.

Cross-correlation tests were conducted to examine the lag or displacement of correlative relationship between the dependent variables. New cases and KLCI variables were chosen as reference variables to observe the displacement of correlative relationship with the other dependent variables. The selection of both variables as references are to observe whether the lag time of changes in social mobility has effect upon the COVID cases and the economy (with KLCI as proxy). To control the variation and errors due to long lags in cross-correlation, the maximum lag days was set at 90 days, which represent 181 days displacements ($-90 \leq x \leq 90$ days). These analyses will help to identify the days required (lag days) for the referenced variables to react to changes (significant correlation) with other variables. Due to the non-normal nature of all the variables, Spearman's rank correlation method was adopted. All the dependent variables were rank transformed, prior to cross-correlation via Pearson's correlation. Lag days with the highest and lowest correlation values were extracted and represented in this study. The significance level was set at α=0.050, with correlation score more than R_s=|0.300| will be considered in this study (Mukaka 2021).

RESULTS

DESCRIPTIVE STATISTICS

Table 2 provides the descriptive statistics of the sample in this study. The mean, standard deviation, and median of new cases, death cases, recovery rate, and KLCI during all nine lockdown stages are presented in Table 2. They are further divided into the different localities according to the data provided by Google Mobility data. The results of the table will show the consistency of each variable at different STAGES, especially the disparity between mean (average) and median.

Figure 3 provides line graphs along the dates and lockdown stages illustrating new cases, recovery rate, and death rate on the top graph. The middle graph illustrates the retail and recreation, grocery and pharmacy, parks, transit station, workplace, and residential mobility from baseline. Meanwhile, the bottom graph shows the KLCI closing prices. The KLCI did not experience a steep decline in the beginning of MCO as the cases were not high initially. However, when the number of new cases and deaths began to increase exponentially during CMCO2, the KLCI experienced a dip but subsequently rebounded higher. Figure 4 shows the boxplots of new cases, death cases, recovery rate, and KLCI according to the nine lockdown stages. The plots represent the variations of each variable among and within each STAGES, which showed longer boxplot having wider variation. Similarly, the data are also divided into the respective localities.

TABLE 2. Mean, standard deviation (SD) and median of the dependent variables based on MCO stages.

No.	Stages	New Cases, Cases			Recovery Rate, Cases			Death Rate, Cases		
		Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
1	MCO1	120	52	122	93	57	90	2	2	2
2	CMCO1	55	54	39	69	44	63	0	1	0
3	RMCO1	59	119	14	32	46	15	0	1	0
4	CMCO2	1202	446	1114	963	423	948	4	3	3
5	RMCO2	2377	479	2364	1804	791	1435	7	4	8
6	MCO2	3120	996	3250	3318	1055	3350	11	5	11
7	RMCO3	1829	723	1543	1607	440	1488	6	4	5
8	MCO3	5426	1738	4855	3686	922	3497	44	20	45
9	FMCO	5987	919	5798	6421	1028	6606	79	17	76

No.	Stages	Retail and Recreation, %			Grocery and Pharmacy, %			Parks, %		
		Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
1	MCO1	-77	5	-78	-45	9	-44	-60	7	-57
2	CMCO1	-53	9	-52	-12	9	-11	-43	9	-43
3	RMCO1	-22	6	-21	-1	5	-1	-7	12	-9
4	CMCO2	-30	6	-31	-6	5	-7	-26	13	-31
5	RMCO2	-23	4	-22	3	8	3	-15	11	-17
6	MCO2	-42	12	-48	-10	10	-11	-45	9	-47
7	RMCO3	-23	5	-22	6	4	5	-28	8	-30
8	MCO3	-40	10	-42	5	14	4	-43	6	-43
9	FMCO	-58	3	-58	-14	6	-12	-52	4	-52

No.	Stages	Transit & Station, %			Workplace, %			Residential, %		
		Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
1	MCO1	-78	7	-79	-59	6	-61	35	3	36
2	CMCO1	-54	6	-54	-34	13	-31	21	4	21
3	RMCO1	-26	6	-27	-17	9	-15	7	2	7
4	CMCO2	-48	9	-51	-23	7	-23	15	3	15
5	RMCO2	-35	3	-35	-23	11	-22	12	3	12
6	MCO2	-59	7	-60	-30	10	-30	18	5	20
7	RMCO3	-45	4	-45	-17	5	-16	11	3	11
8	MCO3	-58	9	-58	-30	16	-27	21	6	22
9	FMCO	-71	3	-71	-45	8	-46	31	3	31

