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Original Article

The Effects of COVID-19 on Economic and Financial Indices an Intervention Function Analysis

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Abstract: *The news of the spread of COVID-19, its toll on public health and the shut-down of the economic activities in major industrial countries have resulted in major volatility in economic variables and global financial markets. Every positive news of discoveries on mitigation of the disease or its treatment has caused an immediate upturn in major financial indices and economic activities and negative news have resulted in downturns in economic activities. At the same time, the Fed and US government are applying traditional macroeconomic policies to reduce the economic pains and sufferings caused by loss of jobs and income by millions of working people. Although it is not possible to quantify the direct effect of COVID-19 on financial markets and economic activities at this early stages of pandemics, the effect of announcements on major economic indices can be estimated and their time path to new equilibrium can be projected using intervention and transfer function analysis. Therefore, we treat the announcements on pandemic as an intervention in markets to estimate and compare the pre-announcement mean and volatility of indices with their post-announcement means and volatility using intervention function time series analysis. If the announcement results in a change in the levels, we then study the time path of the adjustment to equilibrium using impulse response function.*

Keywords: *COVID-19, Intervention Function Analysis, Impulse Response Function.*

I. INTRODUCTION

Wall Street versus Main Street: The news of the spread of COVID-19, its toll on public health and safety (Appendix: Figures1 and 2) and the shut-down of the economies in major industrialized countries have resulted in major volatility in economic variables and global financial markets. Every positive news of discoveries on mitigation of the disease or its treatment has caused an immediate upturn in major economic and financial indices and the negative news has resulted in downturn in financial and economic variables (Baker, Bloom, Davis, and Sammon, 2019).

Starting on March 15, the partial shutdown of the US economy resulted in over 30% drop in industrial production with unemployment rising over 15%. By the end of April, S&P500 was back to its all-time highs, with a V-shaped recovery, after dropping almost 35% in a very short time period. The rapid recovery of the financial indices in US (Appendix: Figures 5 and 6) was quite contrary to response of European and Asian markets (Liu ,et al, 2020) which have been struggling after having their own major downturns (Appendix: Figures 7 to 12). Akesson, Ashworth-Hayes, Hahn, Metcalfe, and Rasooly Itzhak (2020), attribute this difference to "fatalism" belief in US that, the more infectious people believe the COVID-19 is, the less they care about it.

Policy-Makers' Reactions: Economists have used different names to describe the event. "Synthetic" recession, a recession that "happened due to decisions made about a virus, not about the economy (Imrohoroglu, 2020); "COVID-19 recession", a relatively short two quarter recession (James Doti, 2020); "Deep recession", where " bankruptcies, pandemic's devastating effect on business and household balance sheets, and precautionary consumer behavior may well cause an inevitable COVID-19 downturn to morph into a deep, prolonged recession", (Stiglitz, 2020). We will be calling the event a shock to the economy, a COVID-induced shock that is different from conventional supply or demand shocks to the economy.

Being an election year, Fed and government hastily applied traditional expansionary monetary and fiscal policies to prop up employment and ease the pain of job and income losses. Fed flooded the economy with $2.5 trillion of asset purchases lowering the federal funds rate to 0.00-0.25% and providing economy with enough liquidity to bolster the financial institutions. In response to COVID-19 damage, the government put together huge spending and loans packages of Payroll Protection Plan (PPP), forgivable loans to small businesses and others amounting to $2 trillion.

The government spending has been criticized by some as "not well targeted and, even worse, badly administered," (Stiglitz, 2020). The policies have reduced the initial financial panics and some economists have already expressed optimism

on a quick "V-shaped" recovery (Doti, 2020). Others predict a "W-shaped" recovery from recession with the ups and downs of the economy decided by developments on COVID vaccine and health related news.

The pandemic started in China in the 4th quarter of 2019. US downplayed its effect on healthcare and the economy until March of 2020, when the number of infected people to COVID-19 and the number of dead started rising exponentially (Appendix: Figures 1 and 2). The US economy started the shut-down on March 15 with the real GDP dropping 4.8% in the first quarter of 2020. The pandemic and the efforts to contain it had similar effects on other countries. China's economy shrank at an annualized rate of 6.8% and the Eurozone economies dropped by 3.8% in the first quarter of 2020.

The very fast ascend of financial indices from their lows to their all time highs is US gave rise to optimism that the shock to real economic variables such as employment and industrial production will also be short lived. While China, Korea and Europe directed most of their fiscal spending towards mitigating of the pandemic and leveling off the infection rates, US policies (Baker, et al, 2019, Baker, et al, 2020) were directed more towards a temporary support of businesses to keep the economy open while the infection rate and death rate kept on rising (Appendix: Figures 2 and 4).

