SCHOOL OF
ECONOMICS AND
MANAGEMENT

LUND UNIVERSITY

# Stock Abnormal Returns During the SARS Pandemic

Analysis based on 31 countries and regions

by

Mengying Man

Meixuan Ren

[May 2020]

Master's Programme in Finance

Supervisor: [Anders Vilhelmsson]
Examiner: [Full name]

## Abstract

In the 21st century, science and technology are developing rapidly, but the threats of infectious diseases caused by the fatal virus to human beings are still not eliminated. In history, outbreaks of pandemics usually seriously influenced local economic and financial markets in many ways. This thesis focuses on a pandemic that occurred more than a decade ago, SARS, to investigate the magnitude of abnormal fluctuations in the stock market of different areas at the beginning and end of the outbreak. An event study method is used to compute the abnormal returns in each country and region with SARS cases during the beginning and end of the outbreak. And the Lasso model is built by aggregate abnormal returns and seven predictors representing local economic and medical care development conditions. Among them, GDP per capita growth, Gross saving rate of GDP, hospital beds per 1000 capita, health expenditure per capita are selected by the Lasso model. Then in the cross-sectional regression, we found that health expenditure per capita and GDP per capita growth are significantly related to the magnitude of abnormal returns, and the relationships are positive.

Keywords: SARS, pandemics, stock market, abnormal return, event study, Lasso

## Acknowledgements

We, Mengying Man and Meixuan Ren, would like to take this opportunity to express our gratitude to our supervisor and family for their favour and support. Particularly, we appreciate the patience and valuable suggestions from our supervisor, Anders Vilhelmsson, throughout the process of writing the thesis. Furthermore, we would like to appreciate the help from our seminar group members, for their favourable recommendations. Lastly, we would like to thank our family members and friends---Zhiyong Ren, Xiuyan Zou, Maria Xu.

## Table of Contents

**List of Abbreviations** .......... **4**

**1.Introduction** .......... **5**
1.1 Background .......... 5
1.2 Problem Discussion .......... 7
1.3 Purpose .......... 8
1.4 Outline of the Thesis .......... 8

**2.Literature Review** .......... **9**
2.1 Outbreak of SARS .......... 9
2.2 Economic Impacts of SARS .......... 10
2.2.1 Impacts on China Mainland .......... 11
2.2.2 Impacts on Hong Kong .......... 12
2.2.3 Impacts on Taiwan .......... 13
2.2.4 Impacts on Canada .......... 14

**3. Methodology** .......... **16**
3.1 Research Approach .......... 16
3.2 Research Design .......... 16
3.2.1 Event study .......... 17
3.2.1.1 The Definition of the Event .......... 17
3.2.1.2 The Time Horizon of Events .......... 19
3.2.1.3 The Market Model .......... 20
3.2.1.4 Calculating Abnormal Returns .......... 20
3.2.1.5 Aggregation Abnormal Returns .......... 21
3.2.2 Lasso Model in Machine Learning .......... 21
3.3 Delimitation .......... 23

**4. Data** .......... **25**
4.1 Data Resources .......... 25
4.2 Data Description .......... 26

**5. Empirical Results and Analysis** .......... **30**
5.1 Cumulative Abnormal Returns in the Event study .......... 30
5.2 Selected Predictors in the Lasso Model .......... 32
5.3 Cross-sectional Regression Results .......... 33

**6. Conclusion** .......... **35**

**7. Reference** .......... **37**

**8. Appendix** .......... **43**

## List of Abbreviations

| | |
|---|---|
| AARs | Average Abnormal returns |
| CAR | Cumulative Abnormal Return |
| CDC | Centres for Disease Control and Prevention |
| CEIC | China Entrepreneur Investment Club |
| GARCH | Generalized AutoRegressive Conditional Heteroskedasticity |
| GDP | Gross Domestic Product |
| MSE | Mean Square Error |
| OECD | Organization for Economic Co-operation and Development |
| OLS | Ordinary Least Squares |
| SARS | Severe Acute Respiratory Syndrome |
| TAIEX | Taiwan Stock Exchange Capitalization Weighted Stock Index |
| TSX | Toronto Stock Exchange |
| WHO | World Health Organization |

# 1.Introduction

## 1.1 Background

For thousands of years, human beings have been fighting various sudden disasters and infectious diseases, but we still cannot prevent them from changing the stock market drastically. Looking back at the period of a worldwide outbreak of pandemics in history, people can see that the global economy was affected to a large extent and the stock market fluctuated abnormally. According to Fan, Jamison, and Summers (2018), every year the world was expected to lose about 500 billion United States dollars due to the pandemic risk, which is equivalent to 0.6% of global income. Especially in the countries or regions where the spread of the infectious disease is quick and serious, pandemics could have significant repercussions for local economics (Delivorias & Scholz, 2020). For example, the American stock market experienced unprecedented four circuit breakers during the COVID-19 pandemic in ten days and then skyrocketed, resulting in a volatility clustering in the American stock market (Sun & Wang, 2020). In addition, pandemics may cause heavy damage to some specific industries, such as the tourist industry, catering industry, the airline industry, and so on. The stock market of listed companies in these industries would also experience large abnormal fluctuations.

In the past hundred years, humans experienced several severe pandemics in history. One of them is an acute serve respiratory infectious disease, which occurred 17 years ago with a fatality ratio of nearly 11%. People call it “SARS”. It triggered the global public health crisis, causing serious massive panic during the outbreak (Qiu et al., 2018). At the same time, the financial market crashed and the stock price showed a lot of extra volatilities. Thinking about why fluctuations in the stock market are closely related to pandemics, one of the important reasons is that people’s expectations would change due to the emergence of infectious diseases. In an era where medical science and technology are not ready to cope with the infectious disease outbreak, pandemics would lead to a negative expectation of the public to the future perspective. Shiller (2020) points out, the effect of the pandemic on the stock prices can be considered as a series of investors’ emotional responses to the unique event. When an unknown virus outbreak, people will inevitably be panic and lose the confidence in the financial market. Most investors see pandemic dampening economic activities and thereby decreasing potential returns (Karabell, 2020). Hence, the stock market will enter a period of depression in case of pandemics, and there may be a financial crisis in the worst situation.

A volatile stock market during epidemics always means plenty of uncertainty of wealth (White, 2020). The depressions in the stock market can evaporate an amount of wealth, but also create chances for investors to win the treasure. Table 1 below states the percentage of increase of the S&P 500 index in six months after the outbreak period of various epidemics.

| Epidemic | Terminal Month | Post 6-months change (%) |
|---|---|---|
| Avian flu | 2006-06 | 11.66 |
| Cholera | 2010-11 | 13.95 |
| Dengue Fever | 2006-09 | 6.36 |
| Ebola | 2014-03 | 5.34 |
| MERS | 2013-05 | 10.74 |
| Pneumonic Plague | 1994-09 | 8.2 |
| Swine flu | 2009-04 | 18.72 |

*Data Source: Dow Jones Market Data*

Table 1: Stock market recovery after epidemics

Table 1 indicates that epidemics do not only trigger collapses of the stock market but also lead stock prices to increase when investors get back their confidence in the financial market due to the disappearance of epidemics. Thus, the tendency of stock prices in different stages of pandemics is worth studying. Learning about these price evolutions can help investors to make better reactions when pandemics happen again.

## 1.2 Problem Discussion

Since the early 1990s, more and more economists and researchers begin to analyse the relationship between pandemics and the development of the economy. Cuddington and Hancock (1994) investigated the financial impact of the AIDS pandemic in Malawi. They pointed out there was an obvious difference in the growth path of the local economy for the no AIDS scenario and with AIDS scenario. In an event study focusing on Taiwan economy during SARS, Chen, Jang, and Kim (2007) emphasized the negative effect of pandemics on the local financial market and found that the tourism industry went through the most serious stock price decrease, the stock market of manufacturing, retail trade, and banking industries also experienced depression. At the outbreak of COVID-19 pandemic, many researchers investigate not only whether pandemics have a positive or negative impact on the financial market, but also analyse the abnormal evolution of stock prices and its geographical diversity. Patten (2020) found an interesting phenomenon: U.S. stocks fell by 15% in a week during the outbreak of COVID-19, and the European stocks saw a decrease with the range of 10-13%, but stocks in China only dropped by 5%.