No.	Stages	KLCI		
		Mean	SD	Median
1	MCO1	1351.04	44.21	1357.50
2	CMCO1	1449.94	65.06	1444.25
3	RMCO1	1543.08	37.21	1530.82
4	CMCO2	1578.45	66.12	1594.68
5	RMCO2	1613.62	11.30	1614.89
6	MCO2	1589.84	18.66	1584.92
7	RMCO3	1606.77	13.71	1607.65
8	MCO3	1582.07	7.94	1582.99
9	FMCO	1573.48	15.39	1578.81

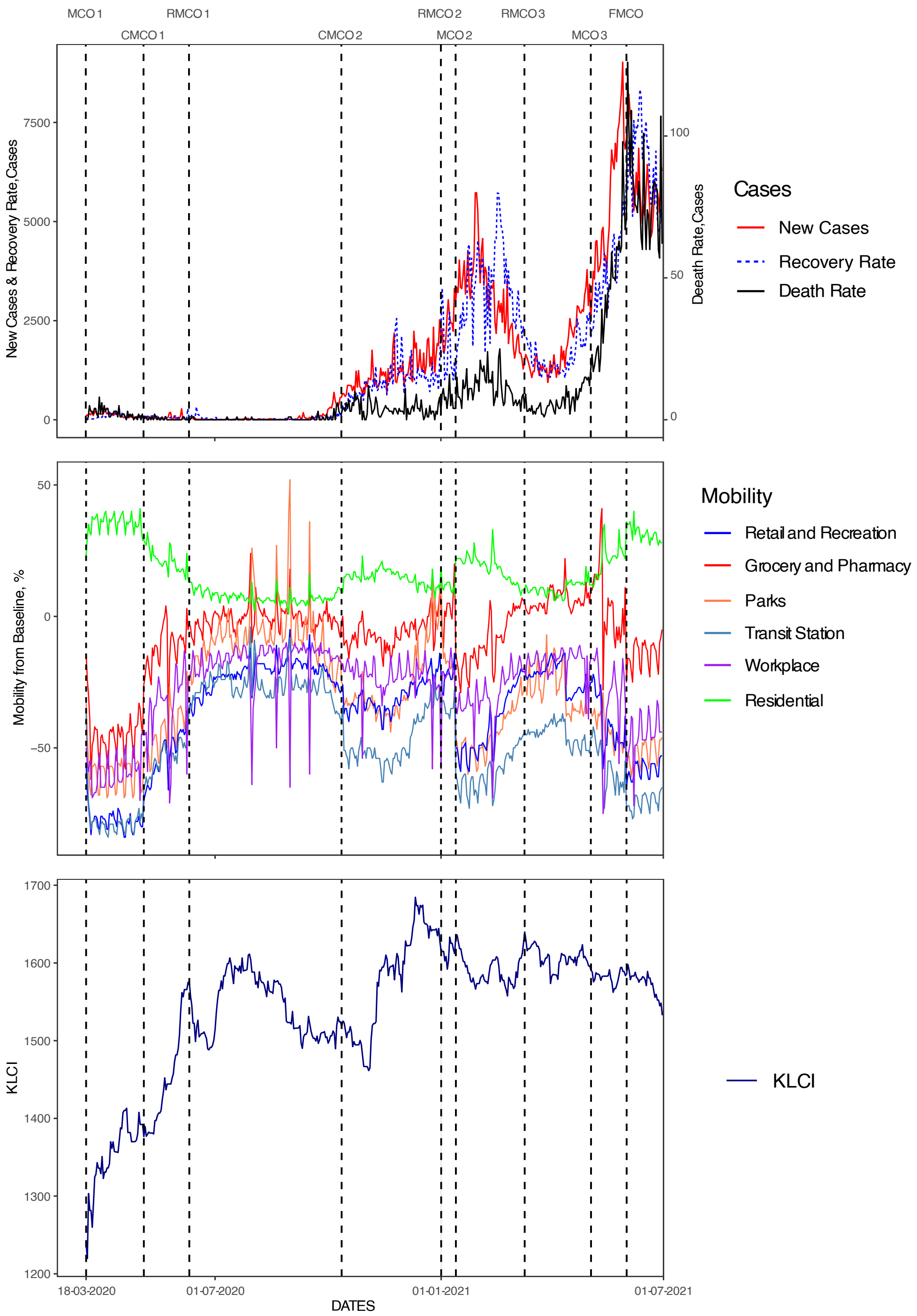

FIGURE 3. Line graphs along the dates and MCO stages with: (Top) New cases, recovery rate, and death rate; (Middle) Retail and recreation, grocery and pharmacy, parks, transit station, workplace, and residential mobility from baseline; and (Bottom) KLCI.

