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Aminu Osman [α], Anthony Abaidoo [σ], Justina Antwi-Konadue [ρ] & Frances Kwaw Andoh [ω]

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Keywords: covid-19, stock exchange, composite index, autoregressive, moving average, ARIMA, GARCH.

I. Introduction

COVID-19 crises add up to several crises that have hit the globe. Counting the likes of World Warl and II and the great depression, the great recession, and Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The COVID-19 spread has travelled more than 150 countries and still spreading. By February 2021, globally, the pandemic had reached a case count of 113,467,303 people with a recorded death of 2,520,550 people (WHO, 2021). Governments all over the world have strived to contain the shocks. Countries across the globe adopted a series of containment measures to curb the spread of the novel coronavirus. Some of these strategies include the closure of borders and schools, restrictions on internal and international travel, washing hands with soap under running water with the aid of handwashing stations, use of hand sanitizer, social distancing,lockdown and the rest. These containment measures were to limit the spread of the virus but have unfortunately been attributed to the cause of shocks experienced by firms. Countries have succeeded through these containment measures to successfully rein the virus but unfortunately, the restrictions have hit firms' operations hard. In Africa, Agribusiness has been constrained in access to production inputs and a market for sales of products as a result of the restrictions imposed (Lakuma & Sunday, 2020). Markets were closed down, borders were closed, social distancing became a compulsory practice for everyone, and suspicion resulted in quarantines. Especially for small enterprises who could not innovate responsively to the shocks, they were either closed temporarily or recorded little sales, and hence large declines in business activities were more felt compared to the medium and large-scale enterprises (Lakuma & Sunday, 2020).

The agricultural and manufacturing sectors have also suffered various levels of shocks. Business enterprises were encouraged to provide an enabling environment by the provision of handwashing centers and equipment, sanitizer, and lodging of employees within the premises of the business if they were to stay in business. The result of all these consequences have showcased in the massive unemployment rate across countries especially the fragile economies. If countries are to keep or increase the containment measures in a response to the risk pose by COVID 19, unemployment is will keep increasing denying a lot of households a livelihood. In the United State, unemployment shot up from 3.8% to 13.5% in May (Kochhar, 2020). The effect of the pandemic on Ghana is not far from the stories in other countries.

This is because COVID-19 is a covariate risk and due to the lockdown of production and economic activities, countries do not benefit from cheaper oil and other commodities. The top ten most heat countries of COVID-19 include the United States of America, India, Brazil, Russia, Colombia, Peru, Spain, Mexico, Argentina, and South Africa. Below is the case count of COVID-19 worldwide by continent and country. By 28th September, the world has reordered a total of thirty-three million cases with an average recovery of the rate of 74.5% which varied across countries and continents from 0.3% to 97.5%.

Despite the fact that COVID-19 incidence is new, some newspapers and quite some articles like the work of Kahn et al. (2020) have given the subject area some discussions. Many corporate companies and national leadership of business interest have been interested in understanding sources of risk that could arise from this pandemic.

Amidst the presence of COVID-19, the study seeks to forecast the volatility of the Ghana stock exchange composite index and examine the presence of

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asymmetry effect from the filtration of the bad news of fatal COVID-19 for the period October 2017 to February, 2021. This would serve as a yardstick to inform investors' decisions into the future with regards to the investment in the stock market in Ghana. As per the theories that underpin this study (i.e. efficient market theory and rational expectation intertemporal asset pricing theory), availability of market information is often in the prices of equities or stocks and as bad new filter the market, it is only rational to hold a less risky asset. The a priori anticipation of the study is that there will exist significantly high volatility and that asymmetric effect will be negative and significant (Kahn et al., 2020). This study will help to firms, investors, and policymakers to know the extent to how risky Ghana stock exchange composite index is and how the index will be shortly. Policymakers and regulators need to know the forecast of the future trend of the stock market to formulate polices based on that empirical findings.

II. Literature Review

The pandemic is reported to have a severe impact on economies all over the world. The pandemicis said to contract the global economy by 3% which is worse than the previously experienced global crises (World Economic Outlook, 2020). The world came to know of the deadly COVID- 19 when the Wuhan Municipal Health Committee officially announced to the World Health Organisation that a "new pneumonia-like disease of unknown cause" detected in Wuhan, the capital city of Hubei province of China.