This thesis will focus on abnormal fluctuations in stock markets during the SARS pandemic and the geographical diversity of their magnitudes to answer two questions: *how big are the abnormal returns of the national or regional stock market affected by the SARS pandemic? Are the magnitudes of abnormal returns related to the local economic and medical care environment?* It will start with calculating the cumulative abnormal returns in influenced countries and regions at the beginning and the end of the SARS pandemic period using the event study method, then investigate whether some predictors can explain the magnitude of aggregate abnormal returns by the supervised machine learning method and the cross-sectional regression. These selected predictors are supposed to be representative of the economic and medical care environment to some extent of the local area, in order to find out the relationship between the national or regional economic and medical care environment and the magnitude of local stock market abnormal fluctuations during pandemics.

## 1.3 Purpose

This thesis focuses on the behaviour of stock prices in the influenced areas during the SARS pandemic, trying to show the geographical diversity of the magnitude of stock abnormal returns. In addition, it seeks significant relationships between some predictors which are representative of the local economic environment or medical care development and the magnitude of stock abnormal returns.

## 1.4 Outline of the Thesis

In section 2, a brief narration of the SARS event and some previous literature about the economic influences caused by SARS in China mainland, China Hong Kong, China Taiwan, and Canada will be presented. Section 3 covers the detailed theoretical framework of the event study method, the machine learning model, the cross-sectional regression and how we will put them into practice. Moreover, this section includes the delimitations of this thesis. Section 4 presents the description of the data collection process and descriptive data. In section 5, the empirical results of the event study, the Lasso model, and the cross-sectional regression based on data of 31 countries and regions will be presented and analysed. Section 6 is a conclusion section, which summaries the results of this study and draws conclusions. In addition, it points out possible research directions in the future.

## 2.Literature Review

This section is going to describe the previous researches done to explore the economic impacts of SARS in some countries and regions which were heavily affected by this pandemic. These countries all have high numbers of probable and confirmed SARS cases and show relatively large socioeconomic fluctuations. For this reason, they have attracted a number of researchers to pay attention to and write plenty of literature to evaluate the economic impacts caused by SARS. In Asia, China mainland, Hong Kong and Taiwan are regions with most seriously influence, thereby previous literature about these regions are presented frequently. Out of Asia, Canada had the most confirmed cases, so the literature concentrating on Canada during the SARS pandemic is also included in this section. For European countries, the confirmed case is only one or two, and the impact caused by SARS in these countries is not as clear as the Asian regions and Canada. Besides, literatures regarding these countries are in a limited number. Therefore, in this section, only the three representative Asian regions and Canada are discussed.

### 2.1 Outbreak of SARS

SARS is the abbreviation of Severe Acute Respiratory Syndrome, which is atypical pneumonia proved to be caused by an animal virus from an as-yet-uncertain animal reservoir, perhaps bats at the end of February 2003. The first human infected by SARS-CoV is from Guangdong province of southern China in late 2002 (WHO, n.d). And the number of cases peaked in the second quarter of 2003 in China as well as in other countries. SARS begins with a high fever that body temperature is greater than 38 °C and then symptoms like headache, a feeling of discomfort and body aches may emerge. Some people may have mild symptoms and about 10 to 20 percent of patients have diarrheal while fever sometimes is absent in elderly and immunosuppressed patients (CDC, 2004).

A huge number of people are scared in that period due to the quick spread speed, the severe sequelae, and lack of effective treatment. The main way that SARS spreads is by close person-to-person contact like the spreading of COVID-19. The virus is thought to be transmitted most readily by respiratory droplets caused by coughs and sneezes, and it can also spread when a person touches a surface or objects contaminated with the virus and then touches his or her mouth, nose and eyes, which can explain the quick spread of SARS. The most important thing is that no specific treatment has been found until the disease disappears. Hence, wearing face masks and washing hands frequently using soap are recommended as precautionary measures. Taking all the characteristics of SARS-CoV into account, it seems that the immediate isolation of these infected persons and quarantine of those who have close contact with these infected individuals act a key role in slowing down the spread of the disease.

According to the World Health Organization (WHO), the epidemic of SARS has affected at least 29 countries and 3 regions, which also resulted in more than 8000 cases in general, of these, over 900 died. Due to the highly infectious feature of SARS, WHO issued the first global alert about SARS on 12 March 2003 and the first travel advisory on 2 April 2003, recommending travellers avoid Guangdong province and Hong Kong.

## 2.2 Economic Impacts of SARS

As mentioned above, the outbreak of SARS has already threatened the growth in the affected countries and regions, such as China mainland, Hong Kong, Taiwan, Singapore and so on. These regions are put under considerable strain due to the economic shocks caused by SARS. Most notably the impact on tourism and food was estimated at 8.5 billion US dollars in China mainland, 4.3 billion US dollars in Canada, 1.3 billion US dollars in Hong Kong, and 0.2 billion US dollars in Singapore (Keogh-Brown & Smith, 2008). Other losses related to trading, exports, and airlines are not counted in the above loss as the estimates are not based on the same type of data for each country.

Considering the impacts caused by SARS, the most severe negative effects are on the demand sides as the local consumption and exports and imports regarding tourism and airline industries are dramatically influenced. Consumer confidence declined dramatically which results in a decrease in private demand. Moreover, many impacts are from fear and uncertainty generated by SARS (Fan, 2003). Besides, not only local investment but also foreign direct investment is affected by the declined demand, increasing the risk of uncertainties. And excess capacity in some industries will emerge.

### 2.2.1 Impacts on China Mainland

The SARS epidemic has brought great harm not only to human's physical and mental health but also to the economy, especially in China mainland where the virus is originated from. Beutel et al (2009) and Hai et al (2004) focus their attention on Beijing when they estimate the economic impact caused by SARS. This is because among all the provinces in China mainland, Beijing has the highest attack rate of SARS.

In the research done by Hai et al, a survey was conducted to estimate losses of various industries. All sectors surveyed had suffered significant losses compared with the revenue earned in the same time period in 2002. Foreign visitors decreased by 80 percent and hotels lost almost 80 percent of their guests, which can be foreseen once the WHO's travel warning was issued and Beijing was assumed to be an epidemic area. After considering the multiplier effect for tourism put forward by Tang and You in 1999, Hai et al assumed the multiplier was 1.5 for the SARS impact in 2003. Under this circumstance, a total loss of 25.3 billion US dollars for China's economy in 2003 was estimated, which accounts for 2 percent of China's GDP in 2002.

While in the study established by Beutels et al, they use daily data to analyse the evolutionary trends. Besides, a cross-correlation function is also considered to see whether there exists a lag. In other words, if one series presents a change at day 100, if lag is zero, then another series will also change at day 100. If the lag is 1 or minus 1, another series will present a change on day 99 or day 101. For example, in their study, they compare the daily SARS cases with the daily number of bus passengers. After doing the research, Beutels et al admit that outbreaks like SARS will generate immediate direct economic impacts despite the assumption made by Smith (2006) that the impact of an infectious disease outbreak is uncertain, especially a new disease without quantifies mode and rate of transmission.

### 2.2.2 Impacts on Hong Kong

SARS is the first deadly infectious disease in the 21st century, and the economic impacts occurred mainly on the demand side instead of the supply side in Hong Kong since goods were still exported through Hong Kong and the manufacturing base in the Pearl River Delta was unaffected (Siu & Wong, 2004). SARS comes at the dark time of Hong Kong as it still needs time to recover from the 1997-1998 financial crisis. Domestic demand collapsed before Hong Kong had an opportunity to recover from the recession.