The shut-down of the economy on March 15 inflected an unprecedented damage to real economic variables that cannot be reversed instantly by conventional expansionary fiscal and monetary policies only. The adjustment path of the economy to a new equilibrium will depend on discoveries on mitigation of the infectious disease, its treatment and the credibility of government officials on convincing the public that they can participate in economic activities without any risk to their well-being. The main objective of this paper is to use the time-series techniques (Enders, 2010) to estimate the initial effect of the COVID-19 shock to US financial markets and the economy and to project the time path of the adjustment in unemployment, industrial production and personal consumption to their pre-shock levels.

II. METHODOLOGY

Intervention Function Analysis: Although it is not possible to quantify the direct effect of COVID-19 on financial markets and economic variables at this early stage of the pandemic, the effect of the event on risk and return to major indices can be estimated and projected using intervention function analysis. Therefore, we treat the announcement on economic shut-down and each major announcement thereafter on pandemic as an intervention in market to estimate and compare the pre-announcement means and variances of the indices with the post-announcement means and variances using intervention function time series analysis. If an announcement resulted in a change in the mean, we then study the time path of the post-announcement adjustment to new equilibrium using impulse response function.

The conventional method of analyzing the impact of a shock to a variable is to compare the means and the variances of the variable before and after the shock using the t and F tests and then test for the statistical significance of the changes. Such tests are probably inappropriate in time-series analysis because, in most time series data, successive values of a variable are serially correlated and some of the effects of the pre-shock period may "carry over" to the next periods. This makes any statistical inference based on the conventional method of comparing the means and variances of the pre-shock and post-shock periods to be biased (Nelson and Plosser, 1982). To account for such "carry over" effects, the means and variances of different periods have been compared using the Intervention Function Analysis techniques.

Intervention Function analysis allows for a formal test of a change in the mean and variance of a variable with time-series characteristics (Enders, 2010). It requires running the best fitting ARIMA on the variable under the study for the longest span of data before or after intervention, to find the order of ARIMA, and then running the same order of ARIMA for the entire study period by including the intervention variable and testing for the significance of the coefficient of the intervention variable. The model to be estimated in this study is:

$$Y_t = a_o + A(L)Y_t + \lambda Z_t + B(L)e_t$$

Where, Y is the variable under study, Z is the intervention variable, and A(L) and B(L) are polynomials in lag operator L (Blanchard and Kahn, 1980). There are several ways to model the intervention function. These are impulse function, pure jump, gradually changing function, and prolonged impulse. In this study, two types of intervention functions are considered: Impulse function and gradually changing function. Impulse function is best characterized by a purely temporary intervention. Gradually changing function assumes intervention happens gradually, with a certain growth or decay pattern to be estimated from the actual data.

In this study, a one-time major announcement on pandemic or an announcement by the Fed or government to deal with the negative effects of the pandemic is treated as impulse function.

Of particular interest are the sign and significance of λ. The significance of λ represents the response of the Y to the intervention variable, Z. Once the coefficient of the intervention variable is estimated, the dynamic response of the Y variable to interventions and the post-intervention adjustment path of Y to the new equilibrium level are estimated using impulse response functions and cumulative impulse response function (Blanchard and Quah, 1989).

III. STATISTICAL ANALYSIS AND INTERPRETATIONS

The pandemic had different effect on different aggregate macroeconomic variables and different sectors of the economy. While the Fed and government policies had instant effect on financial markets, the adjustment path of unemployment rate, industrial production, and personal consumption have been very slow. At the industry levels, while many businesses in service, leisure, travel and other industries have been facing bankruptcies and lay-offs, the pandemic-induced demand in some other industries have been creating jobs, though not at the same rate as the jobs lost.

The three macroeconomic variables studied in this paper are total industrial production index (IPB50001N), civilian unemployment rate (UNRATE) and personal consumption expenditures (PCEC96). COVID-19 and its containment policies had a major effect on industrial production and unemployment, the effect of which naturally carried rapidly to personal consumption expenditures (Federal Reserve Bank).

Before running ARIMA models, each variable was tested for stationarity using Augmented Dickey-Fuller test and if needed the variable was differenced to be made stationary. Total industrial production index, civiliant unemployment rate, and personal consumption expenditures data were tested for the presence of unit root in individual series. Since the literature on the subject of unit roots is far from resolved, it helps to use a variety of tests[1]. In this study, we tested data using the Augmented Dickey Fuller (1979) test and the Phillips-Perron (1988) test of the existence of unit roots in the time series. If a unit root was present, the proper degree of integration was applied before running the ARIMA models. The model selection was based on Schwartz Bayesian Criterion (SBC) and the Aike Information Criterion (AIC). For each of the ARIMA model residuals the Ljung-Box "Q" statistics were estimated to test the hypothesis that all the autocorrelations of the residuals were zero (Falatoon and Safarzadeh1999).