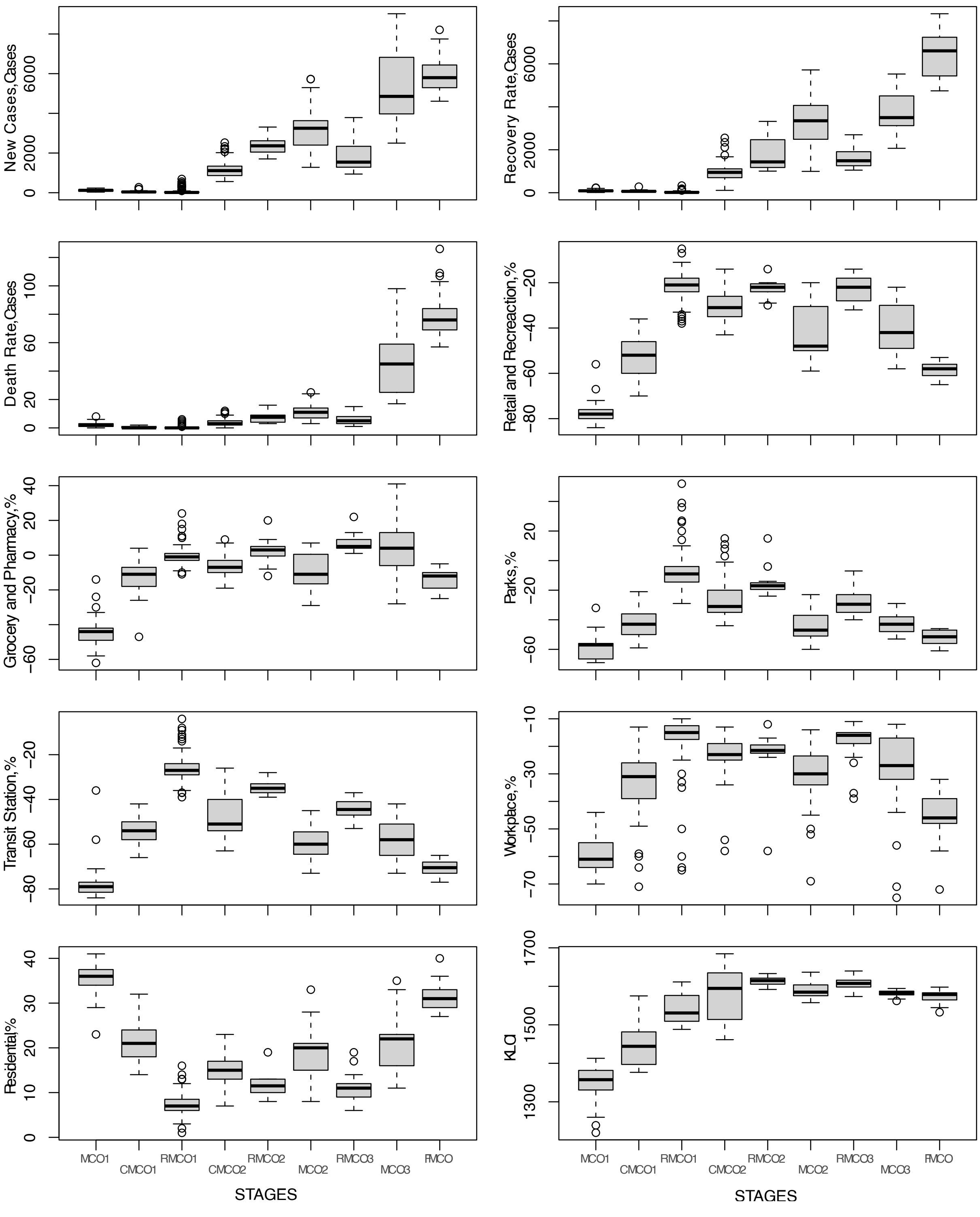

FIGURE 4. Boxplots of all the dependent variables based on MCO stages.

MCO STAGES

Within the study period, RMCO1 was the longest (124 days), while RMCO2 (12 days) was the shortest. Three MCOs had been implemented that range from 29 (MCO3) to 56 (MCO2) days. Test of normality (SW) results showed that all 10 variables were not normally distributed (Supplementary 1). At the same time, the ranked variance among the group of MCO stages were not equal (Supplementary 1, FK: p<0.05). Thus, all the dependent variables were non-normal and heteroscedastic. With that, the representation of the data subsequently will be represented in median, but not mean (or standard deviation).

COVID-19 REPORTED CASES OF DIFFERENT LOCKDOWN STAGES

Daily COVID-19 new cases range from 1 to 9020 cases per day. Test of median (Supplementary 1) showed that there was significant difference of new reported cases among the MCO stages (BF: F=305.59, df=8, p<0.001). The highest daily new cases were during FMCO (5798 cases), while RMCO1 recorded the lowest daily cases (14 cases). Post-hoc (Supplementary 2, WH: New Cases) showed new cases of most stages in MCO were significantly different from each other, except for MCO3 (=4855 cases) and FMCO (WH: p=0.131).