In the path of slow economic growth, with feeble real-estate industry, tourism and services are crucial to Hong Kong's economy. However, due to SARS, services involving face-to-face contact have faced a severe blow by the fear of infection through close contact. Having a glance at the labour market that slackened distinctly, the unemployment rate has leaped from 7.2 percent in the fourth quarter of 2002 to 8.7 percent in May-July 2003 as SARS began to spread quickly in Hong Kong. What is more, the underemployment rate rose from 3.1 percent in the fourth quarter of 2002 to 4.3 percent in the second quarter of 2003 since employees were asked to work from home to avoid the spreading of SARS (Hong Kong economy, 2003).

According to the Hong Kong Monetary Authority, tourism-related activities consist of a very significant part of the export and import services in Hong Kong. In 2002, exports regarding transportation and travel services accounted for 8.2 percent and 4.7 percent of Hong Kong's GDP respectively. Moreover, imports of transportation and travel services took a percentage of 4.1 and 7.7 respectively. Therefore, once the travel warning was issued by WHO, reluctance to travel by air rose and travel and tourism in Hong Kong were devastated. In Sui and Wong' s study (2004), visitor arrivals dropped by 10.4 percent in the second quarter of 2003 compared with arrivals at the same time in 2002. Besides, visitor arrivals in Hong Kong had dropped to the lowest number in the recent 12 years, and a drop of 850000 visitors occurred in April, which can be translated into a reduction of 4.2 billion Hong Kong dollars of spending in the domestic consumption market (Siu & Wong, 2004).

With regard to the local stock market, it had gone through a sharp swing in 2003 as a result of the unexpected epidemic. The representative one Hang Seng index that affected drastically amidst the shock of SARS plunged severely to the lowest number-8409 on 25 April (Hong Kong Economy, 2003).

### 2.2.3 Impacts on Taiwan

Unfortunately, Taiwan cannot be the ride of the impacts caused by SARS in 2003. Taiwan was reported first hit in the middle of March 2003. And the outbreak of SARS begun in late April (Taiwan CDC, 2003). Taiwan is reported to be the area with the third-largest number of SARS infections and deaths, followed by Hong Kong and China mainland (Esswein et al, 2004). It can be seen that this expected shock will affect the Taiwanese economy since Taiwan relies heavily on its industrial manufacturing, especially exports of electronics and machinery (Taiwan economy, n.d.). Besides, the Taiwanese economy is in a relationship with China mainland where SARS-CoV started to spread widely (Lee & Warner, 2005a). Thus, the Taiwanese economy was affected by the decreasing demand from China mainland and the internal individuals' demand.

In Taiwan, the services sector had been dealt a severe blow by the widespread fear of infection through face-to-face interactions. Besides, the impacts of SARS had centred on the hospitality, travel and tourism industries (Lee & Warner, 2005b). The labour-intensive industries had suffered from the reduction of travellers, as a result, stores, restaurants, hotels, and travel-related agencies had to reduce their staff, halt hiring and force their employees to take unpaid leaves. In this case, the unemployment rate in Taiwan was 4.99 percent (Annual report on Manpower Survey, 2004).

In accordance with the research established by Chou et al, the real GDP growth rate in 2003 has decreased by 0.66 percent, amidst this reduction, travel and tourism GDP accounted for about 35 percent. However, pieces of evidence showed that not only negative shocks occurred in the epidemic period, the positive shock did happen in the biotechnology sector. In the research done by Chen et al (2009), the event study approach with the GARCH process was in use to identify whether only negative shocks exist in Taiwan during the SARS epidemic. Chen et al modelled returns according to the GARCH (1,1) estimation to control for time-varying volatility, and Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX) is used to see the impact on the stock market in Taiwan with an event window [-20, +20]. From their research, the stocks of the T&W (tourism, wholesale and retail industries) sector were sensitive to the SARS outbreak as the average abnormal returns (AAR) of the T&W sector were significantly negative, meanwhile, the biotech sector presented a positive AARs.

### 2.2.4 Impacts on Canada

Canada experienced an outbreak of SARS in 2003, which killed 44 people and took an economic toll on Toronto where most infections originated (Rae & Zeng, 2006). In February 2003, suspected cases occurred across all over the country while most of them have largely reported in Toronto. Mackay (2003) claimed that traffic in the downtown area and in the Pacific Mall had been reported to experience a decrease between 70 percent and 90 percent since the outbreak of SARS in Canada.

In the research done by Keogh-Brown and Smith (2008), the economic impact was examined by looking at the change of four indicators (GDP, GDP growth from the previous year, exports and trade and budget) in different sectors. The results showed that the largest economic impact of SARS was related to the GDP and investment, and sectors like hotels and restaurants and tourism in Canada. However, compared to the economic impact caused by SARS with China mainland and Hong Kong, Canada only experienced a minor effect. In Canada, the major decline happened in the Canadian accommodation and food services sector, which did not recover immediately following the end of the epidemic. As a result of the decline, the Canadian accommodation and food services sector may lose around 4.3 billion US dollars. Besides, after the first probable case was reported in February 2003, the TSX index of Canada had declined by about 2.9 percent.

## 3. Methodology

This section will explain the method used in the thesis. First of all, an event study helps to examine the cumulative abnormal return that occurred during the examined period. Here, the sum of cumulative abnormal returns of two events, the beginning of the SARS outbreak and the end of the SARS outbreak, is calculated for each affected country and region, which will be considered as the output variable in the machine learning stage. Then, the Lasso regulation is in use to find out the proper predictors to proceed with the cross-sectional regression and significance tests.

### 3.1 Research Approach

This thesis will mainly rely on the event study method and the Lasso model of the machine learning approach. The event study method is used to compute the cumulative abnormal return for two events in each country and region. And the Lasso model helps us to select predictors by introducing a regularization parameter into the regression between predictors and stock aggregate abnormal returns. After making further selection of predictors by Lasso, we will do the significance test for each explanatory variable in a cross-sectional regression, and investigate the relationship of stock price abnormal fluctuations and national social background.

### 3.2 Research Design

We are going to focus on two events, the beginning, and end of the SARS outbreak, in this thesis. For the end of the SARS outbreak, all countries and regions have the same event date according to the announcement of WHO. However, for the beginning of the SARS outbreak, each country and region have their own event dates that found out the first probable SARS case. Correspondingly, the event period and estimation period will be changed to match different event dates.

In the event study, we select the market model to measure the expected normal return and calculate $CAR_i$(-2,2). For each country and region, we add up $CAR_i$(-2,2) of the SARS outbreak beginning event and $CAR_i$(-2,2) of the end event to get a sum of them, which we called $SumCAR_i$(-2,2). This is the aggregate abnormal return of this country or region when SARS comes and ends.

Then in the machine learning stage, we choose seven predictors that represent the national and regional economic environment and medical care development and apply for the Lasso model to make a further selection. K-fold validation method (with K=5) will be applied to find out the best value of the regularization parameter, lambda, in the Lasso model. Finally, a cross-sectional regression between the $SumCAR_i$(-2,2) and retained predictors will be built, and their relationships will be tested and analysed.

## 3.2.1 Event study

Event study methods are used to examine the behaviours of the stock price of a firm with the occurrence of a specific event (Eckbo, 2008). It is widely used to study the economic impacts of some events on the value of a firm, which the events usually are decisions of the management or changes in macro market conditions. In this thesis, national and regional representative stocks are considered as a bundle of firm stocks. For each country and region influenced by SARS, the aggregate abnormal returns in the event window will be calculated by the market model, then they will be compared with each other.