Governments across the globe had to implement a wide range of policies aimed at protecting workers and supporting businesses to survive the shocks of the pandemic. Containment and economic recovery policies have been in the minds the central government and local governments at the provincial and municipal levels. These policies and long-ranging on tax policies, employment policies, financial policies, health policies, and international trade policies.

In the United State of America, monetary and macro-financial policies touched on lowering the federal fund rate by 150bp in March to 0-0.25bp. the cost of discount window lending was reduced and the existing cost of swapping lines with major central banks was also reduced. There was an extension of the maturity of FX operations with a broadened US dollar swap lines to more centralbanks.

In Ghana, the containment measures adopted by the government include banding of all kinds of social gathering exceeding 25 people for four weeks; closure of all universities and schools until further notice; closure of borders to travelers; and mandatory 14 – day self-quarantine for any Ghanaian who has been to a country with at least 200 confirmed cases of COVID-19.

In the fiscal fonts, as the government intends to commit an amount of GHS 11.2 billion to face COVID-19 and its related social and economic hardships dubbed Coronavirus Alleviation Programme, large government spending has been cut on all economic classifications of government budgeted annual expenditures such as goods and services, transfers, and capital investments. The Coronavirus Alleviation Programme is intended to be used to support industries in the pharmaceutical sector supplying COVID-19 drugs, and equipment, support SMEs, build orupgrade 100 district and regional hospitals and address the availability of test kits, pharmaceuticals, equipment, and bed capacity. To finance pressing needs that COVID 19 has created, the government intends to borrow GH¢ 10 billion from the Bank of Ghana has drawn an amount of US$ 218 million from the stabilization fund.

In the monitory and macro-financial sector, the policy rate was cut by 150 basis points to 14.5%. as part of efforts in mitigating the effect of the pandemic, the Monetary Policy Committee of Ghanalowered the primary reserve requirement and capital conservation buffer from 10% to 8% and 3% to 1.5% respectively. The cost of mobile payment was also lowered and was accordingly complied by both Banking and Non-Banking financial institutions. There were unfortunately no polices on the exchange rate and balance of payment level.

In line with the focus of this study, Kahn et al., (2020) examined the impact of the COVID-19 pandemic on stock markets sixteen countries and found that investors in these countries react to the bad news of the pandemic at the early stage. GPD is claimed to be significantly impacted due to a decline in production among firms (Wren-Lewis, 2020). If the pandemic persists with is magnitude and fatality, Banks will soon fail to meet the financial requirement of firms which will cause the breakdown of the stock markets. The overall downturn in global production as a result of the lockdown of firms and industries risk increasing prices of essential commodities shortly.

III. Study Methodology

The study employed the Autoregressive Integrated Moving Average (ARIMA) model to forecast the Ghana Stock exchange composite index after a period of the 8-months of shock of COVID-19to Ghana and the world at large.

The ARIMA model is also sometimes called the Box Jenkins (2019) methodology. The model uses information derived from its past behaviors to forecast its trend. It is a univariate model and wherethe variable itself is regressed on its pass value. It uses the philosophy of "let variable speak for itself". There are two underlying assumptions of ARIMA modeling. The first assumption is a concern with the stationarity of the time series in question. The series must exhibit mean reversions, has

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infinite, and time-invariant variance and must also have a theoretical correlogram that diminishes as the lag length increases. The second is the invertibility assumption which requires that the series should be able to be represented by a finite order MA or convergent autoregressive process. It is also the ACF and PACF for identification. It also implicitly assumes that the series can be approximated by the AR model.

a) Specification of the ARIMA Model

ARIMA model allows a series say Y_t to be regressed by lagged values of the same series and error term. As a result, it is often called atheoretic model since it is not obtained from any economic theory. RIMA is composed of an AR model and a MA model.
Consider the equation below.