Recovery rates of COVID-19 range from 1 to 8334 cases per day. Test of median (Supplementary 1) showed that there was significant difference of recovery rate among the MCO stages (BF: F=408.13, df=8, p<0.001). The highest daily recovery cases were during FMCO (6606 cases), while RMCO1 recorded the lowest daily recovery cases (15 cases). Post-hoc (Supplementary 2, WH: Recovery rate) showed daily recovery rates of most MCO stages were significantly different from each other; except between MCO1 (=90 cases) and CMCO1 (=63 cases; WH: p=0.075), RMCO2 (=1435 cases) and RMCO3 (=1488 cases; WH: p=0.835), and MCO2 (=3350 cases) and MCO3 (=3497 cases; WH: p=0.220).

COVID-19 reported deaths range from 0 to 126 deaths per day. Test of median (Supplementary 1) showed that there was significant difference of death rate among the MCO stages (BF: F=278.12, df=8, p<0.001). The highest daily death reported was during FMCO (76 deaths), while RMCO1 and RMCO2 recorded the lowest daily reported death due to COVID-19 (0 death). Post-hoc (Supplementary 2, WH: Death Rate) showed daily death rates of most MCO stages were significantly different from each other; except between CMCO1 (=0 death) and RMCO1 (=0 death; WH: p=0.324), and RMCO2 (=8 deaths) and RMCO3 (=5 deaths; WH: p=0.349).

COMMUNITY MOBILITY REPORT OF DIFFERENT MCO STAGES

Community mobility of Malaysia for retail and recreation saw one of the steepest drops with reference to baseline. The largest single day drop of retail and recreation visits was on the 18 and 19 April 2020 (-84%), a month after the implementation of MCO1. During the entire MCO1, retail and recreation visits experienced 78% median reduction from the baseline. Aside from that, Community Mobility to retail and recreational outlets could be grouped into three major groups (Table2, Supplementary 2: Retail and Recreation, WH: p >0.05): FMCO-CMCO1 (-52% to -58%), RMCO1-RMCO2-RMCO3 (-22% to -23%), and MCO2-MCO3 (-40% to -42%). Throughout the MCO period, the retail and recreational mobility did not recover close to the baseline.

Visits at grocery and pharmacy stores, even though experienced mostly reduction of mobility during MCO period, was the only outlets that saw recovery above baseline. The steepest reduction from baseline was during MCO1 (-44%), while RMCO3 experienced 49% recovery from MCO1 to 5% above baseline value. There are two major clusters of community mobility rate during the MCO period (Table 2, Supplementary 2: Grocery and Pharmacy, WH: p>0.05): RMCO1-RMCO2-RMCO3-MCO3 (-1% to 5%) and CMCO1-MCO2-FMCO (-11% to -12%). In general, except for MCO1, community visits to grocery and pharmacy outlets were not affected badly as compared to retail and recreation.

Visits to the parks by Malaysians recorded the steepest drop during MCO1 (-57%), while RMCO1 saw the least reduction (-9%). There are two major clusters of community mobility rate during the MCO period (Table 2, Supplementary 2: Parks, WH: p>0.05): CMCO1-MCO2-MCO3 (-43% to -47%) and CMCO2-RMCO3 (-30% to -31%).

Community mobility to transit stations experienced the steepest reduction during MCO1 (-78%) while RMCO1 (-27%) experienced the least reduction. The single day with the steepest reduction of mobility at transit stations was on 5 April 2020 (-84%) of MCO1, while the highest mobility was on 30 July 2020 (-4%). The community mobility at transit stations were significantly different among MCO stages, except for CMCO1-MCO2-MCO3 (-54% to -60%).

Workplace mobility was lesser than the baseline throughout the MCO stages, ranges between -75% (MCO3) to -10% (RMCO1). MCO1 recorded the most reduction of community to workplace mobility (-61%), with RMCO1 recorded the least reduction of workplace mobility (-15%). The workplace mobility reduction during MCO3 (-27%) was right between CMCO1-MCO2 (-30% to 31%) and CMCO2-RMCO2 (-22% to -23%). Furthermore, RMCO1 and RMCO3 showed the same rate of workplace mobility reduction (Table 2, Supplementary 2: Workplace, WH: p>0.05).

The community mobility within residential areas increased during the lockdown period. The highest increase of mobility within residential area was during MCO1 (41%), while the lowest was during RMCO1 (7%). There were two clusters of mobility in residential area increase (Table 2, Supplementary 2: residential, WH: p>0.05): CMCO1-MCO2-MCO3 (20% to 22%) and RMCO2-RMCO3 (11% to 12%).