### 3.2.1.1 The Definition of the Event

We start from the definition of the event. We set the event date of the end of SRAS outbreak to 5th, July 2003, which is the date that WHO announced that SARS had been successfully controlled in the worldwide. However, the beginning date of the SARS outbreak varies from country to country. According to the announcement record on the WHO official website, we find the date of finding the first probable case in each country and region, so we set this date as the beginning date of the SARS outbreak for each country and region. For example, Sweden declared the first probable case on 28th, March 2003, so we simply set this date as the event date of outbreak beginning for Sweden. Table 2 below shows the events date of the beginning of the SARS pandemic for each country and region. By using a 10-days window length, the event window will be five trading days before and after the event date.

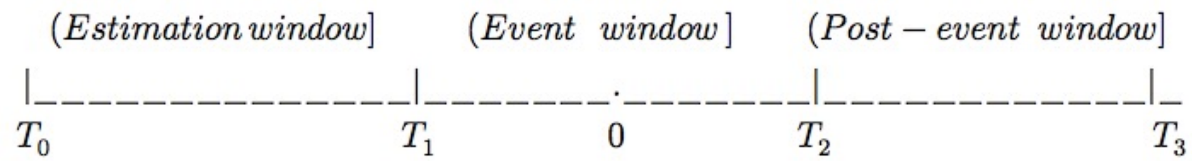
| Region | Date onset first probable case |
|---|---:|
| Australia | 24-Mar-03 |
| Brazil | 3-Apr-03 |
| Canada | 23-Feb-03 |
| China | 16-Nov-02 |
| Hong Kong | 15-Feb-03 |
| Taiwan | 25-Feb-03 |
| Colombia | 2-Apr-03 |
| Finland | 30-Apr-03 |
| France | 21-Mar-03 |
| Germany | 9-Mar-03 |
| India | 25-Apr-03 |
| Indonesia | 6-Apr-03 |
| Italy | 12-Mar-03 |
| Kuwait | 9-Apr-03 |
| Malaysia | 14-Mar-03 |
| Mongolia | 31-Mar-03 |
| New Zealand | 20-Apr-03 |
| Philippines | 25-Feb-03 |
| Ireland | 27-Feb-03 |
| Korea | 25-Apr-03 |
| Romania | 19-Mar-03 |
| Russia | 5-May-03 |
| Singapore | 25-Feb-03 |
| South Africa | 3-Apr-03 |
| Spain | 26-Mar-03 |
| Sweden | 28-Mar-03 |
| Switzerland | 9-Mar-03 |
| Thailand | 11-Mar-03 |
| UK | 1-Mar-03 |
| US | 9-Jan-03 |
| Vietnam | 23-Feb-03 |

Table 2: Event dates of the beginning of the SARS pandemic in each region

When selecting target national stock markets, a simple and straightforward criterion, if there are confirmed cases in the country or region, is followed. According to this standard, 32 affected countries and regions are supposed to be included. However, not all of them have their own national or regional stock market. The absence of the Macau stock market turns the number of target countries into 31.

#### 3.2.1.2 The Time Horizon of Events

To define the expected normal return and abnormal return, the time horizon is divided into three non-overlapping parts, the estimation window, the event window, and the post-event window. A graph below is used to illustrate them.




The estimation window is used to measure the expected normal return, and some models are constructed by the return observations in the estimation window. In this event study, the estimation window will include 250 trading days before the event date, and 249 return observations correspondingly. The event window covers the event date, where the actual returns during the window are used to define the abnormal return. The horizon of the event window is 10 days. The post-event window sometimes plays the same role as the pre-event window (estimation window) in a few of researches to define the expected normal return (Werner, 2010), but it usually only serves as a reference stage to verify whether the returns go back to the normal situation or not after the event (Dwyer, 2013). In this study, the post-event window will not be put into use.

#### 3.2.1.3 The Market Model

Then, the market model is going to be constructed by 249 return observations in the estimation window to measure the expected normal return. A stable relationship between the world stock index return, the MXWO stock index, and each national and regional stock representative index return will be estimated in the following formula.

$$R_{it}=\alpha_i+\beta_i R_{wt}+\varepsilon_{it}$$

where $R_{it}$ is the return of the national representative stock index, $R_{wt}$ is the return of the world MXWO stock index, $\varepsilon_{it}$ is the error term, $\alpha_i$ and $\beta_i$ are both constants.

Then, the expected normal return can be defined by the following function.

$$E[R_{it}^{*}|\Omega_{\mathrm{it}}]=\hat{\alpha}_i+\hat{\beta}_i R_{wt}^{*}$$

where $R_{it}^{*}$ is the normal return, $\Omega_{it}$ means some given conditions, $R_{wt}^{*}$ is the return of world MXWO stock index in the event window.

We apply for the OLS method to estimate coefficients $\hat{\alpha}_i$ and $\hat{\beta}_i$ in the estimation window, then plug in the world MXWO stock index return in the event window to get the expected normal return. By assuming a relation between world and national stock index return, the market model has less variance (Var $[\varepsilon_{it}] = \sigma_{\varepsilon i}^2$) than the constant mean model since it removes the portion of national stock index return which is related to the world index (Campbell, Lo & Macinlay, 1996). For this reason, the market model has better accuracy and reliability.

#### 3.2.1.4 Calculating Abnormal Returns

After estimating the expected normal return by using the market model, the abnormal return will simply be the difference between the actual return and the expected normal return

(Campbell, Lo & Macinlay, 1996). This calculation can be expressed as a function in the matrix notation.

$$\hat{\varepsilon}_i^* = R_i^* - X_i^* \hat{\theta}_i$$

where $R_i^*$ is a (9 x 1) vector of event-window returns for an event $i$, $X_i^*$ is a (9 x K+1) matrix with the vector of observations on the explanatory variables in the event window and $\hat{\theta}_i$ is a (K+1 x 1) estimated parameter vector.

#### 3.2.1.5 Aggregation Abnormal Returns

The aggregate abnormal return is computed by adding up all abnormal returns for each day and each security. However, we do not need to aggregate cross-sectional abnormal returns since the national representative stock index can be treated as a bundle of securities. In this study, a 10-days event period is chosen. Then, to examine the impact of SARS on stock returns, $CAR_i$(-2,2) is calculated, which is the sum of abnormal returns of the two days before and after the event date. The formula of aggregation through time is applied here.

$$\widehat{CAR}_i(s_1, s_2) \equiv \gamma' \hat{\varepsilon}_i^*$$

where $\gamma$ is a (9 x 1) vector of ones in positions $s_1 - T_1$ to $s_2 - T_1$ and zeros elsewhere.

Finally, we add up $CAR_i$(-2,2) of the beginning event and the end event of each country and region to get a sum of them, which we name $SumCAR_i$(-2,2). This indicator will be the output variable in the following machine learning analysis.

### 3.2.2 Lasso Model in Machine Learning

Machine learning is an artificial-intelligence application that allows the system to learn and improve through experience automatically without being explicitly programmed, which is widely used in large-scale data analysis and model building (Expert System Team, 2017). It uses two main types of techniques: supervised learning and unsupervised learning. The former highlights the relationship between the known input data and output data, trying to predict the future output by the relationship of trained models, while the latter excavates the intrinsic pattern in known input data (Kelleher, Namnn & Darcy, 2015).