$$Y_t = a + bY_{t-1} + u_t \quad (1)$$

$$Y_t = a + b(LY) + u_t \text{ or } (1 - bL) = a + u_t$$

where a and u_t denote constant and stochastic white noise respectively. Y_t is the Ghana stock exchange composite index. A key assumption of ARIMA modeling is stationarity and so it is assumed that $|b| > 1$, the composite index will tend to be bigger and bigger at each period time and the composite index will become explosive. More lags can be included as a generalization ofthe AR model. For instance, an AR (2), AR (3), and AR(p) is given as;

$$\text{AR}(2): Y_t = a + b_1Y_{t-1} + b_2Y_{t-2} + u_t$$

$$\text{AR}(3): Y_t = a + b_1Y_{t-1} + b_2Y_{t-2} + b_3Y_{t-3} + u_t \quad (2)$$

$$\text{AR}(p): Y_t = a + \sum_q^p b_iY_{t-i} + u_t$$

For a moving average model, the composite index is explained by the value of the error term andthe immediate past error term. An MA(1), MA(2) and MA(p) can be specified as;

$$\text{MA}(1): Y_t = \gamma + d_0u_t + d_1u_{t-1}$$

$$\text{MA}(2): Y_t = \gamma + d_0u_t + d_1u_{t-1} + d_1u_{t-2} \quad (3)$$

$$\text{MA}(p): Y_t = \gamma + d_0u_t + \sum_j^q d_ju_{t-j}$$

Combining the AR(q) and AR(q) we obtain Autoregressive Moving Average (ARMA) specified in equation (4).

$$\text{ARMA}(p,q): Y_t = a + \sum_i^p b_iY_{t-i} + d_0u_t + \sum_j^q d_ju_{t-j} \quad (4)$$

where p lags of the dependent variable and q lags of the error term.

Most economic variables are non-stationary and so ARIMA brings in the case of integration of thevariable which is not stationary. The difference between ARMA and ARIMA and the integration of the dependent variable. In real-life situations, most time series variables are not stationary and therefore will need to be transformed to be stationary. The ARIMA model can be specified in different ways depending on the lag(s) of the AR and MA.

ARIMA (p, d, q) implies there are p number of lags of the dependent variable, the variable has been differenced d times to become stationary and there are q lags of the error term. Parsimoniousmodels give a better forecast than over parameterized model. Therefore, it is important to pick themodels with the smallest number of parameters to be estimated.

b) Identification of the ARIMA model

The identification involves the selection of the ideal lags for the AR and MA process. It is usually done using the correlogram. The correlogram is simply the plots of the ACFs and PACFs against the lad length. PACF measures the correlation between observations that are k time period apart after controlling for correlations at immediate lags.

It is important to know the pattern of ACF and PACF before one can decide whether the series isgoing to follow an AR process, MA process, or a combination of an AR and MA. To know whether it is going to be an ARIMA, Table 2 presents provides a guide to aid one in choosing an appropriateARIMA model.

Table 2: Guide for Identification

Model	ACF Pattern	PACF Pattern
AR(p)	Exponential decay or damped sine wave pattern or both	Significant spikes through first lag
MA(q)	Significant spikes through first lag	Exponential decays
ARMA (1,1)	Exponential decays from lag 1	Exponential decays from lag 1
ARMA(p,q)	Exponential decays	Exponential decays

c) Exponential GARCH Model

Exponential GARCH also found out whether the bad news COVID-19 which filtered every part of the world and for that matter Ghana had a significant shock on the volatility of the Ghana stockexchange composite index. The GARCH model was introduced by Tim Bollerslev in 1986 and has been employed by many economists and financial analysts. Following Sunarya (2019), we specify GARCH(1,1) in equation (5) as;

$$h_t = \varphi + \theta_1h_{t-1} + b_1u_{t-1}^2 \quad (5)$$

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where h_t is the conditional variance, t denotes time, and u_{t-1}^2 is the lagged squared error term. The model spefies that the conditional variance at time t depends on both the past values of the shocks captured by lagged squared error terms and past figures of itself. The GARCH (p,q): h_t model whengeneralized becomes;

$$\text{GARCH}(p,q): h_t = \varphi + \sum_k^p \theta_k h_{t-k} + \sum_i^q b_i u_{t-i}^2 \quad (6)$$

where P=0, equation (6) reduces to ARCH(q).

