

## Article

# The Impact of the COVID-19 on Economic Sustainability—A Case Study of Fluctuation in Stock Prices for China and South Korea

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**Abstract:** The coronavirus disease (COVID-19) pandemic has had a global impact on lives, livelihoods, and economies. This study investigates whether a contagious infectious disease can affect the prices of the Chinese and Korean stock markets. Specifically, we aim to discover discrepancies in the impact of COVID-19 on the stock prices of China and South Korea through panel data. To test these discrepancies, we first regressed the stock indices on confirmed cases and deaths. We then validated the stability of coefficients over the past days. The empirical results show that (1) responses of stock indices are stable and impulsive and (2) response patterns toward COVID-19 events considerably vary across nations, especially in the counties such as China and South Korea.

**Keywords:** economic sustainability; COVID-19; stock price; big data analytics; MA model



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## 1. Introduction

At the dawn of 2020, coronavirus disease 2019, or the novel coronavirus (COVID-19), became a worldwide epidemic. COVID-19 is a contagious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Nations struggled to respond to this deadly and mysterious pandemic, which rapidly spread around the world. This fast spread was facilitated by the greater economic integration and liquidity of the international network formed by the globalization process over the last several decades [1].

COVID-19 was first identified among patients with the signs of pneumonia in the city of Wuhan, the provincial capital of Hubei province, China, in December 2019 [2]. The virus first affected Chinese economic sustainability and then global economic sustainability. To prevent the spread of COVID-19, the Chinese government proposed a series of effective health policies, such as total or partial lockdown to control the pandemic. On 23 January 2020, just one day before the Chinese Lunar New Year, the most widely celebrated Chinese holiday, the city of Wuhan was totally locked down, and all public transportation to and from Wuhan was suspended. However, these policies to combat the pandemic had some negative consequences on the sustainable growth of the Chinese economy. On the other hand, South Korea reported its first confirmed case on January 20, but the epidemic spread remained relatively slow and was contained until the occurrence of massive outbreaks among the religious sects of Shincheonji, which hit the southern South Korean city Daegu, the provincial capital of North Gyeongsang province, and other areas in that province. The South Korean government imposed stricter measures due to this epidemic, including the compulsory wearing of face masks, ample testing, and contact tracing, along with a 2 m social distancing movement to prevent the spread of COVID-19. Such measures had a huge impact on the economic sustainability of almost every nation around the world, mainly due to reasons of the stock market prices listed in those nations.

The Asian Development Bank estimates that the global economy could suffer between USD 5.8 trillion and USD 8.8 trillion in losses, equivalent to 6.4% to 9.7% of global gross

domestic product [3]. The stock market fluctuation during the epidemic period within the period of late 2019 and throughout 2020, as well as in 2021, is expected to be greater than that in 2003. The COVID-19 crisis, which first hit the developed world and developing nations, then started spreading into the least economically and socially developed nations, i.e., countries with infrastructures that are not as established as those in China, South Korea, India, Japan, the United States, the United Kingdom, and the European Union. This impacted the sustainable growth of their economies, thus adversely affecting the economic sustainability of these least developed nations as well. However, the stock market derived a long-term benefit in the sense that it can serve as an alternative portfolio to others that are more prone to episodes of crisis [1].

Georgieva [4] pointed out that the COVID-19 pandemic brought the entire globe near to financial crises more hazardous than the global crisis of 2007–2008. The impact of COVID-19 is of crucial importance, especially since its first outbreak happened in China, one of the main hubs of foreign investment in Asia. Therefore, the sustainability of economic progress with respect to tackling this deadly pandemic posed an immense challenge for the Chinese administration [5]. Like the other viruses belonging to the same family of coronaviruses, COVID-19 can cause symptoms ranging from mild flu-like symptoms, such as cold, sore throat, cough, and fever, to more severe ones, such as pneumonia and breathing difficulties, and can even lead to death [6].

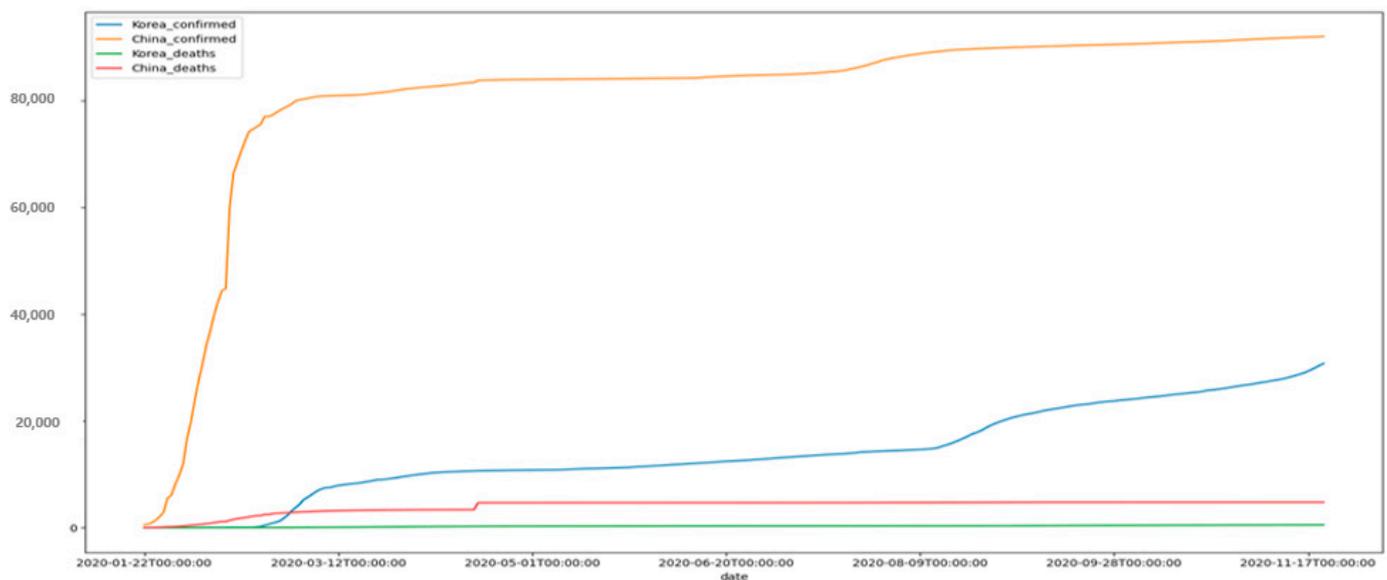
Globalization increases the likelihood that an infectious disease appearing in one nation can easily and rapidly spread to other nations. Rahman et al. [7] found four latent dimensions of a pandemic, namely social distancing, pandemic severity, lockdown measures, and socioeconomic and institutional characteristics. Although prophylactic measures, such as distancing, social isolation, or strong limitations on all transport, certainly saved thousands of lives, they also caused an economic crisis of incalculable effect in most of the nations in the world [8]. The WHO and the CDC have both issued guidance on key clinical and epidemiological findings suggestive of a COVID-19 infection, including travel and transport history from and to affected locations, a list which started with Hubei Province but expanded to include nearly the entire world [9].