This thesis will apply for the supervised learning technique. It chooses seven predictors as input variables and treats the $SumCAR_i$(-2,2) as the output variable to construct a cross-sectional regression. According to the representativeness of local economic environment criterion, we include the inflation rate, GDP per capita growth rate, gross saving rate of GDP, tax revenue of GDP and a dummy variable to distinguish developed countries and developing countries as predictors. What's more, we also include two predictors revealing the medical care development of each country and region, which are hospital beds per 1000 capita and annual health expenditure per capita (US dollar). Since we guess that the coefficients for some of the predictors will be actually zero, Least Absolute Shrinkage and Selection Operator (Lasso) model is chosen here, instead of Ridge regression. The Lasso model will help us to eliminate the overfitting problem and keep proper predictors by introducing a regularization parameter, called lambda, which can be expressed by the following function.

$$\beta_\lambda^L = \arg\min \sum_{i=1}^{31}(y_i - \beta_0 - \sum_{j=1}^{5} \beta_j\, x_{ij})^2 + \lambda \sum_{j=1}^{5} |\beta_j|$$

Lambda imposes the penalty to parameter coefficients, making some of them as zero, to realize the selection of predictors. To find out the suitable lambda for our analysis, we are going to apply for K-fold cross-validation with K=5. The lambda with the minimum MSE will be the best lambda in our study. After getting the best lambda, we can find chosen predictors accordingly, which will keep their non-zero coefficients in the Lasso model. Other predictors will have zero coefficients.

### 3.2.3 Cross-sectional regression

After making further selection by the Lasso model, a cross-sectional regression that reveals the relationship between the magnitude of cumulative abnormal returns and proper predictors will be constructed. The observations in this regression are from 31 countries and regions in 2003. The significance tests with a significance level of 0.1 will be done for each retained predictor.

## 3.3 Delimitation

In this thesis, only one pandemic SARS will be included to investigate. The uniqueness of the event may make that some results of the study are not comparative with other pandemic periods. For instance, people cannot compare the magnitude of cumulative abnormal returns for some countries during SRAS period with the figure during another pandemic for the same areas, since the property of infectious diseases such as the fatality rate and the basic reproduction number may have effects on the financial market fluctuations (Albulescu, 2020). This thesis will not compare the performance of the stock market for the same country in different pandemic periods but focus on the analysis of the abnormal return of the stock market in different areas during a specific pandemic. What's more, this thesis will not take the average of cumulative abnormal returns for one country's or region's stock market during different pandemic periods to summarize the overall reactions of the local stock market against the appearance of infectious diseases.

Another important delimitation is about the update speed of data of predictors in the database. As mentioned above, the predictors selected as the inflation rate, growth rate of GDP per capita, gross savings of GDP, hospital beds per 1000 capita, tax revenue of GDP and annual health expenditure per capita may have a delayed update in the database excluding the dummy variable. These data of predictors for each country are all updated annually in the database, so it is hard to see how they vary monthly or daily. Since in the event study we will calculate the abnormal return for each day, this difficulty will be a hindrance to the quantitative analysis in our regression. Therefore, the thesis will mainly focus on the qualitative analysis to see whether the predictors are significantly related to the magnitude of cumulative abnormal returns or not. In this way, the data of predictors will only serve as a relative comparison of the degree of economic and medical care development in different countries and regions, to show the diversity between countries during the SARS pandemic period.

Another delimitation is that the number of observations in the cross-sectional regression is not massive. In the event study, the cumulative abnormal returns of all countries and regions with probable SARS cases are computed. However, the SARS pandemic only spreads to 32 countries and regions in the worldwide finally, which limits the number of observations in the regression to be 32 at most. According to Deziel (2018), a small sample may lead to the power of the statistics to decrease, thereby reducing the credibility and accuracy of the regression conclusions to some extent.

# 4. Data

This section will describe the data resources used in this thesis, which mainly focus on the origination of national stock prices and data regarding the indicators chosen in this study. Furthermore, descriptive statistics will be presented in this section as well as the correlation matrix.

## 4.1 Data Resources

The data resource in this thesis is very wide, including the world bank database, WHO database, WHO annual reports for different regions, trading economy database, OECD database, CEIC database, Bloomberg, the annual reports of national and regional Ministry of Health and so on. We collect data of predictors in 2003 and stock prices in the estimation window and event window for 31 countries and regions. These 31 areas include Australia, Brazil, Canada, China mainland, China Hong Kong, China Taiwan, Colombia, Finland, France, Germany, India, Indonesia, Italy, Kuwait, Malaysia, Mongolia, New Zealand, Philippines, Republic of Ireland, Republic of Korea, Romania, Russia Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, United Kingdom, United States, Vietnam.

The world bank offers us most data in 2003 of the inflation rate, GDP per capita growth rate, the gross saving rate of GDP, tax revenue of GDP and annual health expenditure per capita (US dollar). However, the gross saving rate of GDP for Ireland, the tax revenue for Hong Kong, China and Vietnam, the annual health expenditure per capita for Hong Kong and all data for Taiwan are missed in the world bank database. We found these missing data in the OECD database, CEIC database, trading economy database, and official websites and Ministry of Health annual reports of Hong Kong and Taiwan. WHO database, WHO annual reports and world development indicator provide us with the exact date of each event, and data of the predictor hospital beds per 1000 capita. Bloomberg provides us with the prices for each national and regional representative stock in the estimation window and event window. When collecting stock prices in Bloomberg, we notice that a few of stock prices are missing in some trading days for some specific countries. We use the price of the closest previous trading day instead, keeping zero return in these days.

## 4.2 Data Description

The data used in this study is from over five continents to 31 countries and regions. Among them, 11 Asian countries and two regions are involved in, 13 European countries are included, in Oceania, South America and North America, two countries are involved in each continent, and one African country is included. To sum up, there are 18 developed countries and 13 developing countries and regions.

Table 3 shows the descriptive data of predictors except for the dummy variable, based on 6 predictors and 31 data for each predictor. We can see that most predictors have relatively low sample variances which are between 6.29 and 73.05, but the predictor “health expenditure per capita” has a very large sample variance of 2441133.01. This figure indicates that countries and regions affected by SARS show a high diversity regarding the spending in medical care and sanitation supplies, but have similar development levels in other economic and medical care indicators.

| | *Inflation rate (%)* | *GDP per capita growth (%)* | *Gross saving of GDP (%)* | *Hospital beds per 1000 capita* | *Tax revenue of GDP (%)* | *Health expenditure per capita($)* |
|---|---|---|---|---|---|---|
| *Mean* | 3.56 | 3.36 | 27.30 | 4.31 | 16.20 | 1414.07 |
| *Standard Error* | 0.75 | 0.61 | 1.54 | 0.45 | 1.13 | 280.62 |
| *Median* | 2.29 | 2.80 | 27.82 | 4.00 | 14.65 | 766.72 |
| *Standard Deviation* | 4.16 | 3.37 | 8.55 | 2.51 | 6.27 | 1562.41 |
| *Sample Variance* | 17.29 | 11.37 | 73.05 | 6.29 | 39.31 | 2441133.01 |
| *Kurtosis* | 3.09 | 5.62 | -1.06 | -0.33 | -0.17 | 1.09 |
| *Skewness* | 1.80 | 1.94 | 0.34 | 0.55 | 0.13 | 1.21 |
| *Range* | 17.95 | 16.76 | 28.14 | 9.90 | 27.92 | 5714.79 |
| *Minimum* | -2.67 | -0.77 | 15.40 | 0.60 | 1.33 | 22.07 |
| *Maximum* | 15.27 | 15.99 | 43.54 | 10.50 | 29.25 | 5736.86 |

Table 3: Descriptive Data of Predictors (except for the dummy variable)

By observing the minimum and maximum of Table 3, we can notice that the minimum values of the inflation rate and GDP per capita growth rate are both negative numbers, indicating some countries and regions were experiencing deflation and GDP negative growth (compared with increasing population) in 2003. The maximum value of gross saving is nearly half of GDP while the minimum proportion is only around a quarter. In the country with the highest average number of hospital beds, every 1000 people can enjoy more than 10 hospital beds. However, in the country with the lowest number, there is less than one hospital bed per 1000 capita.