Drawing insights from GARCH and threshold GARCH, Nelson (1995) introduced exponential GARCH to capture the test for asymmetries. When bad news filter into the market, assets tend to enter into a state of turbulence and volatility increases. Unlike the case of the TGARCH, the EGARCH uses the log of the series as the dependent variable and not the levels. The conditional variance for the EGARCH (p,q) model is given as;

$$\log(h_t) = \varphi + \sum_{i=1}^q \eta_i \left|\frac{u_{t-i}}{\sqrt{h_{t-i}}}\right| + \sum_{i=1}^q \lambda_i \left|\frac{u_{t-i}}{\sqrt{h_{t-i}}}\right| + \sum_{k=1}^p \theta_k \log(h_{t-k}) \quad (7)$$

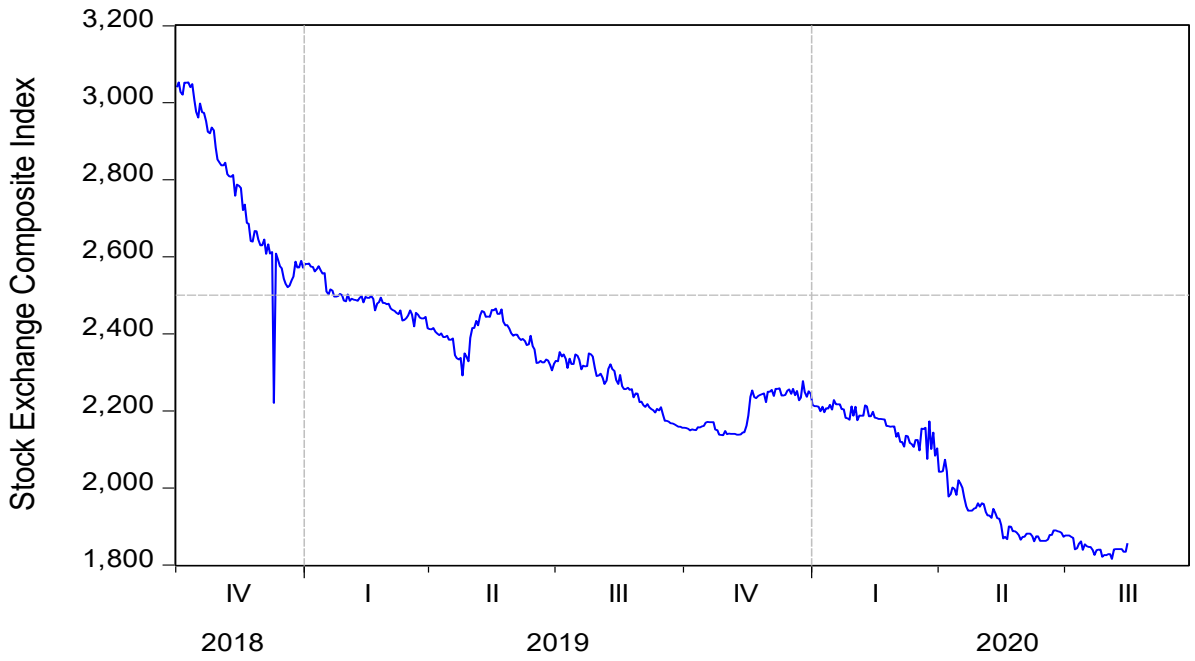
Where log(h_t) denotes the log of the variance series, which makes the leverage effect exponential instead of quadratic. The implication is that the estimates are non-negative. V denotes theconstant, η represents the ARCH effects, λ denotes the asymmetric effect, and θ represents the GARCH effect. The condition is that if $\lambda_1 = \lambda_2 = \cdots = 0$, the model is symmetric. However, where $\lambda_i < 0$, it implies that negative shocks generate larger volatility than good news.

d) Diagnostics test for the EGARCH

The preferred model must have the following features; the model must be parsimonious; the ARCH and GARCH coefficients must be statistically significant; the adjusted R-square and the log-likelihood ratio must be high; the SIC information criterion which gives the heaviest penalties for loss of degrees of freedom must be low; and must pass both heteroscedasticity and autocorrelation test. Every model may not pass all these specifications but there could be a reasonable tradeoff. In GARCH diagnostics, a normality test is not necessary because, by nature,the GARCH model have fat tails and are either skewed to the left or right.