Daily KLCI range from 1219.72 (MCO1) to 1684.58 (CMCO2). Test of median showed that there was significant difference of KLCI among the STAGE (BF: F=235.14, df=8, p<0.001). On average, the highest KLCI was recorded during RMCO2 (1614.90), while MCO1 recorded the lowest KLCI (1357.50).

The Pairwise Wilcoxon test with Holm's (WH) correction post-hoc test output for all the 10 dependent variables with different MCO STAGEs can be obtained at Supplementary 2.

Cross-Correlation Of Lag Time

NEW CASES

New cases of COVID-19 throughout the study period were cross correlated with the other 9 dependent variables and the result are presented in TABLE 3. Only significant correlations and lag time within 3 weeks (21 days) were represented here. The recovery and death rate due to COVID-19 were lagged 2 days behind new reported cases, whereby it took 2 days after the increase of new cases reported to observe increase of recovery or death reported, and vice versa. Meanwhile, community mobility to parks and transit stations reacted negatively and were two weeks behind with the fluctuation of new COVID-19 cases. On the other hand, it took 18 days behind for community mobility in residential area to correlate strongly positive with new cases.

TABLE 3. Cross correlation of New COVID-19 cases with other dependent variables.

	MAX	LAG, DAYS	MIN	LAG, DAYS
Recovery Rate, Cases	0.935	-2, -1 & 0	0.390	89
Death Rate, Cases	0.900	-2	0.329	90
Retail and Recreation, %	0.442	79	-0.346	-22
Grocery and Pharmacy, %	0.432	50 & 51	-0.079	-23
Parks, %	0.242	87	-0.514	-16
Transit Station, %	0.171	87 & 90	-0.565	-15
Workplace, %	0.319	70 & 90	-0.392	-24
Residential, %	0.489	-18	-0.314	80
KLCI	0.656	57	0.168	-90

MAX and MIN represent the maximum and minimum (Spearman) correlation with compared variables. LAG, DAYS represent the New COVID-19 cases correlations (MAX/MIN) recorded after lag days with each respective vairable; negative days represent days ahead, while positive represent days later. Highlightd correlation values represent significant correlation (p<0.05).

KLCI

The KLCI index was cross correlated with the other 9 dependent variables within the period of this study and the result are presented in Table 4. A strong positive correlation was observed with new COVID-19 cases, recovery rate, and reported deaths (R_s>0.63), with KLCI trend was 51 to 61 days ahead of the COVID-19 reported cases. On the other hand, KLCI experienced fluctuation faster with community mobility to retail and recreation, and grocery and pharmacy, with one day lagged behind the community mobilities. This represents that the decrease/increase of community to these outlets will observe the effect on KLCI after one day.

TABLE 4. Cross correlation of KLCI with other dependent variables.

	MAX	LAG, DAYS	MIN	LAG, DAYS
New Cases, Cases	0.656	-57	0.168	-90
Recovery Rate, Cases	0.634	-61	0.110	90
Death Rate, Individual	0.651	-51	0.073	90
Retail and Recreation, %	0.416	1	-0.214	-90
Grocery and Pharmacy, %	0.463	1	-0.058	84
Parks, %	0.285	0	-0.426	-64
Transit Station, %	0.266	1	-0.433	-69
Workplace, %	0.283	5	-0.200	-88
Residential, %	0.312	-90	-0.280	5

MAX and MIN represent the maximum and minimum (Spearman) correlation with compared variables. LAG, DAYS represent the KLCI cases correlations (MAX/MIN) recorded after lag days with each respective vairable; negative days represent days ahead, while positive represent days later. Highlightd correlation values represent significant correlation ($p<0.05$).

Discussion

THE FIRST AND SUCCESS OF MALAYSIA IN CONTROLLING COVID-19

In order to curb the spreading of the disease, the economy of the Malaysia was mostly shut down, with almost every community ordered to stay at their domicile (home), except for frontliner and essential workers (MKN 2021). Travel restrictions (from home, state and overseas) were implemented, quarantine for incoming travelers, business operation restriction and recreational sector shut down were enforced (FIGURE 3). This saw a fall of Malaysia KLCI by 15.52% from 1443.83 (11 March 2020) to 1219.72 (19 March 2020). Nevertheless, the KLCI gradually recovered throughout the first stage of lockdown, while the movement restriction of the community persisted. MCO1 would be the strictest restriction of movement by the then government, throughout the study period (FIGURE 3).

MCO1 proved to be detrimental to the KLCI, and to the extend the economy of the country (Lee et al. 2020). However, many had acknowledged that the MCO1, and subsequently CMCO1 and RMCO1, was a success as the cases managed to be controlled from 217 (3 April 2020) to only a single digit of new cases reported by 8 June 2020. Many has commended the effort by Malaysian with their success story in controlling the spread of COVID-19 (Andrea 2020; Shah et al. 2020; Tang 2020). Thus, the stages of MCO moved to CMCO and RMCO saw increased of community mobility, closed to baseline in RMCO (<-26%). This period also experienced recovery of Malaysian KLCI.