In Table 4, the correlations coefficients between predictors and $SumCAR_i$(-2,2) are presented. The highest correlation coefficient, nearly -0.48, occurs between GDP per capita growth and health expenditure per capita, which indicates a moderate correlation according to Cohen's conventions (1988). In the remaining correlations, 30% of correlation coefficients are less than 0.1, representing a weak correlation.

| | Inflation rate (%) | GDP per capita growth (%) | Gross saving of GDP (%) | Hospital beds per 1000 capita | Tax revenue of GDP (%) | Health expenditure per capita | SumCAR(-2,2) |
|---|---|---|---|---|---|---|---|
| Inflation rate (%) | 1 | -0.03 | -0.43 | 0.10 | 0.03 | -0.36 | -0.06 |
| GDP per capita growth (%) | -0.03 | 1 | 0.44 | -0.20 | -0.40 | -0.48 | -0.18 |
| Gross saving of GDP (%) | -0.43 | 0.44 | 1 | -0.02 | -0.24 | -0.17 | -0.05 |
| Hospital beds per 1000 capita | 0.10 | -0.20 | -0,02 | 1 | 0.23 | 0.27 | -0.05 |
| Tax revenue of GDP (%) | 0.03 | -0.40 | -0.24 | 0.23 | 1 | 0.11 | -0.17 |
| Health expenditure per capita | -0.36 | -0.48 | -0.17 | 0.27 | 0.11 | 1 | -0.08 |
| SumCAR(-2,2) | -0.06 | -0.18 | -0.05 | -0.33 | -0.17 | -0.08 | 1 |

Table 4: Correlation Matrix

## 5. Empirical Results and Analysis

In this part, the empirical results of the event study, machine learning and the cross-sectional regression will be presented. Then, the indications behind the data and relationships will be discussed and analysed.

### 5.1 Cumulative Abnormal Returns in the Event study

In Table A1 in Appendix 1, the estimated alphas and betas for all market models can be found. We measure the expected normal returns by these coefficients during the outbreak beginning and end of the SARS pandemic and then calculate the cumulative abnormal returns. Table 5 below presents the sum of two $CAR_i$(-2,2) of the beginning event and end event for 31 countries and regions.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Australia | Brazil | Canada | China | HK | Taiwan | Colombia | Finland |
| 1.95% | 5.31% | -10.62% | -0.90% | 3.95% | 3.03% | 4.95% | 3.06% |
| France | Germany | India | Indonesia | Italy | Kuwait | Malaysia | Mongolia |
| 0.29% | 0.05% | -0.52% | 5.67% | 3.14% | 3.34% | 5.04% | -1.36% |
| New Zealand | Philippines | Ireland | Korea | Romania | Russia | Singapore | South Africa |
| -3.46% | 4.64% | -2.32% | 2.59% | -0.34% | -5.03% | -0.25% | 10.62% |
| Spain | Sweden | Switzerland | Thailand | UK | US | Vietnam | |
| -0.13% | -0.93% | 7.36% | 2.08% | 1.30% | 3.57% | 0.37% | |

Table 5: $SumCAR_i$(-2,2) of 31 countries and regions (10-days vector)

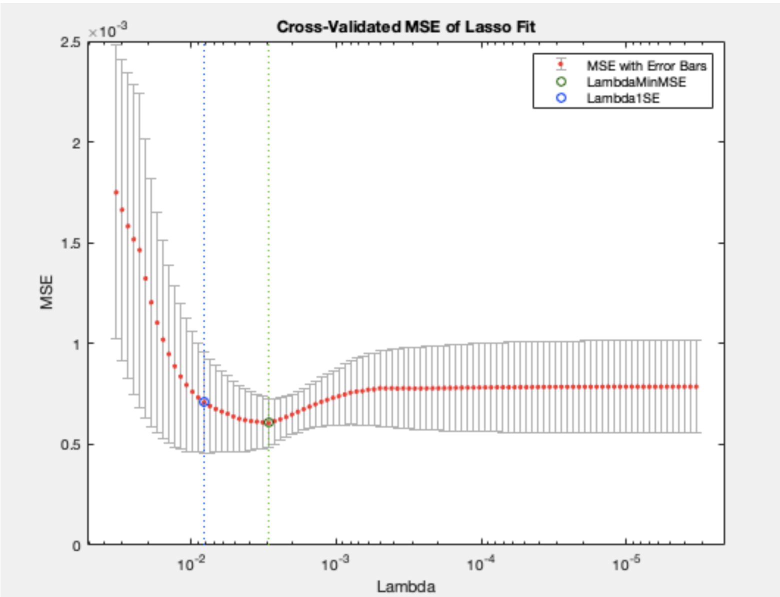
As illustrated from Table 5, the sum of 2 days' abnormal returns before and after the event date is measured. Among all countries and regions, 10 regions show a negative $SumCAR_i$(-2,2), which are Canada, China mainland, India, Mongolia, New Zealand, Ireland, Romania, Russia, Singapore, Spain and Sweden, while the $SumCAR_i$(-2,2) of the rest of the 21 regions presents a positive sign.

To have a deep understanding of the signs shown by the cumulative abnormal return, we need to have a view of the meaning of abnormal return and cumulative abnormal return. As discussed in Section 3, it is acknowledged that abnormal returns are used to evaluate the stock performance against market performance. What is more, the abnormal return can also help to identify the influences of different factors on stock prices. Under these circumstances, the cumulative abnormal return is used when investors want to analyse the effects of announcements and events on stock prices.

In this study, the cumulative abnormal return is used to evaluate the impacts on the financial market caused by the outbreak of SARS and the end of this pandemic. The negative sign may indicate that SARS had caused an unexpected impact on the economy. As mentioned above, SARS has already affected the economy in the 10 regions and the impact is negative. While for the rest 21 regions, it cannot be denied that SARS did affect the economy there. This is because the stock market can be influenced by different factors, and the stock prices may not reflect all the impacts caused by SARS. In addition, the cumulative abnormal return can only sum up the daily returns in a short event period, it cannot reveal all information. Moreover, different factors in affected 31 countries and regions may attribute to different results.

## 5.2 Selected Predictors in the Lasso Model

To find out the reason behind the various financial impacts, seven predictors are chosen as the input variables in the Lasso model. Lasso regulation shows that the best lambda with minimum MSE is 0.0029 in this study, which is illustrated in Graph 1 below.




Graph 1: Cross-validated MSE of Lasso fit

Then, we find the proper predictors with the lambda of 0.0029. According to Table 6, four predictors are proved to influence the $SumCAR_i$(-2,2) and selected by the Lasso model. We can see the trace plot of these four predictors by Lasso regulation shown in Appendix 2. Therefore, we can know that these four predictors, GDP per capita growth, Gross saving of GDP, hospital beds per 1000 capita, and health expenditure per capita, are considered as the potential factors influencing the magnitude of stock abnormal returns.

| PREDICTORS | VALUE |
|---|---|
| INFLATION RATE (%) | 0 |
| GDP PER CAPITA GROWTH (%) | 0.00303545181200759 |
| GROSS SAVING OF GDP (%) | -0.00269214481311578 |
| HOSPITAL BEDS PER 1000 CAPITA | -0.00172347648629443 |
| TAX REVENUE OF GDP (%) | 0 |
| HEALTH EXPENTITURE PER CAPITA | 0.0307329002492681 |
| DUMMY VARIABLE | 0 |

Table 6: Proper predictors from the Lasso model

## 5.3 Cross-sectional Regression Results

Then, a cross-sectional regression was run to see whether these four predictors do have an impact on $SumCAR_i$(-2,2) or not. Having a glance at Table 7, we can conclude that a significant relationship between health expenditure per capita and $SumCAR_i$(-2,2) exists with the significance level of 0.1. In addition, the explanatory variable health expenditure per capita presents a positive relationship with the explained variable. It means higher health expenditure per capita may help the region to avoid severe impact caused by the infectious disease outbreak like the SARS pandemic.

| | Estimated Coefficient | SE | tStat | pvalue |
|---|---|---|---|---|
| Intercept | 0.010952 | 0.018869 | 0.58044 | 0.56662 |
| GDP per capita growth (%) | 0.00076488 | 0.00046264 | 1.6533 | 0.1103 |
| Gross saving of GDP (%) | -0.0017668 | 0.0015454 | -1.1432 | 0.26336 |
| Hospital beds per 1000 capita | -0.0005396 | 0.00062129 | -0.86862 | 0.393 |
| Health Expenditure per capita | 1.1351 | 0.13037 | 8.7066 | 3.49e-09 |

Table 7: Cross-sectional regression results

As illustrated by Table 7, although the p-value of GDP per capita growth is 0.1103, it is still close to the significance level (0.1). Therefore, we can say that a significant relationship exists between GDP per capita growth and $SumCAR_i$(-2,2). And the coefficient means that a one percent increase of the GDP per capita growth, the $SumCAR_i$(-2,2) will increase by 0.010952 percent, which shows a positive relationship between them. Besides, looking at health expenditure per capita, a positive relationship also exists that one unit increases in health expenditure per capita will lead to 1.1351 units increase in the $SumCAR_i$(-2,2). It can be seen that increase in the GDP per capita growth and health expenditure per capita will promote to increase the magnitude of stock market abnormal fluctuations.