IV. Results and Discussions

The plot of the GSECI for the period under study is shown in figure 1. The series is observed to be declining sharply from the last quarter of 2018 and continues to depict a slow downward trend till quarter four of 2019 where it gained some momentum increased slightly. At the beginning of 2020, the GSECI showed a downward trend from quarter one to quarter three.



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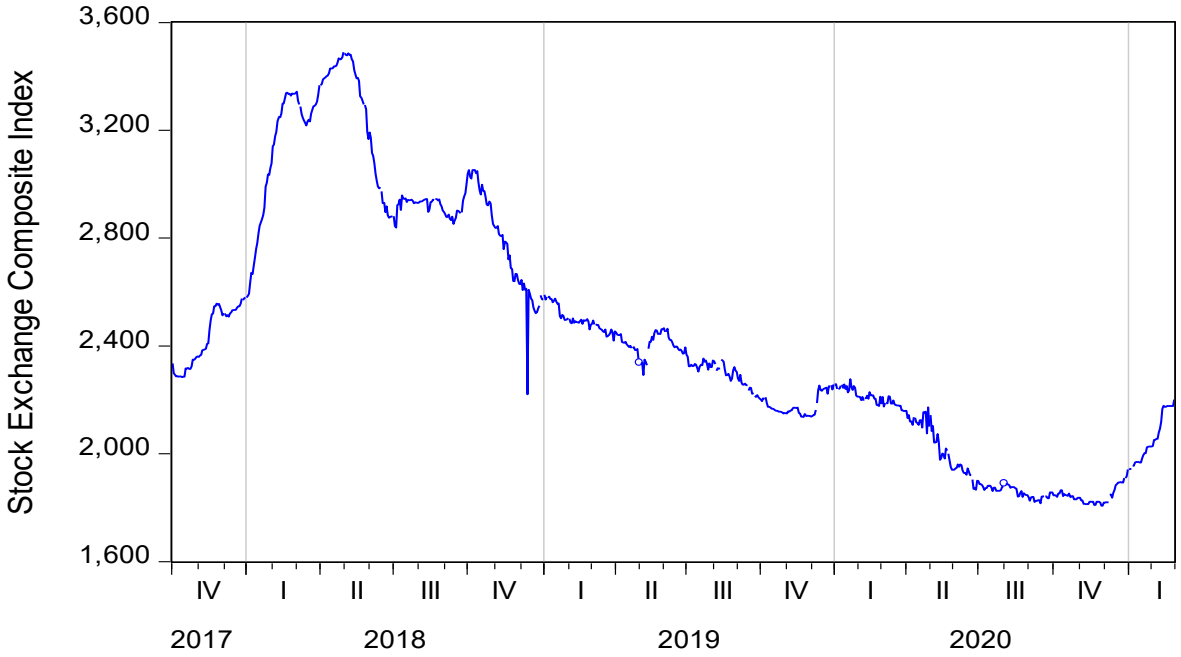

Figure 1: Historical Plots of GSECI

The plot of the historical daily GSECI shows that the series is trending downwards and not reverting to its mean. By visualizing it, we say the series is non-stationary. fluctuates around some common mean and therefore it is non-stationary. This is confirmed with the use of the Dickey- Fuller test for unit root presented in Table 1.

a) Unit Root Test for Stationarity

Table 1: ADF test statistics

IGSECI	I (0)		I (1)	
	t-Statistic	P-value	t-Statistic	P-value
AIC	-3.366978	0.0566	-5.599723	0.0000
SIC	-3.242959	0.0769	-6.149055	0.0000
HQC	-3.366978	0.0566	-5.599723	0.0000

Table 1 presents the test for unit roots of the series using all the criteria (i.e. Akaike Information Criterion, Schwarz Info Criterion, and Hanna-Quin Criteria). For all the criterion at the intercept and trend, it is found that the daily series of Ghana Stock exchange composite index for the period under study is not stationary at 5% level and therefore the series must be transformed. It is confirmed by using a correlogram. With the aid of a correlogram, we check for stationarity. In Appendix 1, it is found that the series is not stationary at level since the ACF declines very slowlyup to about 36 lags. It showed a significant autocorrelation that is outside the error bounds and decays slowly. It is indicative that the series is nonstationary since they are outside the standard error bounds or confident interval at 95%. The PACF also drops immediately after the first and second lag continuously. The series is therefore not stationary.