Industrial Production: The total index of industrial production (IPB) dropped from its all time high of 112.05 in August of 2019 to 89.10 in April of 2020, a drop of 20.48%. The estimated equation for the total index of industrial production was an ARIMA(1, 1, 1) with an impulse at the closure of the economy on March 15, Z_{7} . The estimated equation is:

$$dIPB_t = 0.83dIPB_{t-1} - 0.64\epsilon_{t-1} + 4.97Z_{7}$$

s.e. (0.33) (0.37) (1.45)

aic = 301.71

All the coefficients of the model were significant at 95% or higher except for the moving average component, which was significant at 92% level of significance. The graphs below show the total index of industrial production from May 2002 to March 2020 (Figure 13), the 12-period ahead forecast of the index (Figure 14) and its impulse response function (IRF) time path of adjustment for 12 months (Figure 15). Our analysis shows that, assuming no major new shock to production activities and new government and Fed policies, it will take at least 12 to 18 months for the index of industrial production to rise to its pre shut-down level of 110.

Figure 13: Monthly Industrial Production Index, May 2002 – March 2020

[1] For a critical review see, for example, Christiano and Eichenbaum (1990).

Figure 14: 12-Period Ahead Forecast of Industrial Production Index, April 2020 – Feb 2021

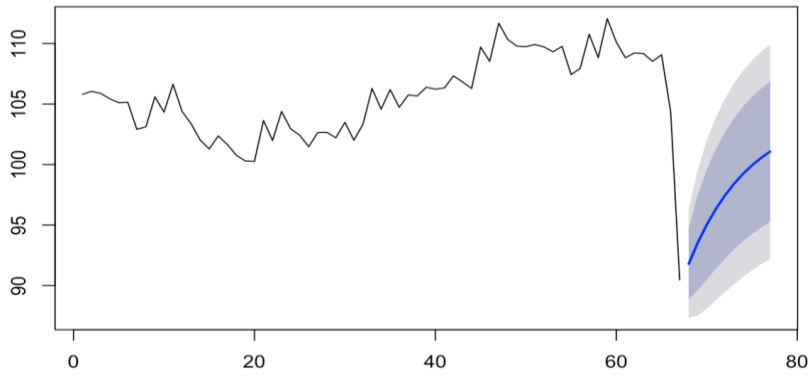
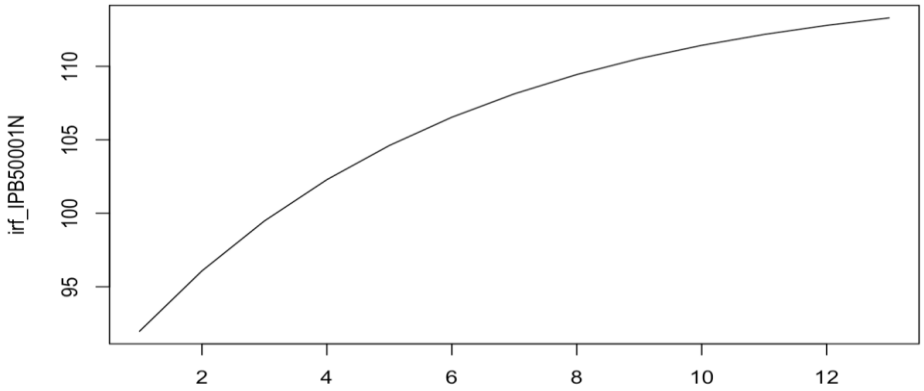


Figure 15: 12-Period Ahead Time Path of Adjustment for IPB50001N, IRF Model



Unemployment Rate: The civilian unemployment rate (UNRATE) had a steady decrease since its high of 10% during the great recession. With the shut-down of the economy, the unemployment rate increased from 3.6% to over 14%, an increase of over 10% in a very short period of time.

The estimated equation of unemployment rate (U) was an ARIMA(1, 1, 0) with an impulse at the closure of the economy on March 15, Z_{7} :

$$dU_t = .35dU_{t-1} - 4.85\ Z_{7}$$
s.e. (0.085) (0.040)
aic = 266.65

Both coefficients of the model are significant at 95% or higher. The graphs below show the unemployment rate index (Figure 16), the 10 period ahead forecast of unemployment rate (Figure 17) and its IRF time path of adjustment (Figure 18). Our analysis shows that, assuming no new adverse effect from COVID-19 and no drastic government and Fed job creation policies, it will take at least six months for unemployment rate to move below 7.5%.