Figure 1 shows the comparison of confirmed cases and deaths in China and Korea. The Figure 1 prepared by referencing and correcting the CSSE data at Johns Hopkins University. The orange line shows the number of confirmed cases in China, exceeding 80,000, while the red line represents the number of deaths (fewer than 5000) in China. The blue line represents more than 20,000 confirmed cases in South Korea, and the green line represents the number of deaths related to COVID-19, which is just above 500. Table 1 shows the fatality rates and infection rates of COVID-19 and other epidemics. While COVID-19 and SARS belong to one family of coronaviruses, researchers believe that these two epidemics differ significantly. The stock market may also respond to pandemic diseases, such as the severe acute respiratory syndrome (SARS) outbreak and Ebola virus disease (EVD) outbreak.

**Table 1.** Fatality rates and infection rates of COVID-19 and other epidemics.

Epidemics	Fatality Rate (Deaths/Cases)	Infection Rate (Per Infected Person)
Seasonal Flu	1–3.4%	1.3
SARS (2003)	10%	3
MERS (2012)	34.30%	0.42–0.92
Ebola (2014)	50%	1.5–2.5
COVID-19 (2019)	1–3.4%	1.5–3.5

Source: Asian Development Bank report No. 128 (<https://www.adb.org/sites/default/files/publication/571536/adb-brief-128-economic-impact-covid19-developing-asia.pdf>, accessed on: 6 March 2020).



**Figure 1.** Comparison of confirmed cases and deaths in China and Korea (2020.01–2020.11).

The effect of COVID-19 on an economy is potentially important, particularly in China and Korea. As one of the two important stock markets in Asia, China (Shanghai SE A Share) and South Korea (Korea SE Composite) have a direct impact on the Asian stock markets. However, relevant research on the impact of the number of confirmed cases and the number of deaths in China and South Korea from the early stage to the post-epidemic period has been scarce. Stock market returns may respond to major events. We began our analysis by examining whether confirmed COVID-19 cases and deaths affected the Chinese and Korean stock markets. To estimate the results, we used Stata and Python. The novelty of the article is that, to the best of our knowledge, this study is the first empirical research focused on the impact of COVID-19 on the Chinese and Korean stock markets. The novelty is in conducting empirical experiments from the technical standpoints of moving average model and operations research. The results of the present study contribute to the financial literature by providing several stylized facts on how stock markets react and can be expected to recover from the COVID-19 pandemic.

## 2. Literature Review

In a study on the daily stock return for nine Asian markets for the period of 1996 to 2003, Chiang [10] found a high correlation among sample Asian nations during the periods of crisis. Furthermore, by examining the long-run link between China and the other five Asian stock markets before and after SARS, Chen et al. [11] demonstrated that infectious diseases negatively influence stock market integration among nations in the same regional economic block. Kapecki [6] mentioned that at the end of March 2020, just at the beginning of the pandemic, stock exchanges around the world were reaching levels not seen for 30 years, and the main index on Wall Street on March 17 alone lost over 12%. Ali et al. [12] argued that the novel coronavirus disease (COVID-19) quickly evolved from a provincial health scare to a global meltdown, bringing nearly half the world to a standstill. The epidemic affected the financial markets in unseen ways by eroding a quarter of wealth in nearly a month. Maxim et al. [13] mentioned how the COVID-19 pandemic influenced the economic sustainability of China, the first nation in the world to face this pandemic.

Furthermore, Hsieh et al. [14] found that the volatility of stock prices increased substantially during crisis periods (e.g., the SARS outbreak, the 2002 anti-terror war, and the Enron scandal). To date, the humanitarian COVID-19 crisis has lasted for one year, and no one knows what the world economy will look like in 3 or 6 months [15]. In this respect, Pickles [16] noted that the biggest economic impact of SARS-CoV-1 did not come from death

or sickness, but from people's attempts to avoid infection. SARS-CoV-2 appears to follow the same scenario. Bhuiyan et al. [17] argued that the effects of the COVID-19 pandemic are not limited only to health, but also have a major impact on social life, which impacts the sustainability of mental health and the economy. Huo [18] investigated how stock markets in China reacted to the sudden outbreak of COVID-19 in 2020, particularly to the announcement of the lockdown to curb the spread of the pandemic. Baker et al. [19] found that the sudden outbreak of the COVID-19 significantly increased economic uncertainty. Shigemura et al. [20] emphasized the adverse economic impact of COVID-19 and its effects on well-being, as well as the likely high levels of fear and panic behavior, such as hoarding and stockpiling of resources, among the general population. Baker et al. [21] were the first to investigate the household spending and debt responses to COVID-19, or any major epidemic, given that detailed high-frequency household financial data did not exist during previous pandemics.

All aforementioned studies agree that the economic crisis will be long-lasting and extremely painful, particularly because unemployment is still rising. This reminds us of the beginning of the financial crisis in the United States in 2007 [22]. As mentioned in *The Japan Times* [23], the economic impact of the current epidemic on Asian markets has been quite serious and can be compared to the 9/11 terror attack on the eastern coast of the United States and the 2007 financial crisis, which affected the world synchronously from west to east. This time, however, stock prices have dropped in China and Japan, and other parts of the world are also showing synchronous declines from east to west. This decrease will adversely impact the economic sustainability of rising Asian economies. At present, a clear difference can be seen in the economic sustainability of Asian economies before and after the COVID-19 pandemic [24]. For instance, Norton and Toman [25] mentioned that managing "economic sustainability"—whether the starting point is economic, social, or environmental—can help many through the approach based on financial and economic growth, income, and human profits. The only difference is that the coronavirus crisis will be more powerful in all respects, and the financial, economic, and human losses are difficult to estimate precisely [22]. There have been several attempts to define the economic, social, environmental, and institutional sustainability of the economy [26]. Economic theories can be evaluated regarding their usefulness for the description of a complex evolving system, such as the economy. The economic sustainability of a nation contains requirements for the development of sustainability determination and mechanisms to achieve the context of the implementation with respect to different scenarios for the development of society, the economy, and the environment [27].