## 6. Conclusion

By implementing the event study, the Lasso model and a cross-sectional regression on the national and regional representative stock index during the SARS epidemic, we find the magnitude of stock abnormal return is significantly related to the annual health expenditure per capita of local people. In this process, the event study helps us to calculate the exact cumulative abnormal return for every affected country and region (except for Macau) in the event period. Then, the Lasso regulation does a favour on finding the potential predictors explaining the magnitude of cumulative abnormal returns. Finally, the variable health expenditure per capita and GDP per capita growth are examined to have a positive impact on the $SumCAR_i$(-2,2) in a cross-sectional regression. Resulting from the significant relationship, we can hold that the more government and households spend on medical care and sanitation supplies and the more prosperous of the GDP per capita growth, the larger the positive impact the stock market will show.

Previous researches done by various authors have proved that SARS has a huge impact on the economy in many ways. This thesis also gets the same result that the economy in the infected areas has been influenced. However, previous studies find the result via observing the change in GDP and the decreasing revenue in some related sectors, such as the tourism sector, restaurant sector and hotel sectors without digging into the different economic impacts caused by pandemics in different regions. This study reveals the geographical diversity of the economic impacts in the financial market by the SARS pandemic and helps investors to have a better understanding of the potential factors resulting in different degrees of impacts in different areas. Furthermore, the results of this research also have some suggestive favour on national and regional governments.

Since the data in this study is collected from different databases, minor mistake may occur. This is because different databases have their own methods to record and calculate the indicators. Data from the same database might have better trust. Furthermore, some stock prices are not fully recorded in Bloomberg, which causes the stock returns to be zero in some trading days. Future researches can try other resources to find complete stock market prices and have full data to investigate.

## 7. Reference

Albulescu, C. (2020). Coronavirus and Oil Price Crash, *SSRN Electronic Journal*.

Annual report Manpower Survey. (2004). Number of Unemployment Persons and Unemployment Rate. Available online: www.stat.gov.tw/public/Attach ment/53910463571.xls [Accessed 16 April 2020]

Beutels, P., Jia, N., Zhou, Q.-Y., Smith, R., Cao, W.-C., & Vlas, S. J. D. (2009). The economic impact of SARS in Beijing, China. *Tropical Medicine & International Health*, vol. 14, pp. 85–91. doi: 10.1111/j.1365-3156.2008.02210.x

Campbell, J. Y., Lo, A. W. & Macinlay. A. C. (1996). The Econometrics of Financial Markets, Princeton University Press: New Jersey

Centers for Disease Control and Prevention. (2004). SARS (Severe Acute Respiratory Syndrome). Available online: https://www.cdc.gov/sars/about/fs-SARS.pdf [Accessed 06 April 2020]

Chen, C., Chen, C., Tang, W., & Huang, B. (2009). The Positive and Negative Impacts of the Sars Outbreak: A Case of the Taiwan Industries. *The Journal of Developing Areas*, vol. 43, no. 1, pp.281-293.

Chen, M.-H., Jang, S. & Kim, W. G. (2007). The Impact of the SARS Outbreak on Taiwanese Hotel Stock Performance: An Event-Study Approach, *International Journal of Hospitality Management*, vol. 26, no. 1, pp.200–212.

Chou, J., Kuo, N.-F., & Peng, S.-L. (2004). Potential Impacts of the SARS Outbreak on Taiwans Economy. *Asian Economic Papers*, vol. 3, no. 1, pp.84–99.

doi: 10.1162/1535351041747969

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences, Hillsdale, NJ: L. Erlbaum.

Cuddington, J. T. & Hancock, J. D. (1994). Assessing the Impact of AIDS on the Growth Path of the Malawian Economy, *Journal of Development Economics*, vol. 43, no. 2, pp.363–368.

Delivorias, A. & Scholz N. (2020). Economic impact pf epidemics and pandemics, Available online:https://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI(2020)646195 [Accessed 9 April 2020]

Deziel, C. (2018). The effects of a Small Sample Size Limitation, Available online: https://sciencing.com/effects-small-sample-size-limitation-8545371.html [Accessed 11 April 2020]

Dwyer, G.P. (2013). Lecture: Event studies, powerpoint presentation, Trinity College, Dublin, January 2013.

Eckbo, B. E. (2008). Handbook of Empirical Corporate Finance, Elsevier.

Esswein, E. J., Kiefer, M., Wallingford, K., Burr, G., Lee, L. J., Wang, J....Su, I. (2004). Environmental and Occupational Health Response to SARS, Taiwan, 2003. *Emerging Infectious Diseases*, vol. 10, no. 7, pp.1187-1194. doi:https://dx.doi.org/10.3201/eid1007.030728.

Expert System Team. (2017). Available online: https://expertsystem.com/machine-learning-definition/ [Accessed 15 April 2020]

Fan, E. (2003). SARS: Economic Impacts and Implications. Asian Development Bank. Available online: https://www.adb.org/sites/default/files/publication/28073/pb015.pdf [Accessed 09 April 2020]

Fan, V. Y., Jamison, D. T. & Summers, L. H. (2018). Pandemic Risk: How Large Are the Expected Losses?, *Bulletin of the World Health Organization*, vol. 96, no. 2, pp.129–134.

Hai, W., Zhao, Z., Wang, J., & Hou, Z.-G. (2004). The Short-Term Impact of SARS on the Chinese Economy. *Asian Economic Papers*, vol. 3, no. 1, pp.57–61.

doi: 10.1162/1535351041747905

Hong Kong Economy. (2003). Economic situation in 2003. Available online: https://www.hkeconomy.gov.hk/en/pdf/03q4_er.pdf [Accessed 14 April 2020]

Karabell, Z., (2020). As Covid-19 Spreads, Listen to the Stock Market—for Now, Available online: https://www.wired.com/story/covid-19-spreads-listen-stock-market/ [Accessed 10 April 2020]

Kelleher, J. D., Namee, B. M., & Darcy, A. (2015). Fundamentals of Machine Learning for Predictive Data Analytics: Algprithms, Worked Examples, and Case Studies, MIT Press: Cambridge.

Keogh-Brown, M. R., & Smith, R. D. (2008). The economic impact of SARS: how does the reality match the predictions?. *Health policy (Amsterdam, Netherlands)*, vol. 88, no. 1, pp. 110–120. doi: https://doi.org/10.1016/j.healthpol.2008.03.003

Kothari, S. & Warner, J. B. (2004). The Econometrics of Event Studies, *SSRN Electronic Journal*.

Lee, G. O., & Warner, M. (2005a). Epidemics, labour markets and unemployment: the impact of SARS on human resource management in the Hong Kong service sector. *The International Journal of Human Resource Management*, vol. 16, no. 5, pp.752–771.

doi: 10.1080/09585190500083202

Lee, G.O., & Warner, M. (2005b). The Impact of the SARS Epidemic in Taiwan: Implications for Human Resources, Labor Markets, and Unemployment in the Service Sector. Working Paper Series.