Figure 16: US Civilian Unemployment Rate Jan 2010 –April 2020

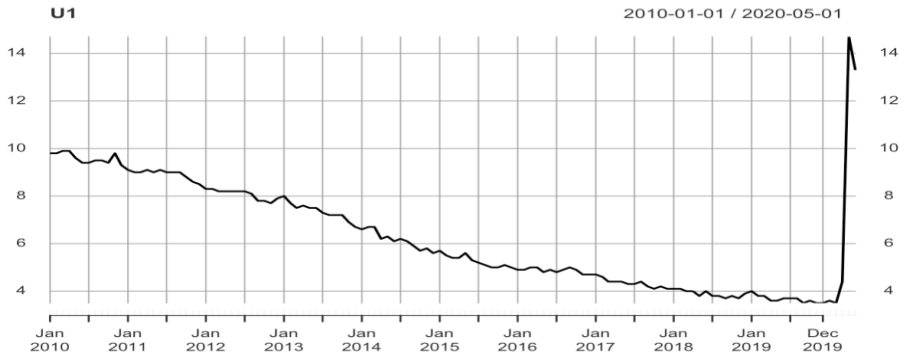


Figure 17: 10-Period Ahead Forecast of Unemployment Rate

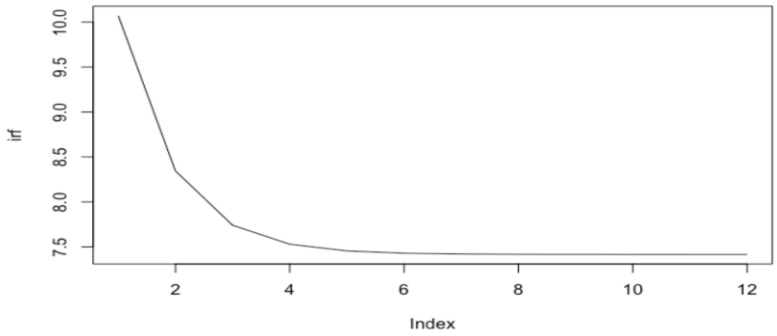
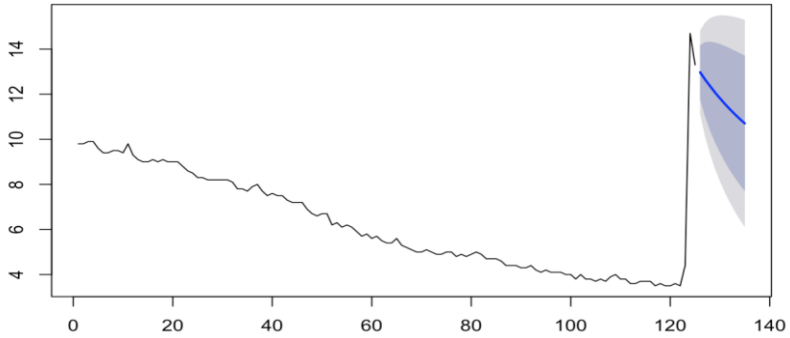


Figure 18: 10-Period Ahead Time Path of Adjustment for Unemployment, IRF Model



Personal Consumption Expenditure: The shutdown of the economy on mid March, the uncertainty about the future of the economy, and the increase in unemployment rate resulted the personal consumption expenditure to drop by over 20% in a very short period of time.

The estimated equation of the personal consumption expenditure (PCEC96) was an ARIMA(1, 1, 0) with an impulse at the closure of the economy on March 15, Z_7 :

$$dPCEC_t = 0.727 dPCEC_{t-1} + 325.20\, Z_7$$
$$\text{s.e.} \quad (0.099) \qquad\qquad (40.28)$$

aic = 1437.57

Both coefficients of the model are significant at 95% or higher. The graphs below show the personal consumption expenditure index from January 2002 to May 2020 (Figure 19), the 12 period ahead forecast of personal consumption expenditure (Figure 20) and its IRF time path of adjustment for the 12 month (Figure 21). Our analysis shows that, assuming no extreme government and Fed job creation policies, it will take at least 12 months for personal consumption expenditure to rise to its pre shut down level.