In addition, Marinč [28] investigated whether the geographical proximity of information disseminated by the Ebola outbreak events to financial markets had a statistically significant impact on the U.S. stock prices. Mishra et al. [29] mentioned that the net foreign institutional investment was negative, implying that, although the average gross sales of foreign institutional investors (FIIs) are higher than their average gross purchase, the growth of FII outflows from the emerging Asian economies such as Indonesian and Vietnamese financial markets is still lower in the COVID-19 pandemic, while the foreign investors are pulling out their funds, particularly from short-term debt funds, during the ongoing COVID-19 outbreak [30]. Rajkumar et al. [31] argued that impacts of the COVID-19 pandemic on mental health (e.g., depression, anxiety, panic, and traumatic stress) can also occur due to the lack of social life; overall, having to stay at home may lead to overconsumption.

In another relevant study, Zaremba et al. [32] explored the effects of COVID-19 on stock market volatility. Furthermore, Mazur et al. [33] mentioned that natural gas, food, healthcare, and software stocks earn high positive returns, whereas equity values in petroleum, real estate, entertainment, and hospitality sectors fall dramatically, while loser stocks exhibit extreme asymmetric volatility that correlates negatively with stock returns as the firms react in a variety of different ways to the COVID-19 revenue shock. Paresh Kumar Narayan [34] investigated the relationship between the exchange rate and the stock

market in the context of the COVID-19 pandemic. Likewise, Goodell [35] presented a comprehensive literature survey regarding the economic impact of global disasters, such as nuclear war or climate change, and localized disasters, highlighting that the COVID-19 pandemic inflicted unprecedented global destructive economic damage. Furthermore, in a study on the impact of growth in COVID-19 confirmed cases and deaths on the stock market from 22 January 2020 to 17 April 2020, Ashraf [36] found that stock markets react more proactively to the growth in the number of confirmed cases than to the number of deaths, based on 64 nations. Gómez and Favorito [37] mentioned that the current pandemic represents a sanitary, social, and economic challenge on the global level: since the City of Wuhan in China declared its lockdown on 23 January 2020, nations representing one-third of the world's population had to follow the same policies of restriction and isolation at home, imposed by governments, to proactively reduce the spread of the disease and the growth in the number of confirmed cases. In their study of how COVID-19 has impacted the financial system, Phan and Narayan [38] used data analysis to provide an understanding of government responses to COVID-19 and seek an understanding of their consequences.

Furthermore, Baker et al. [39] emphasized that government restrictions on commercial activity in response to COVID-19 are more stringent, broader in scope, more widespread, and lengthier in duration than policy responses to the Spanish Flu and completely unlike the governmental response to the 1957–1958 and 1968 influenza pandemics. Zaremba et al. [32] highlighted that governments need to be aware of a vast detrimental economic impact, as the COVID-19-related restrictions may adversely influence the trading environment in financial markets. Specifically, governments should be encouraged to engage in public information campaigns, which are instrumental in greater trading activity and, consequently, a lower cost of equity capital. Furthermore, an empirical study was conducted on the effects of social distancing policies adopted to prevent the spread of COVID-19 in four regions (China, North America, Africa, and Europe) [40]. In another relevant study on the immediate effect of COVID-19 on the stock markets of the major affected nations, Liu [5] investigated the unexpected outbreak effects on financial markets of a feared disease. In the capital market, emergencies were found to influence investor behavior by affecting investor sentiment, which ultimately affects stock prices. Likewise, Gormsen and Kojien [41] studied the stock price and dividend future reactions to the epidemic and used these to back outgrowth expectations for a potential recession caused by the virus. When the information effects of dividend changes are considered [42], the apparent price effects of the split will vanish. Alfaro et al. [43] demonstrated that day-to-day changes in the predictions of standard models of infectious disease could be used to forecast changes in aggregate stock returns during the 2003 SARS outbreak in Hong Kong and the COVID-19 pandemic in the United States.

Furthermore, Al-Awadhi et al. [44] investigated the effect of the COVID-19 pandemic on the Chinese stock market by employing a panel regression approach using two measurements: (1) daily growth in total confirmed cases and (2) daily growth in total deaths. The results provided evidence of a significant negative effect of both measurements on stock returns across all companies included in the Hang Seng Index and Shanghai Stock Exchange Composite Index over the period from January 10 to March 16. In another pertinent investigation, Zhang et al. [45] employed simple statistics to explore the relationship between stock risks and the COVID-19 outbreak in global financial markets. Fernandes [46] mentioned that, along with the collapse of the Asian stock markets, the U.S. stock markets also collapsed in March 2020. As most stock indices around the world registered their biggest one-day falls on record, several well-known companies saw their share prices fall by more than 80% in a few days [46]. In this respect, Topcu and Gulal [47] found that the negative impact of the outbreak on emerging stock markets gradually fell and started to taper off by mid-April in 2020; overall, Asian emerging markets were the worst-affected, whereas the impact in Europe was in general rather modest.

Chevallier [48] explored the cataclysmic impact of the COVID-19 pandemic on financial markets. According to the results, the recession is expected to be severe. Financial

contagion is in motion, not only across asset markets, but also across countries. According to the theory of behavioral finance, emergency events will affect the basic value of stocks and the psychological and behavioral responses of investors, which will further affect stock prices [49]. Batrancea [50] focused on the link between fiscal pressure and financial equilibrium for energy companies listed on the stock exchange market.

However, while numerous previous studies have investigated the impact of COVID-19 on different sectors, such as health, agriculture, industry, trade, and commerce, relevant research on the impact of COVID-19 on stock market prices has been scarce. In this relation, Hsieh [51] noted that some news items or events can influence stock price behavior to a great degree. For an accurate estimation of the capacity of the health care network to respond to COVID-19, it is essential to construct models that assist in the prediction of cases and deaths [52]. Such models can assist in the decision-making process for the allocation of human, financial, and material resources. Sun and Sang [53] investigated the relationship between management characteristics and corporate social responsibility (CSR) by analyzing the firms listed on the Korean Stock Exchange (KSE) along with the reference for decision-making by relevant authorities and stakeholders; the results of this study revealed that this relationship is differentiated by the level of corporate governance. Furthermore, Czech et al. [54] reported that COVID-19 has had a profound negative impact on the financial markets of the Visegrád group (a group consisting of four Central European nations and members of NATO: Czech Republic, Hungary, Poland, and Slovakia). As argued by Gunther and Adrien [55], it remains very difficult to assess the overall evolution of stock markets that might be largely driven by narratives and subject to over-reaction. Indeed, fundamentals seem to explain a very small part of the stock market variations; therefore, it is difficult to deny that the link between stock price movements and fundamentals has been anything but loose. Czech et al. [17] applied the TGARCH model to evaluate the impact of COVID-19 cases on the exchange rates and stock market volatility in the Visegrád nations. Umar et al. [39] analyzed the impact of the COVID-19 pandemic crisis, which is having repercussions worldwide comparable to the global financial crisis caused by subprime mortgages, and the effect of this global pandemic outbreak on the most relevant markets.