Mackay, B. (2003). As SARS toll climbed, so did economic cost to Toronto. *CMAJ: Canadian Medical Association Journal* vol. 168, no. 11, pp.1456

Patton, M. (2020). How Stocks Reacted During Past Flu Pandemics and Steps You Can Take to Minimize Losses, Available online:
https://www.forbes.com/sites/mikepatton/2020/02/28/how-stocks-reacted-during-past-flu-

pandemics-and-steps-you-can-take-to-minimize-losses/#3ffdc922448d [Accessed 15 April 2020]

Qiu, W., Chu, C., Mao, A., & Wu, J. (2018) The impacts on Health. Society, and Economy of SARS and H7N9 Outbreaks in China: A Case Comparison Study, *Journal of Environment and Public Health*, Vol. 2018, pp.1-7

Rae, R. & Zeng, A. (2006). *SARS In Canada | The Canadian Encyclopedia*. [online] Thecanadianencyclopedia.ca. Available online: https://www.thecanadianencyclopedia.ca/en/article/sars-severe-acute-respiratory-syndrome [Accessed 19 May 2020].

Shiller, R.J. (2020). Predictions for the Coronavirus Stock Market, Available online: https://www.nytimes.com/2020/04/02/business/stock-market-predictions-coronavirus-shiller.html [Accessed 10 April 2020]

Siu, A., & Wong, Y. C. R. (2004). Economic Impact of SARS: The Case of Hong Kong. *Asian Economic Papers*, vol. 3, no. 1, pp.62–83. doi: 10.1162/1535351041747996

Sun, M. & Wang Y. (2020). Circuit breaker reveals four major contradictions existing in US, Available online: http://www.china.org.cn/opinion/2020-03/24/content_75854483.htm [Accessed 9 April 2020]

Taiwan Centres for Disease Control. (2003). Important Diseases: SARS (Severe Acute Respiratory Syndrome), Available online: https://www.cdc.gov.tw/En/Category/ListContent/bg0g_VU_Ysrgkes_KRUDgQ?uaid=u1D6dRGtmP4Q5YA1GmSKIw [Accessed 15 April 2020]

Taiwan economy sector. (n.d.) Economy of Taiwan. Available online: https://www.taiwan.gov.tw/content_7.php [Accessed 16 April 2020]

Tang, M., You, X. L. (1999). Some Thoughts on Starting Up the Chinese Economy. *Economics Highlights*.

Werner, S. P. (2010). Short Selling Activities and Convertible Bond Arbitrage Empirical Evidence from the New York Stock Exchange, Wiesbaden: Gabler.

White, R. E. (2020). Coronavirus: What the Viral Epidemic Means for Investors. Available online: https://www.tricapitalgroup.com/blog/item/coronavirus-what-the-viral-epidemic-means-for-investors.html [Accessed 14 April 2020]

World Health Organization. (n.d.). SARS (Severe Acute Respiratory Syndrome). Available online: https://www.who.int/ith/diseases/sars/en/ [Accessed 06 April 2020]

# 8. Appendix

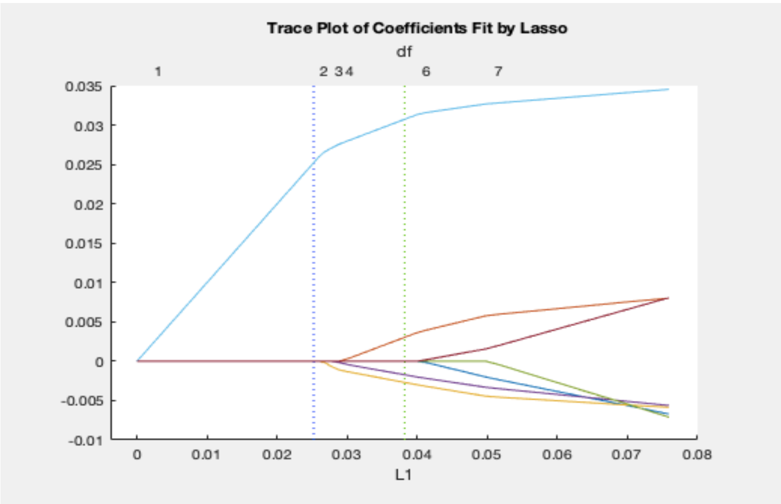
**Appendix 1**

| | The Market Model of The Beginning Event | | The Market Model of The End Event | |
|---|---|---|---|---|
| Area | Alpha | Beta | Alpha | Beta |
| Australia | -0.000687166 | 0.138773971 | -0.000213143 | 0.121830231 |
| Brazil | 0.000148075 | 0.694365104 | 0.000877037 | 0.657065708 |
| Canada | 0.000618345 | -0.301010333 | 3.74423E-05 | -0.135840818 |
| China mainland | -0.000120642 | 0.025756325 | -0.000490152 | 0.023349889 |
| China HK | -0.0003545 | 0.265379906 | -0.000317456 | 0.25707839 |
| China Taiwan | -0.000534726 | 0.305860575 | 6.90447E-05 | 0.240219278 |
| Colombia | 0.001506229 | 0.000860407 | 0.002028955 | 0.006246809 |
| Finland | 0.000154505 | 1.171644067 | -7.14913E-05 | 1.140824634 |
| France | -0.000374366 | 1.367918052 | -0.000576586 | 1.432048855 |
| Germany | -0.000734076 | 1.652227435 | -0.000733108 | 1.766636562 |
| India | -0.000353645 | 0.070591385 | 0.000399873 | 0.076033381 |
| Indonesia | 6.59887E-05 | 1.168896955 | 0.000184879 | 1.151548564 |
| Italy | -0.000113316 | 1.064570487 | -0.0003173 | 1.099175025 |
| Kuwait | 0.001614969 | -0.065560406 | 0.001906872 | -0.010959048 |
| Malaysia | -0.000530393 | -0.007420601 | -0.000149441 | -0.020976688 |
| Mongolia | 0.002708819 | -0.142904657 | 0.002222812 | -0.255673282 |
| New Zealand | -4.7574E-05 | 0.040774772 | 0.000403821 | 0.044172911 |
| Philippines | -0.001293431 | -0.079347477 | 0.000143955 | -0.046350052 |
| Ireland | -0.000281879 | 0.534528266 | -0.000246574 | 0.563963271 |
| Korea | -0.00118116 | 0.318877127 | -0.00020828 | 0.271445182 |
| Romania | 0.00287915 | -0.005431274 | 0.001602044 | 0.033050306 |
| Russia | 0.000655525 | 0.298180267 | 0.001642109 | 0.294643416 |
| Singapore | -0.001023689 | 0.242751208 | -0.000208283 | 0.266522626 |
| South Afrcia | -0.0011161 | 0.361790059 | -0.000986271 | 0.415992912 |
| Spain | 1.03152E-05 | 1.03889435 | 0.000200529 | 1.050624922 |
| Sweden | -0.000481756 | 1.144647933 | -0.000274883 | 1.160943483 |
| Switzerland | -0.000464091 | 1.021845793 | -0.000607408 | 1.1103423 |

| | | | | |
|---|---|---|---|---|
| Thailand | -2.78613E-05 | 0.13901617 | 0.00071856 | 0.132712948 |
| United Kingdom | -0.000318792 | 0.930264865 | -0.000374322 | 1.02089789 |
| United States | -0.000507644 | 0.093422391 | 0.00021258 | 0.10182763 |
| Vietnam | -0.000669513 | 0.011765811 | -0.001024179 | 0.071012523 |

Table A1: Estimated coefficients in the market model

**Appendix 2**




Graph 2: Trace plot of coefficients Fit by Lasso