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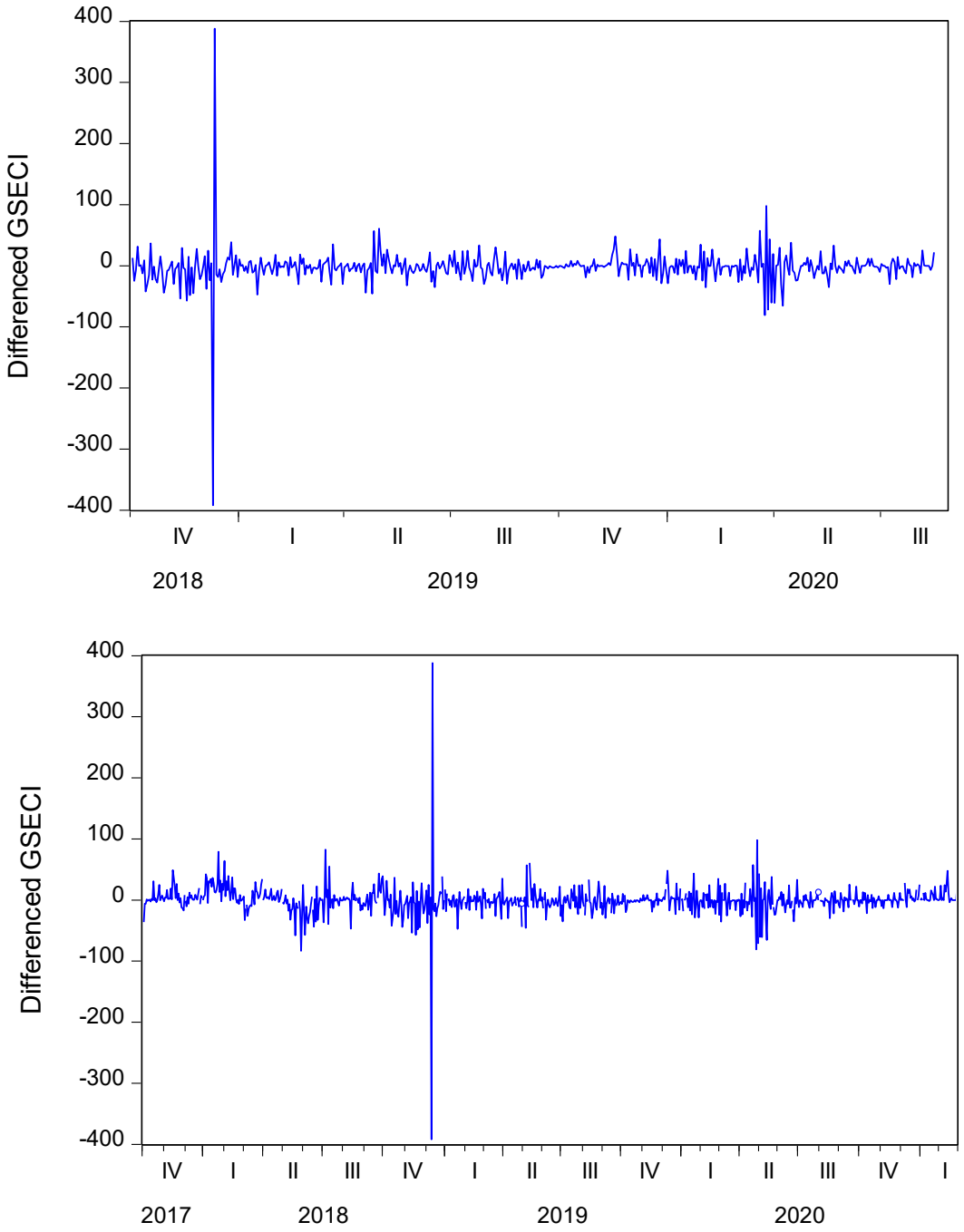

Figure 2: Plot of transformed GSECI

After first differencing, the series shown in Figure 2, is now mean-reverting. That is, the GSECI is now integrated of order one, I (1).

b) Estimates of ARIMA Model

ARIMA informs that the series in question has gone through an integration process before being used for any analysis. Before deciding on the appropriate ARIMA model to be used for the data sequence, Figure 1 presents the correlogram plots of the differenced GSECI which indicates the level of significance of the Q-statistics of a specific set of lags from one to inform our decision on the ideal ARIMA model.