Furthermore, Singh et al. [56] used a moving area model to predict the COVID-19 pandemic for the top 15 affected nations, where cumulative cases, deaths, and recoveries from COVID-19 were compared among the United States, the United Kingdom, Turkey, China, Russia, Switzerland, Germany, Iran, Brazil, the Netherlands, Italy, France, Germany, and Spain. On the other hand, Dansana et al. [57] explored the fatal cases of the pandemic outbreak using a moving average (MA) model and forecasted the cases of COVID-19 in the future by successfully calculating the total confirmed cases and fatalities over the studied dates. As reported by Pal et al. [58], the MA model provides a sparing description of a stationary stochastic process in terms of a polynomial.

In the present study, we applied a modified version of the moving average model (MA model), a common approach to data analysis. Panel data analysis can reflect the differences between the subjects of cross-sectional components. In the present study, we proceeded with our analysis to identify discrepancies of stable coefficients of two sets of panel data.

### 3. Materials and Methods

#### 3.1. Research Model

In time series analysis, the moving average model (MA model) is a common approach for modeling univariate time series. A simple MA model aggregates recent historical data to predict the current value of a time series. In advance, in order to test response times of COVID-19 epidemic events, we added parameters  $\beta_i$  without the limitation of  $\sum_i \beta_i = 1$ . In order to measure time-varying effects of COVID-19 events on stock market indices, we selected MA to keep static autocorrelation of errors, other than decaying autocorrelation of AR. We applied MA to exclude the tendency of the stock market itself while measuring more pure effects of COVID-19 events. In other words, MA was used to measure volatility from the market itself, while other variables were used to measure the effects of COVID-19 events.

To apply the MA model, we first differentiated the time series to achieve stationarity. Then, changes in stock indices were regressed with a univariate model (see below).

$$X_t = \sum_{k=1}^K \alpha_k X_{t-k} + \epsilon \quad (1)$$

where  $X_t$  denotes change of stock index of day  $t$ . To test the influence of COVID-19 events on the stock market, we added confirmed cases or deaths to the exogenous variables.

$$X_t = \sum_{k=1}^K \alpha_k X_{t-k} + \sum_{q=1}^Q \beta_q \Delta_{t-q} + \epsilon \quad (2)$$

where  $\Delta_t$  denotes the change of confirmed cases or deaths at day  $t$  and  $Q$  denotes the number of past days as an order parameter to estimate the current change of stock index. Given the regression formula, we ran ordinary least squares (OLS) to minimize the following residual sum of squares (RSS):

$$\text{RSS} = \sum_{i=1}^N \|\hat{X}_t - X_t\|^2 \quad (3)$$

where  $N$  denotes total days of the time series and  $\hat{X}_t$  denotes the predicted value of day  $t$ . In the regression, we also tested significance levels of the coefficients  $\alpha$  and  $\beta$  with stats models [59]. Distribution of the significance levels was used to validate discrepancies between response patterns of China and South Korea.

### 3.2. Time Window and Sample Selection

In the regression models, we settled  $K = 3$ , since the current value in stationary stock indices has the strongest correlation with recent indices. For the selection of  $Q$ , we tested the stability of coefficients within a range of integers and then selected a representative  $Q$  value to explain discrepancy across nations. For example, a  $Q$  value of 19 was selected to illustrate the discrepancies in confirmed cases.

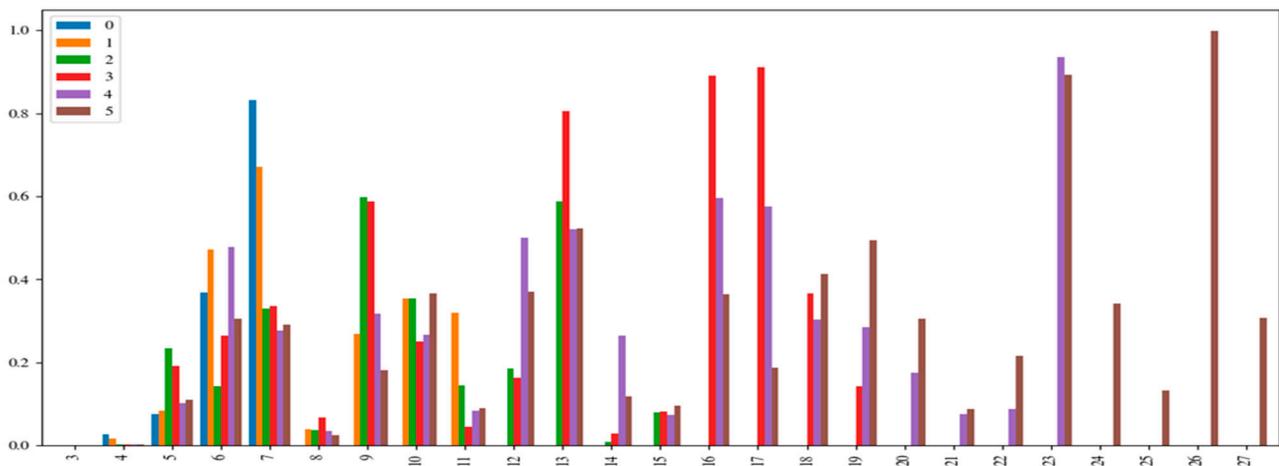
Statistics of COVID-19 were acquired from CSSE at Johns Hopkins University, which includes numbers of confirmed cases, deaths, and recovered cases for every country and every day since 22 January 2020. Accordingly, we used confirmed cases and deaths from 22 January 2020 to 20 November 2020, which included 279 samples. For the same period, we downloaded historical indices of stock markets from Yahoo Finance. Chinese data were from the Shanghai SE Composite Index, and Korean data were from the KOSPI Composite Index.