Figure 19: US Monthly Personal Consumption Expenditure, January 2002 – May 2020

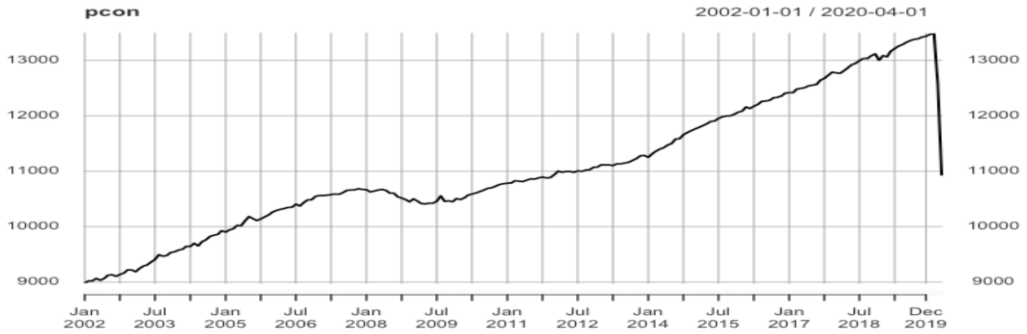


Figure 20: 10-Period Ahead Forecast of the Change in Consumption Expenditure

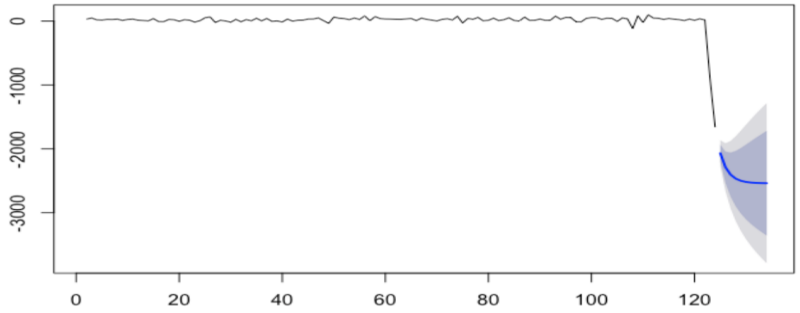
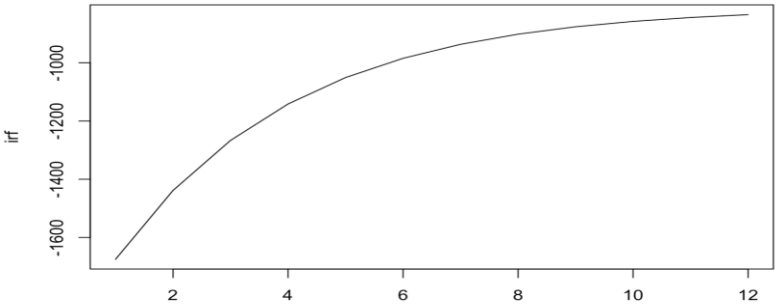


Figure 21: 10-Period Ahead Time Path of Adjustment for Personal Consumption, IRF Model



IV. CONCLUDING REMARKS

The COVID-19 shock had a devastating effect on physical, mental and economic well-being of the public, the effects of which may last long to the future. The early optimistic expectations of a V-shaped quick recovery has been replaced with expectations of an extended severe slump in the world economy. In US, the real GDP is expected to decrease at an annual rate of 4% with the worst decrease being in the second quarter of 2020. The ECB's baseline forecast of decrease in Eurozone economies is 8.7%. These estimates are based on the assumption that the countries have flattened the infection and death rate curves and that there will be no resurgence of the COVID-19 resulting in more shut-downs of the economies. While the data from China, UK, Germany and many other countries show that they have flattened the curves successfully, the US data points to emergence of some hot spots in the country due to a hasty opening of the economy with no consistent enforceable health guidelines (Appendix: Figures 3 and 4).

The shut-down of the economy on March 15 inflected an unprecedented damage to real economic variables that cannot be reversed by conventional expansionary fiscal and monetary policies only. How fast the US economy will recover will depend on public trust and adherence to CDC guidelines and developments in discoveries of vaccine or medicine to mitigate the spread of COVID-19 and treat the infected people. Although the speed of adjustment to equilibrium for each economic time-series is different from others, for the three major indices of total industrial production, personal consumption and civilian unemployment rates studied in this paper the data points to adjustment periods of 12 to 18 months under the best scenarios. The speed of adjustment and the adjustment pathways of the variables and the economy to pre-shock levels will depend as well on the credibility of the government officials on convincing the public that they can participate in economic activities without any risk to their well-being.