In general, the initial lockdown was successful whereby MCO1, CMCO1, and RMCO1 were in a cluster of lowest new cases reported. Furthermore, there was an indication of economic recovery in tandem with the easing of the community mobility and economic restrictions. There was unfortunate rise of COVID-19 in Malaysia that corresponded with global trend.

The lockdown that was subsequently implemented did not see any improvements in the number of cases, instead the numbers spiked. Between 1 January 2021 to 30 June 2021, the daily recorded new cases of COVID-19 generally exceeded 1000 cases per day. Cases further spiked to the peak after a major religious celebration (Adib et al. 2021; Amir Yusof 2021; The Straits Times 2021). As the more virulent and aggressive Beta and Delta variant was spreading across the country (Campbell et al. 2021; Chookajorn et al. 2021), the government of Malaysia imposed the FMCO, which was the second strictest lockdown stage after the MCO1 (Lai 2021).

The newly reported cases of COVID-19 within the post RMCO1 period could be clustered into three major groups. MCO2, MCO3 and FMCO were in a cluster where new COVID-19 cases spiked and hit high. Nevertheless, there was a decrease of daily new recorded cases between the beginning and end of MCO2 and FMCO, citing effective measures of controlling the spreading of the disease. While RMCO2 and RMCO3 experienced a U-turn shape and relatively low new cases as compared to the former cluster. CMCO2 experienced a steady increase of COVID-19 cases from 563 to 2525 new cases by the end of the period.

With the multiple MCO stages imposed throughout January to June of 2021, the community mobility was still relatively relaxed as compared to MCO1. Nevertheless, there is a close similarity (except for Park and Transit Station) of RMCO1, RMCO2 and RMCO3 community movement, citing the easing of rules and restriction. Furthermore, with the peaking of new report and death COVID-19 cases, the stock market of Malaysia (KLCI) did not fall drastically and stayed above 1500 index point most of the time.

As of 13 July 2021, Malaysia shifted to National Recovery Plan (NRP) with the increase of vaccinated population (MOFM 2021). These stages relied on the vaccination rate of the population (90% of the adult population), while easing the accessibilities of economic and social facilities. To date (7 October 2021), Malaysia is moving into the endemic stage, which the community must live with the endemism of COVID-19 in the country (Bernama, 2021).

COVID-19 CASES, COMMUNITY MOBILITY AND KLCI

Efforts to relate COVID-19 cases (new, recovery, death), community mobility, and KLCI using General Additive Model (GAM), and later general linear model (GLM), were futile. This was because knowing that the three datasets were reactive with each other, there would be correlation mismatch with the same time frame. When tested with GAM, there was no consensus as the models were under fitted (k-index<1.00), even with high basis functions (k=30). Furthermore, collinearity (estimated degrees of freedom, edf ≈ 1.00) and concurvity (>0.8) effects were detected on the model we tried to fit in (Supplementary 3). Later, GLM also showed no significant patterns, or not fitted well on the models with the selected variables (Death rates, retail and recreational, grocery and pharmacy, residential, STAGES). This was probably due to the lag time reactions among the COVID-19 cases, community mobility and KLCI.

LAG TIME BEHIND THE COVID-19 CASES

Lag time occurs in society and economics in reacting to certain events and incidents. Hence, observation of lag time and correlations of COVID-19 cases with other dependent variables are conducted. This is to observe lag time for community mobilities and KLCI in catching up with the COVID-19 cases. However, we only focus on cross correlation with 3 weeks (21 days), as longer that that might be influenced by multiple factors.

There is a lag time behind of 0-2 days observed with rate of recovery and reported death from COVID-19 new cases. Most reports showed that patients took longer to recover from the virus, and death might come at least 10 days after first symptom reported (Barman et al. 2020; Bhapkar et al. 2020; Hull et al. 2021). However, the current data might be a façade, as of this write up, new cases of COVID-19 are still increasing. Furthermore, due to the increased number of cases, the public health system is probably constrained or overwhelmed to keep track of the data collection (Amul et al. 2021). This probably resulted in backlogs of official reports. Thus, this might result in shorter lag time, as death cases were spiking with the increasing number of new cases. Furthermore, due to the spike in COVID-19 spread within the general community, most cases brought to medical attention were mostly in critical categories (Categories 4 and 5), which complicated the recovery, or Brought in Dead (BID) (Kaos Jr 2021). Furthermore, community mobility in residential area increased 18 days after the increase rate of new COVID-19 cases, showing that populations were advised to Work from Home (WFH) at that point. In contrast, it took two weeks for parks (16 days) and transit stations (15 days) to reduce in community visit, after the increase of COVID-19 cases. This might show that the reaction of the restrictions took place only 2 weeks after the new recorded cases increase.