## 4. Empirical Result and Analysis

### 4.1. Stability of Coefficients

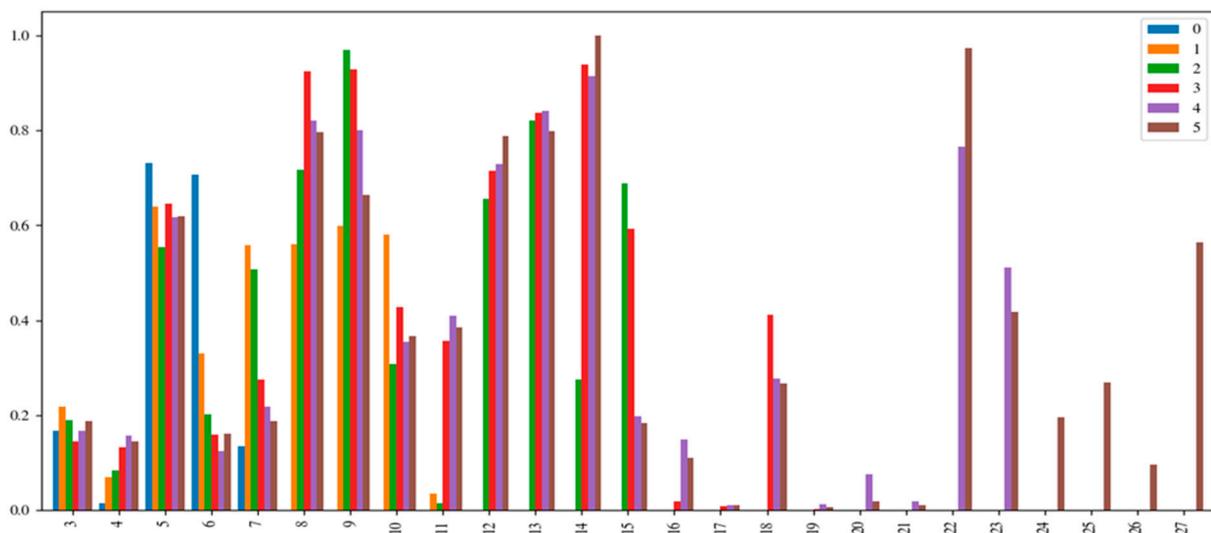
To apply the time series model, we differentiated time series with first order to pass the cointegration test. We applied the augmented Engle–Granger two-step cointegration test. After the differentiation,  $p$ -values of the Chinese data reached 0.000, and  $p$ -values of the Korean data reached 0.000. Therefore, in both nations, there is a cointegration relationship between differentiated confirmed cases and stock market indices.

We first tested the stability of coefficients on a confirmed case. Within a range of  $Q$  values, Figure 2 compares coefficients of six models of the South Korea stock market with  $Q$  values in (5,9,13,17,21,25).



**Figure 2.** Stability of  $p$ -values of Korean Stock Market.

Each color represents a model with a specific  $Q$ . As can be seen in Figure 2, specific past day  $q$  obtained similar  $p$ -values corresponding to the six models. Adjacent  $q$  values, such as (12,13,14) or (19,20,21), were also located in a similar range. Compared to the Korean model in Figure 3,  $p$ -values of the Chinese model in the past days were less concentrated but still continuous and coherent along past days in a global vision. Therefore, confirmed COVID-19 cases of a day have a stable significance level in affecting the stock index after  $q$  days.



**Figure 3.** Stability of  $p$ -values of Chinese stock market.

#### 4.2. Significance Levels

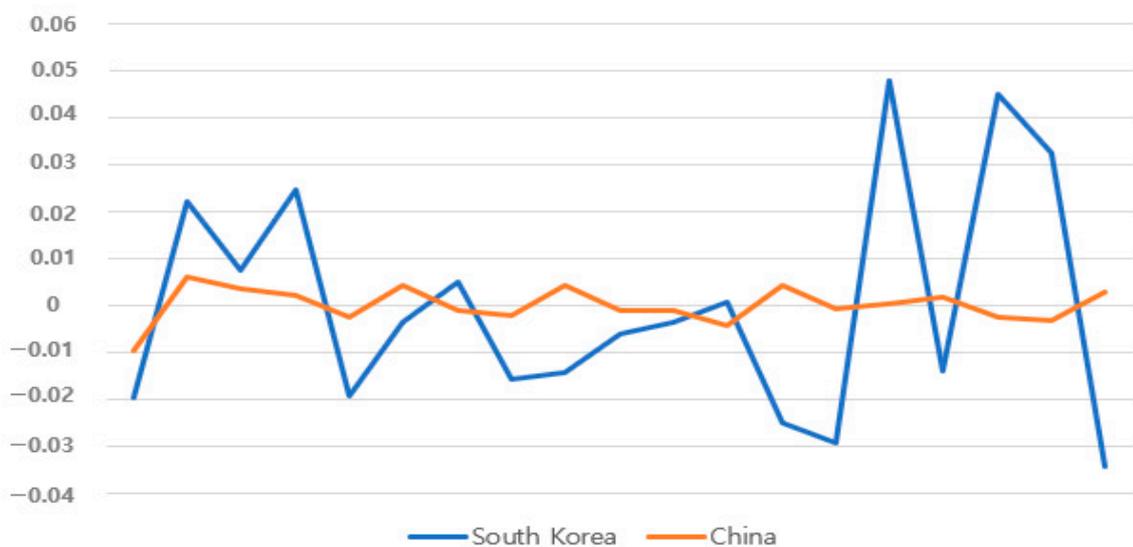
To analyze significance levels across nations, we selected  $Q = 19$  which generated quite a few significant coefficients in regression models on confirmed cases. Table 2 summarizes the regression results of the two nations. As can be seen in the results, the significance levels of many past days differed between China and South Korea.

**Table 2.** Regression results for confirmed cases.

Day q	Korea, South		China	
	p-Value	Coefficient	p-Value	Coefficient
1	0.178675	−0.019898	0.000 ***	−0.009831
2	0.157966	0.022057	0.00454 ***	0.00599
3	0.640623	0.00746	0.09174 *	0.003638
4	0.128742	0.024411	0.341981	0.001931
5	0.233798	−0.019377	0.178651	−0.002671
6	0.832447	−0.003734	0.045492 **	0.004077
7	0.788552	0.004797	0.556332	−0.001166
8	0.380494	−0.015721	0.278731	−0.002165
9	0.424072	−0.014405	0.049687 **	0.004333
10	0.732235	−0.006184	0.562264	−0.001287
11	0.832709	−0.003807	0.576351	−0.001239
12	0.972033	0.000629	0.034979 **	−0.004217
13	0.160803	−0.025152	0.032595 **	0.004293
14	0.093097 *	−0.02954	0.738474	−0.000686
15	0.004361 ***	0.047974	0.897864	0.000252
16	0.401358	−0.013988	0.34842	0.00185
17	0.007124 ***	0.044988	0.207861	−0.002504
18	0.046514 **	0.03254	0.103176	−0.003226
19	0.028045 **	−0.034316	0.169287	0.002645

Note: \*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ .

Figure 4 shows the confirmed cases in China and South Korea.