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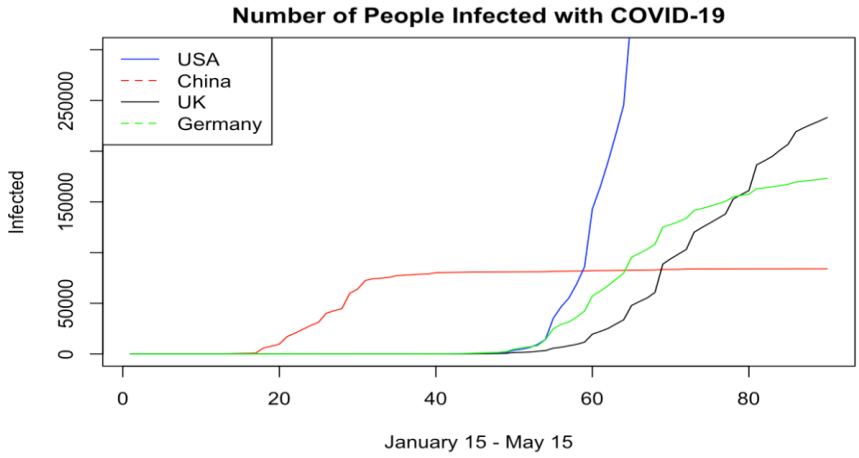
VI. APPENDIX

Figure 1: Number of People Infected from January15- May 15, 2020



Data Source: Johns Hopkins Center for Public Health

Figure 2: Number of People Dead from January 15- May 15, 2020

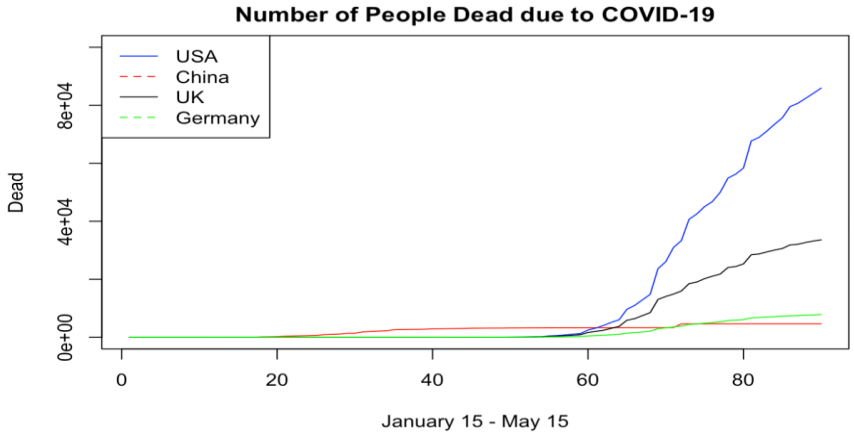
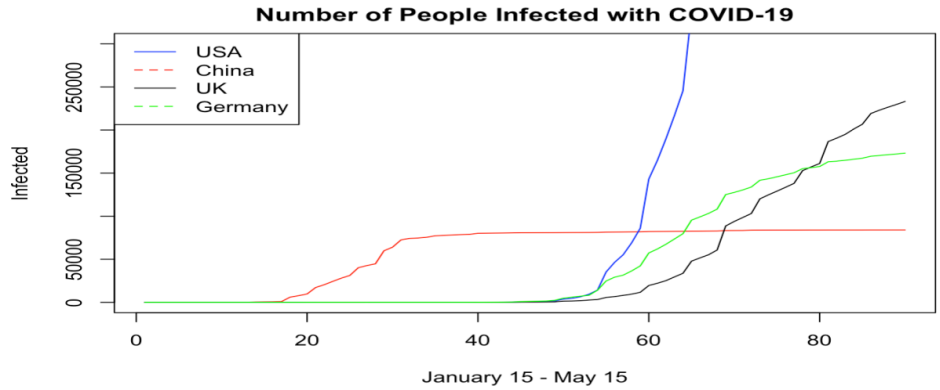
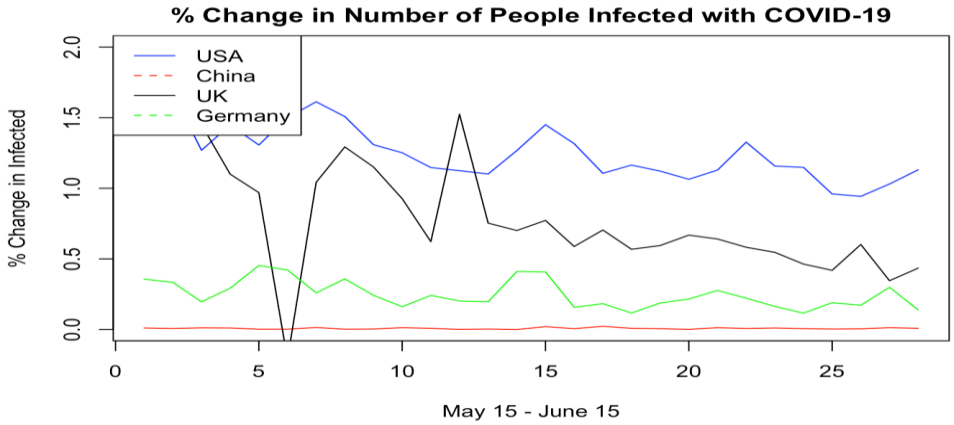