The decision on the appropriate lags for the ARIMA model is to arrive using the Autocorrelation Function (ACF) and the Partial Autocorrelation Function (PACF). The autocorrelation of the first difference of the Ghana stock exchange composite index shows that at the lag one, the ACF is significant and shows an exponential decay till lag 4 where the ACF extends beyond the confidence interval bounds and continue decaying exponentially. There exists a slight similarity between the ACF and the PACF (see Appendix 2 for the correlogram). Since the pattern of the ACF and PACF looks the same, we can conclude having a set of

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tentative ARIMA models (1,1,1), ARIMA (1,1,4), ARIMA (4,1,1) and ARIMA (4,1,4).

It is advised to choose a model that is parsimonious as it gives a better forecast than an overidentified model. Models with the smallest number of parameters to be estimated are usuallyparsimonious. From Table 2, between the contest ARIMA (1,1,1) and ARIMA (4,1,1) which all have 2 significant coefficients, ARIMA (4,1,1) is ideal for the study since it has the lowest volatility, highest adjusted R-square, and lowest AIC and SBIC.

Table 2: Determination of Appropriate ARIMA Model

Differenced GSECI	ARIMA (1,1,1)	ARIMA (4,1,1)	ARIMA (1,1,4)	ARIMA (4,1,4)
Significant coefficient	2	3	3	3
Sigma^2(volatility)	619.0792	599.9418	599.9776	651.5751
Adj R^2	0.080375	0.108803	0.108750	0.032103
AIC	9.275762	9.244577	9.244561	9.327075
SBIC	9.298344	9.267160	9.267144	9.349658

c) ARIMA Model Estimate

The final model has been determined as ARIMA (4,1,1) and it is presented in Table 3.

Table 3: ARIMA (4,1,1) estimates of the Ghana Stock Exchange Composite Index.

Variable	Coefficient	Std. Error	t-Statistic
Constant	-0.161561	0.976326	-0.165478
AR (4)	0.212911***	0.014475	14.70849
MA (1)	-0.287736***	0.007387	-38.94937
SIGMASQ	599.9418***	5.705647	105.1488

*Note: *, ** and *** represent 10%, 5% and 1% level of significance respectively*

d) Forecast analysis of GSE-CI

The ARIMA (4,1,1) model is used to forecast the closing price of the Ghana stock exchange composite index from 1st March, 2021 to 26th February, 2022. The forecast of the outer year from March 2021 to February 2022 shows a upwards trend of the GSECI.

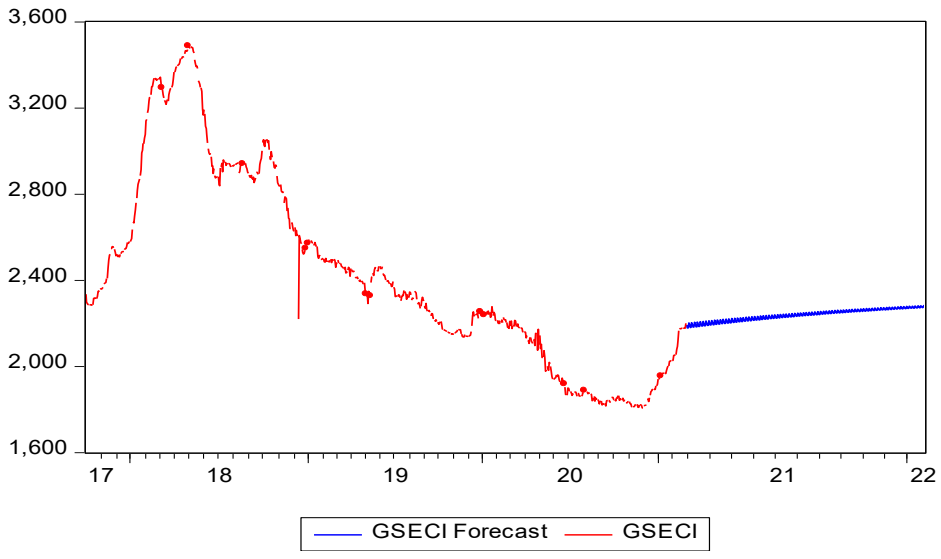

Figure 3: Forecast of GSECI showing Actual and Forecast

The correlogram after estimation of the ARIMA (4,1,1) model indicates there is no information uncaptured since all the residuals are barely flat and do not lie above the standard error bound. Thus, all the lag structures should lie within the 95% confidence intervals or the standard error bounds. Since all the residuals lie