**Figure 4.** Regression results for confirmed cases.

According to the global financial development database, both stock price volatility and turnover ratio of China exceeded those of South Korea after 2012 [60]. Perception of this volatility essentially nourished quick responses of investors and financial institutions. These phenomena also are reflected in Table 1 where  $q = 1$  has the most significant negative coefficient of the Chinese model. After market response at the beginning, sideliners will participate in trading and influence the market with lower significance levels. On contrary, the smoother volatility of the Korean markets allowed investors to construct reasonable trading strategies.

Furthermore, in the regression models on confirmed deaths, Table 3 reports another type of discrepancy. Concerning the confirmed deaths, the Korean stock market responded to the event of death with impulsive and decayed coefficients; i.e., the long-past days have

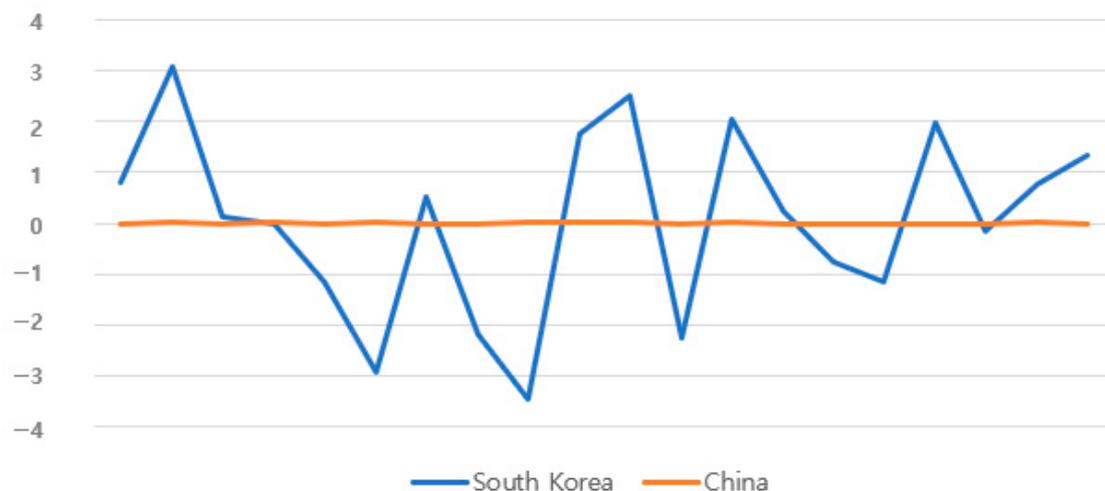
smaller coefficients. In contrast, the Chinese stock market did not respond to the event, but its coefficients only decayed along the past days.

**Table 3.** Regression results for confirmed deaths.

Day $q$	South Korea		China	
	$p$ -Value	Coefficient	$p$ -Value	Coefficient
1	0.481843	0.790918	0.464179	−0.02234
2	0.006774 ***	3.074064	0.321619	0.030371
3	0.91829	0.115937	0.846784	−0.00594
4	0.977527	−0.0316	0.455624	0.022968
5	0.300516	−1.15122	0.586145	−0.01677
6	0.029569 **	−2.91106	0.855061	0.005676
7	0.695089	0.529279	0.987309	0.000494
8	0.109936	−2.16002	0.917079	−0.00323
9	0.010898 **	−3.46944	0.786947	0.008394
10	0.187499	1.768861	0.721733	0.011066
11	0.062614 *	2.509618	0.567442	0.017778
12	0.097251 *	−2.26332	0.983377	0.000
13	0.139073	2.025763	0.519007	0.020041
14	0.869895	0.224925	0.98954	−0.00041
15	0.569922	−0.77394	0.547725	−0.01867
16	0.319164	−1.14847	0.630317	−0.01482
17	0.089263 *	1.964433	0.461672	−0.02265
18	0.886483	−0.16686	0.480807	−0.02166
19	0.519876	0.754851	0.87311	0.004896
20	0.257693	1.321677	0.576682	−0.01706

Note: \*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ .

Figure 5 shows the deaths that occurred due to the COVID-19 pandemic in the two nations. Consistently with previous studies, our empirical results revealed impulsive responses regarding major public events [61]. Besides, as indicated by the sector analysis [22], opportunity and risk coexist in the COVID-19 pandemic.



**Figure 5.** Regression results for deaths.

The two models for a pandemic [62] also provided us with a subjective manner of explaining the models. That is, COVID-19 affected both the real economy and the perception of the pandemic [62]. Subjective perception and collective consciousness also influenced public responses. We could naturally speculate that the population in China could cause instant herding and investing opportunities.

#### 4.3. Correlations of the Regression Models

The results in Table 2 show correlations and coordination. Between the two regression models on confirmed cases, the correlation of  $p$ -values is  $-0.151$ , while the correlation of coefficients is  $0.230$ . The coordination in Figure 3 presents the results along with coordinates of the Chinese and South Korean models based on confirmed cases. In the left figure of  $p$ -values, past days less than the dashed lines are significant variables, such as  $q = 6$  or  $q = 9$ .

In the left part of Figure 6, major past days have different  $p$ -values between Chinese and South Korean models, while others are similar, such as  $q \in [8, 10, 16]$ . South Korea focused on responses of long-past days, while China focused on recent days and relatively middle response. In the right part of the figure, coefficients were roughly consistent with uniform distributions.