Figure3: Number of People Infected from May 15- June 15, 2020



Data Source: Johns Hopkins Center for Public Health

Figure4: Percent Change of People Infected from May 15- June 15, 2020



Data Source: Johns Hopkins Center for Public Health

Figure5: S&P 500 Index Monthly Data January 2019 – May 2020

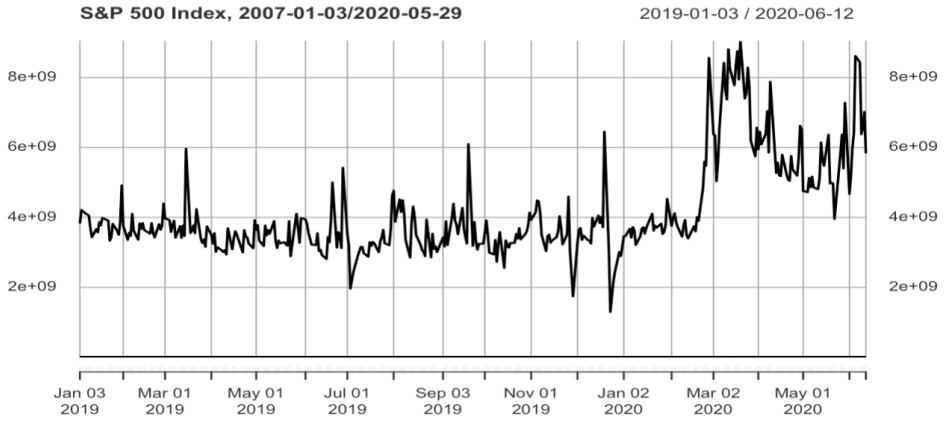


Figure6: Monthly Return to S&P 500 and its Volatility January 2019 – May 2020

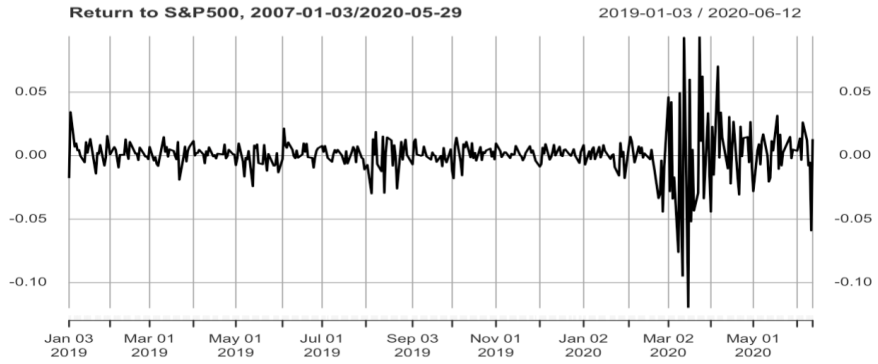


Figure7: DAX Index Monthly Data January 2019 – May 2020