It is common that such cause-and-effect studies will look into the regression relationship among the variables. However, GLM and GAM failed to observe the relationship of the variables. Further observations showed that lag time provided better fit in explaining the situation than direct regression. Nevertheless, with the data of lag time available technically could predict the mobility with the restriction of movement. However, structuring a formula/regression relationship with set lag times for each related variable will create a very complicated and incomprehensive outcome. Hence, trying to keep it simple, the best inference will be lag time relationship among the variables.

CONCLUSION

Results showed that even though there were stronger correlation between the KLCI with the COVID-19 cases, the reaction time was 2 months (61 days) apart, which was too long to directly relate both. Within the time period, there might be a lot of fringing factors that affect the KLCI in relation with COVID-19 cases. Aside from COVID-19 cases, daily necessity economy such as retail and recreation as well as grocery and pharmacy are the main driver of KLCI. The short lag-time between the necessity economy and KLCI indicates that the confidence on the economy relied on the economic circulation. Hence knowing this, MCO1 was the strictest MCO introduced, to keep the economy going without affecting the confidence of investors. Nevertheless, the government had to take a stricter FMCO at the end of the MCO period, due to spiking number of new cases. However, FMCO was not as strict as MCO1, to date. This study has found several lag time relationships among the variables due to the natural state of delayed reactions by the public towards pandemic COVID-19. In reality the consideration of lag time makes more sense, as it takes several days to see the public reactions. Nevertheless, the generalization of relationships in this study is a limitation, as variables have different lag times. Hence, future study should structure a regression relationship with set lag times for each related variable for a more comprehensive outcome.

The findings of this study have several implications. First, the results can be utilized to provide a basis for timely intervention and control in managing community mobility. Second, pandemic COVID-19 creates uncertain environment that negatively influences stock market performance and community mobility. Hence, decision makers could utilize the current community mobility data for better policy and strategy in COVID-19 management. Third, the findings of this study are also relevant especially in looking at stock market trend in uncertain environment and situation. Lastly, more research or studies focusing on daily situation during pandemic is needed to see the real time changes especially in stock market prediction. Future studies should look into stock market recoveries and also explores the spillover effect of different markets over others during uncertainty period like COVID-19 pandemic.

NOTE

[1] Refer to https://covidnow.moh.gov.my/cases/

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SUPPLEMENTARY

Supplementary 1. Statistical analyses output of **Shapiro-Wilk** (SW, normality test), **Fligner-Killeen** (FK, Homoscedestic test), and **Brown-Forsythe** (BF, non-parametric test of variance) based on MCO stages. Significance values were set at α< 0.05 and highlighted in table.

Statistical Test >	Shapiro-Wilk	Fligner Killeen			Brown-Forsythe		
Measure Variables ∨	p-value	statistic	df	p.value	statistic	df	p.value
New Cases, Individual	<0.001	260.883	8	<0.001	305.58	8	<0.001
Recovery Rate, Individual	<0.001	267.289	8	<0.001	408.12	8	<0.001
Death Rate, Individual	<0.001	263.823	8	<0.001	278.12	8	<0.001
Retail and Recreation	<0.001	88.733	8	<0.001	345.46	8	<0.001
Grocery and Pharmacy	<0.001	79.702	8	<0.001	153.76	8	<0.001
Parks	<0.001	18.557	8	0.017	220.34	8	<0.001
Transit Station	<0.001	50.442	8	<0.001	392.60	8	<0.001
Workplace	<0.001	54.053	8	<0.001	97.98	8	<0.001
Residential	<0.001	42.685	8	<0.001	316.92	8	<0.001
KLCI	<0.001	162.734	8	<0.001	235.14	8	<0.001

Supplementary 2. Pairwise Wilcoxon tests of each dependent variable based on MCO stages. The pairwise comparisons were corrected based on Holm's corrections. Significance values were set at α< 0.05 and highlighted in table.