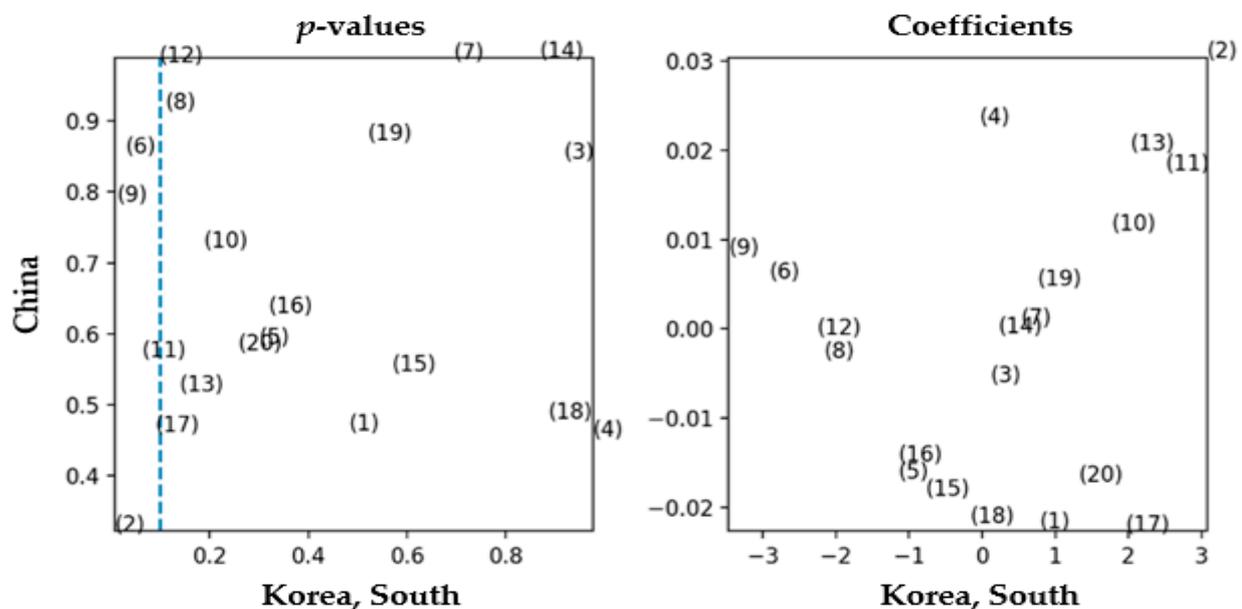


Figure 6. Geometrical characteristics of regression model on confirmed cases.

Figure 7 presents the coordinates of confirmed deaths. In the models,  $p$ -values across nations are roughly independent of each other, and coefficients are half-closed and half-repulsive. From a longitudinal perspective, coefficients quickly changed, so that the coefficients of past days (3,4,5) in Figure 7 are very different from each other. This reflects the impulsive pattern of stock index oscillation.

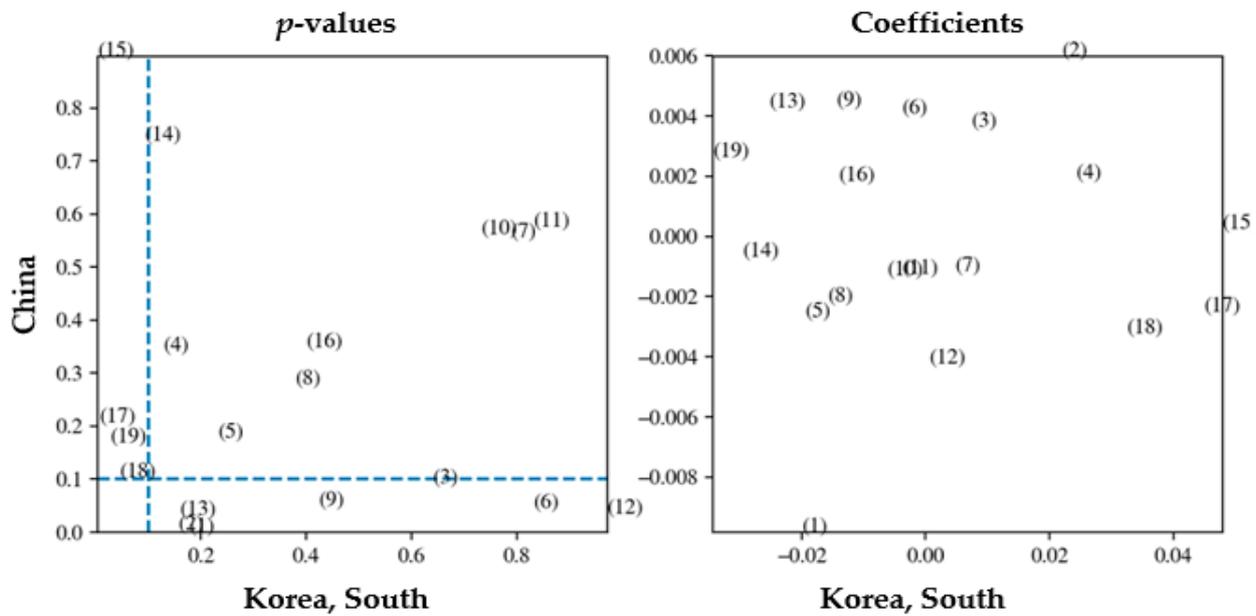


Figure 7. Geometrical characteristics of regression model on deaths.

### 5. Robustness Check

To assess IV GMM (Instrumental Variables Generalized Method of Moments) robustness, we made the following models:

OLS and WLS

$$\text{stock price}_i = \beta_0 + \beta_1 \cdot \text{confirmed}_i + \beta_2 \cdot \text{death}_i + \epsilon_i \quad (4)$$

GMM

$$\text{stock price}_{i,t} = \beta_0 + \sum_{j=1}^n \beta_{1,j} \cdot \text{stock price}_{i,t-j} + \beta_2 \cdot \text{confirmed}_{i,t} + \beta_3 \cdot \text{death}_{i,t} + \epsilon_{i,t} \quad (5)$$

From the perspective of the level of variables, the order of explanatory variable addition does not have much impact on the significance of the first-order lag term of the explained variable, and it does not have much significance on the significance of other explanatory variables. Therefore, there was no problem with the robustness of the variable level (Table 4).

Table 4. Robustness test.

Name	OLS	ROLS	WLS	GMM1	GMM2	GMM3
Variables	Stock price	Stock price	Stock price	Stock price	Stock price	Stock price
L. stock price				0.752 *** (0.00725)	0.701 *** (0.00652)	0.668 *** (0.00140)
L2. stock price					−0.234 *** (0.00114)	−0.301 *** (0.000)
Confirmed	−2.556 (4.387)	0.0141 (0.00652)	0.0141 (0.00641)	−0.0537 (0.0358)	−0.0347 (0.0259)	0.0111 (0.00656)
Deaths	266.6 (575.2)	−0.0886 (0.117)	−0.0886 (0.112)	−1.003 *** (0.158)	−0.836 *** (0.0947)	−0.177 *** (0.0496)

Table 4. Cont.

Name	OLS	ROLS	WLS	GMM1	GMM2	GMM3
Constant	1495 *** (141.1)	1270 *** (88.22)	1270 *** (101.1)	5140 *** (608.6)	4387 *** (600.0)	957.2 *** (303.4)
Observations	83	608	608	604	602	604
Number of Countries				2	2	2
R-squared	0.005	0.067	0.067			
Robust Standard Errors in Parentheses	*** $p < 0.01$					

From the perspective of the level of the models, whether the order of the explained variable was increased as a GMM-style instrumental variable or the regression method was replaced (compare the system GMM and the difference GMM), there was no obvious effect on the significance of most explanatory variables and the significance of the regression intercept. Therefore, the model-level robustness test was also passed.