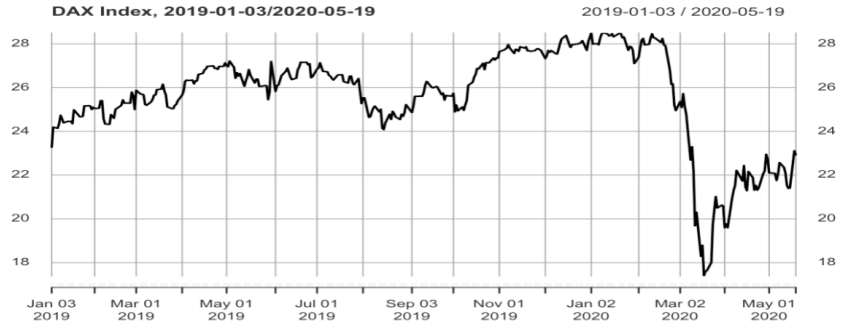


Figure8: Monthly Return to DAX and its Volatility January 2019 – May 2020

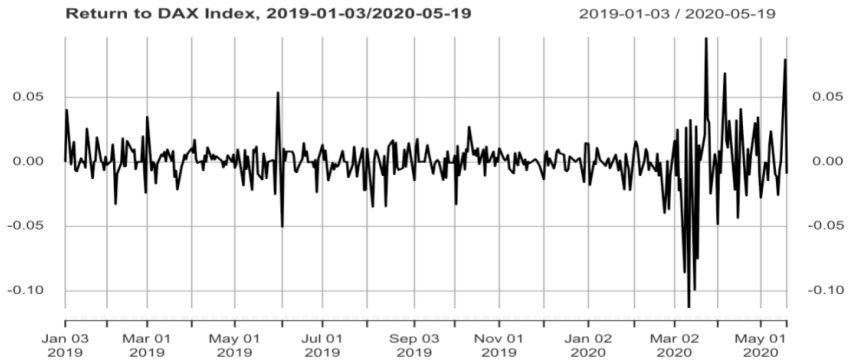


Figure 9: HSI Index, Monthly Data January 2019 – May 2020

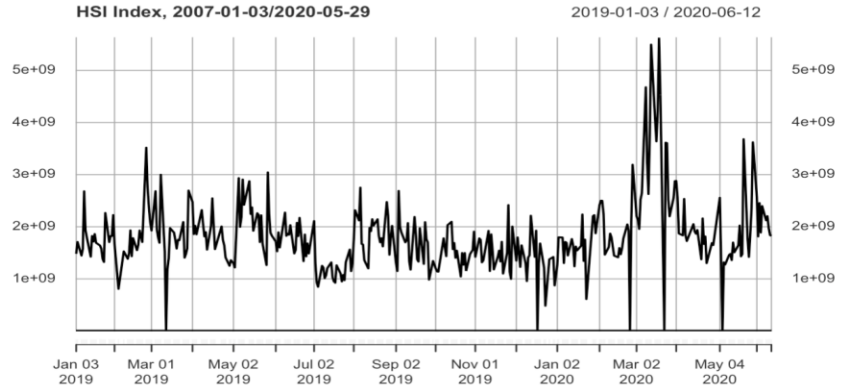


Figure10: Return to SHI Index, Monthly Data January 2019 – May 2020

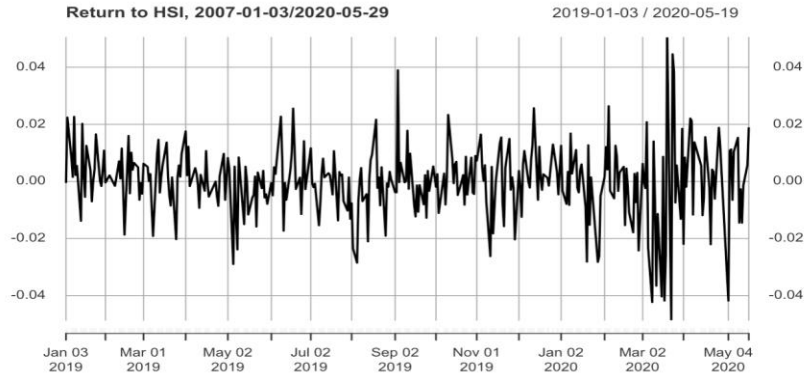


Figure11: FTSE Index, Monthly Data January 2019 – May 2020

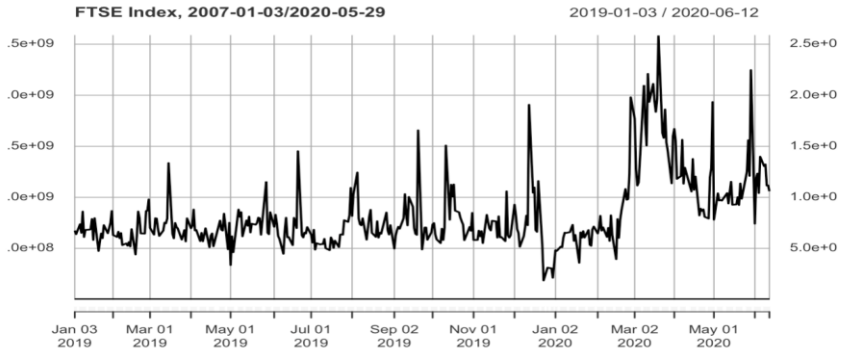


Figure 12: Return to FTSE Index, Monthly Data January 2019 – May 2020