New Cases

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.000	0.000	-	-	-	-	-
RMCO2	0.000	0.000	0.000	0.000	-	-	-	-
MCO2	0.000	0.000	0.000	0.000	0.022	-	-	-
RMCO3	0.000	0.000	0.000	0.000	0.022	0.000	-	-
MCO3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-
FMCO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.131

Recovery Rate

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.075	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.000	0.000	-	-	-	-	-
RMCO2	0.000	0.000	0.000	0.000	-	-	-	-
MCO2	0.000	0.000	0.000	0.000	0.000	-	-	-
RMCO3	0.000	0.000	0.000	0.000	0.835	0.000	-	-
MCO3	0.000	0.000	0.000	0.000	0.000	0.220	0.000	-
FMCO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Death Rate

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.324	-	-	-	-	-	-
CMCO2	0.000	0.000	0.000	-	-	-	-	-
RMCO2	0.000	0.000	0.000	0.003	-	-	-	-
MCO2	0.000	0.000	0.000	0.000	0.039	-	-	-
RMCO3	0.000	0.000	0.000	0.000	0.349	0.000	-	-
MCO3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-
FMCO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Supplementary 2. (cont. 1) Pairwise Wilcoxon tests of each dependent variable based on MCO stages. The pairwise comparisons were corrected based on Holm's corrections. Significance values were set at $\alpha < 0.05$ and highlighted in table.

Retail and Recreation

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.000	0.000	-	-	-	-	-
RMCO2	0.000	0.000	1.000	0.000	-	-	-	-
MCO2	0.000	0.001	0.000	0.000	0.000	-	-	-
RMCO3	0.000	0.000	1.000	0.000	1.000	0.000	-	-
MCO3	0.000	0.000	0.000	0.000	0.000	1.000	0.000	-
FMCO	0.000	0.052	0.000	0.000	0.000	0.000	0.000	0.000

Grocery and Pharmacy

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.003	0.000	-	-	-	-	-
RMCO2	0.000	0.000	0.230	0.002	-	-	-	-
MCO2	0.000	1.000	0.000	0.230	0.008	-	-	-
RMCO3	0.000	0.000	0.000	0.000	0.232	0.000	-	-
MCO3	0.000	0.000	0.373	0.000	1.000	0.000	1.000	-
FMCO	0.000	0.557	0.000	0.000	0.000	0.297	0.000	0.000

Parks

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.000	0.000	-	-	-	-	-
RMCO2	0.000	0.000	0.024	0.004	-	-	-	-
MCO2	0.000	0.730	0.000	0.000	0.000	-	-	-
RMCO3	0.000	0.000	0.000	1.000	0.001	0.000	-	-
MCO3	0.000	1.000	0.000	0.000	0.000	0.458	0.000	-
FMCO	0.000	0.001	0.000	0.000	0.000	0.007	0.000	0.000

Supplementary 2. (cont. 2) Pairwise Wilcoxon tests of each dependent variable based on MCO stages. The pairwise comparisons were corrected based on Holm's corrections. Significance values were set at α< 0.05 and highlighted in table.

Transit Station

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.005	0.000	-	-	-	-	-
RMCO2	0.000	0.000	0.000	0.000	-	-	-	-
MCO2	0.000	0.005	0.000	0.000	0.000	-	-	-
RMCO3	0.000	0.000	0.000	0.005	0.000	0.000	-	-
MCO3	0.000	0.190	0.000	0.000	0.000	0.414	0.000	-
FMCO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Workplaces

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.000	0.000	-	-	-	-	-
RMCO2	0.000	0.009	0.004	0.549	-	-	-	-
MCO2	0.000	0.549	0.000	0.000	0.021	-	-	-
RMCO3	0.000	0.000	0.062	0.000	0.026	0.000	-	-
MCO3	0.000	0.212	0.000	0.170	0.513	0.549	0.000	-
FMCO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Residential

	MCO1	CMCO1	RMCO1	CMCO2	RMCO2	MCO2	RMCO3	MCO3
CMCO1	0.000	-	-	-	-	-	-	-
RMCO1	0.000	0.000	-	-	-	-	-	-
CMCO2	0.000	0.000	0.000	-	-	-	-	-
RMCO2	0.000	0.000	0.000	0.008	-	-	-	-
MCO2	0.000	0.041	0.000	0.000	0.000	-	-	-
RMCO3	0.000	0.000	0.000	0.000	0.536	0.000	-	-
MCO3	0.000	0.995	0.000	0.000	0.000	0.051	0.000	-
FMCO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Supplementary 2. (cont. 3) Pairwise Wilcoxon tests of each dependent variable based on MCO stages. The pairwise comparisons were corrected based on Holm's corrections. Significance values were set at α< 0.05 and highlighted in table.

Supplementary 3. Concurvity output for the Generalized Additive Model with New COVID cases and KLCI. The general output for concurvity of >0.8 represent unreliable model.

	New COVID	KLCI
TOTAL	0.998	0.998
s(New.Cases)	-	0.984
s(Recovery.Rate)	-	0.982
s(Death.Rate)	-	0.983
s(retail)	-	0.996
s(grocery)	-	0.985
s(parks)	0.976	0.983
s(transit)	0.983	0.990
s(workplaces)	0.942	0.965
s(residential)	-	0.991