From the perspective of the regression model, it is obvious that the lagging terms that are interpreted as variables are very significant, which suggests that the prices of the Chinese stock market and Korean stock market have been transformed into a mechanism, and the historical price can be replaced with the expected future price. From the correct perspective of the financial market, this shows that the effectiveness of Chinese and Korean financial markets is relatively insufficient.

GMM1 uses the highest second-order lag of the explained variable as a GMM-style instrumental variable, as well as the first-order lag explained as a variable as the independent variable.

GMM2 uses the highest second-order lag of the interpreted variable as a GMM-style instrumental variable, as well as the maximum second-order lag to be interpreted as a variable as the independent variable.

GMM3 uses the highest second-order lag of the explained variable as a GMM-style instrumental variable, as well as the largest second-order lag to be interpreted as a variable as the independent variable. However, we used the differential GMM to estimate the regression equation.

## 6. Discussion and Conclusions

COVID-19 has caused a significant impact on stock markets across nations. In the response of stock markets, the economy and the perception of investors were affected by the real volatility and oscillation of the stock market. Many studies analyzed the responses regarding the sectors of industry, cumulative abnormal return, search behavior, and the apprehensive motivation of purchase leading to overselling of oil or overbuying of gold in the last year. For the research model, in the present study, we used the moving average model (MA model) to study the impact of the COVID-19 pandemic on economic sustainability in two Asian nations: China and South Korea. The MA model is a widely used approach for modeling univariate time series. A simple MA model can cluster recent historical data to predict the current value of a time series. We considered the confirmed cases and deaths for the period from 22 January 2020 to 20 November 2020 for both nations.

This study aimed to discover discrepancies in the impact of COVID-19 on the stock prices of China and South Korea through panel data. Our aim was also to prove that COVID-19 not only affects countries' financial markets, but also has different impacts across countries. To test the discrepancies, we regressed the stock indices on confirmed cases and deaths and validated their stability of coefficients over the past days. Our regression analysis on China and South Korea yielded different observations. In the output of our regression results, which shows the comparison output of confirmed cases with South Korea and China, we selected the Q value of 19 after we tested the stability of

coefficients within a range of integers. This explains the discrepancies among the confirmed cases among China and South Korea and the significant coefficients in regression models on confirmed cases. The number of confirmed cases from September to October dropped in both South Korea and China, except among foreign visitors of the two countries. Although China did not have any new spike of confirmed cases, the number of confirmed cases remained higher in China than in South Korea, with around 101,561 confirmed cases in China [24] and around 84,325 confirmed cases in South Korea [63]. The output of our regression results shows the comparison output of death cases for South Korea and China. We selected the  $Q$  value of 20 after we tested the stability of coefficients within a range of integers. This explains the discrepancies among the death cases in China and South Korea. The South Korean stock market responded to the events of death with an impulsive and decayed coefficient; in contrast, the Chinese stock market did not respond to the event significantly, but its coefficients only decayed along the past days. There were almost no death cases from September to October in South Korea as well. The number of Chinese death cases was 4838 [64], while that of South Korean death cases was 1534 [63]. Death cases were more prevalent in South Korea when considering the factor of the size of the population.

South Korea focused on the responses of long-past days, while China focused on recent days and had a relatively middle response to confirmed cases. In contrast to death cases,  $p$ -values across South Korea and China were roughly independent of each other, and coefficients were half-closed and half-repulsive.

In summary, the empirical results showed that (1) the stock market prices in China and South Korea have obvious differences in response to COVID-19, (2) responses of stock indices are stable and impulsive, and (3) response patterns towards COVID-19 events are different between China and South Korea. To respond to the pandemic, the two countries reacted differently: (1) in terms of controlling the virus, China curbed the spread of the virus with very strict procedures of total lockdown, while South Korea emphasized public awareness and introduced milder lockdown measures; (2) the populations of these top Asian giant economies are very different. The epidemic prevention measures taken by China and South Korea were also more severe, and the short-term impact on the economy was greater than that of the SARS or SARS-CoV-1 epidemic back in 2003.

### 6.1. Theoretical Implications

When examining the literature review on COVID-19's impact on economic sustainability, we found a limited number of published studies. Almost all these publications are theoretical and conceptual in nature, which is normal and expected due to the very short time between the outbreak of COVID-19 and the dates of publication of these papers. However, this scarcity of research reflects a gap in the literature and shows the importance of conducting empirical studies to examine the COVID-19-related phenomena. Our method is a panel data analysis method, but it is a special kind. Panel data analysis can reflect the differences between the subjects of cross-sectional components. In our study, we advanced the analysis to identify discrepancies of stable coefficients of two sets of panel data. Through the empirical results, we validated the utility of this method for different regression models on two sets of time series.

### 6.2. Practical Implication

Since the beginning of the 21st century, the world has experienced SARS, avian flu, swine flu, and recently the COVID-19 pandemic. These events have had a great influence on global economic sustainability. Infectious disease prevention scientists believe epidemics will happen again and again in the future. The results of the present study show that the economic impact of infectious public health events stems from the uncertainty of infectious diseases themselves and their economic consequences.

The empirical results of the present study have several practical implications. First, we found that the stock market prices in China and South Korea have had obvious differences

in their responses to COVID-19. Second, the differentiated response patterns could support policymakers in the next stage of COVID-19. While our results are consistent with those reported in previous research, our findings offer important implications about response time. To stabilize the financial market, we must consider the two types of the pandemic [62]. On the one hand, real economic status affirmatively complies with an ergodic pattern. On the other hand, we cannot affirm the response times homogeneously but should consider volatility, populations, and cultures to harness panic and speculative behavior. Third, the discrepancy analysis could also be applied to other public events if their coefficients are stable around response days. In most cases, if an index is naturally ergodic or constrained, we could expect that its coefficients would be stable in regression models.

To control these uncertainties, we should further strengthen the infectious disease prevention and treatment system. Information should also be released promptly to raise people's awareness about risks and to take effective measures to prevent the spread of the virus. Moreover, after the vaccination takes place, the information about the vaccinated percentage of the population should be shared among nations while maintaining transparency for the total eradication of the COVID-19 epidemic.

### 6.3. Limitations and Future Research

The present study has two limitations. First, OLS models, which were used in the present study, may cause bias in some cases, because OLS is sensitive to large responses or outliers. Second, the study sample included only two financial stock markets from China and Korea. However, with the mechanism of the circuit breaker, this sensitivity to outliers was alleviated, and our model provided a stable method to discover a discrepancy between different response patterns.

In further research, we will improve our study in two ways. First, we will compare regression models of more nations and intervals. Second, we will propose an index based on the response times and pattern to simplify the description of a discrepancy, utilizing the distribution and modality of the significance levels.

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