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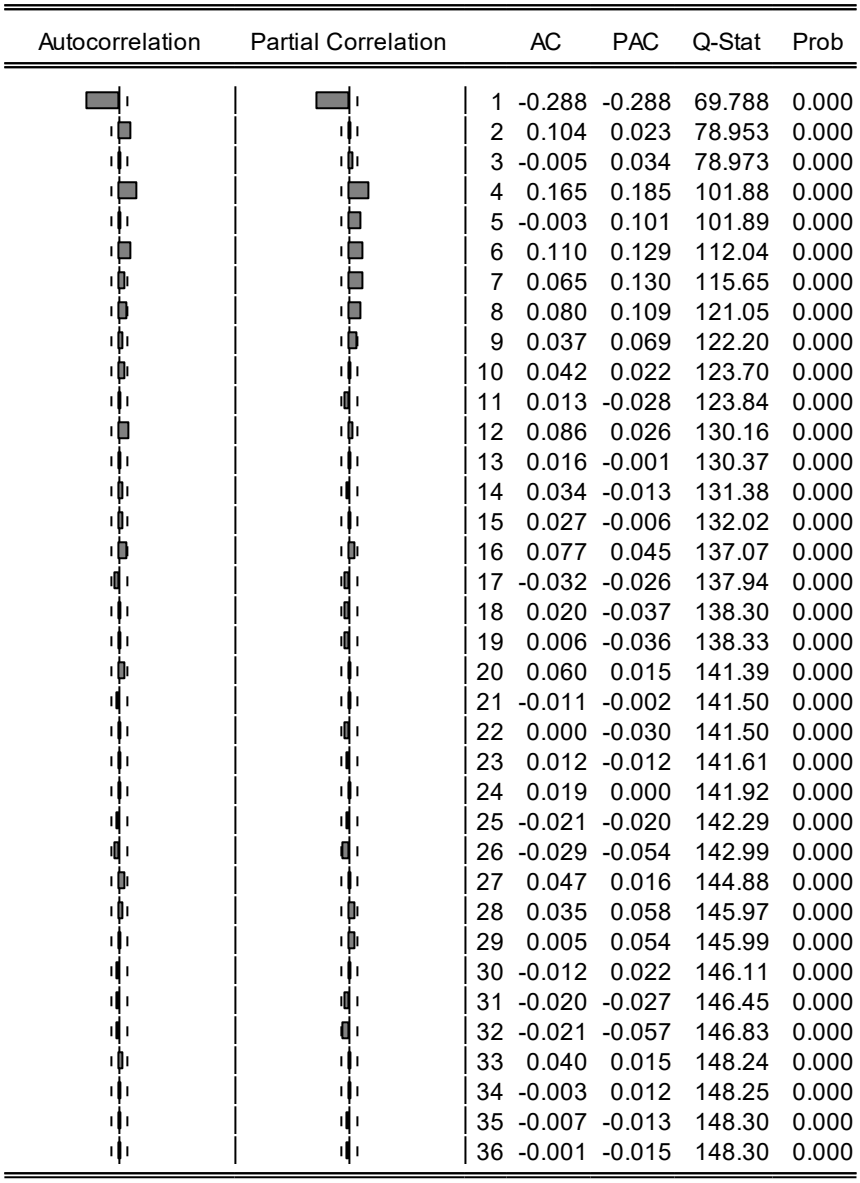
within the standard error bounds, we can conclude that ARIMA (4,1,1) is appropriate. Figure 3 presents the Ljung-Box test for squared residuals; no lag is found to be significant in the correlogram of the residual and hence there is no information leftuncaptured.



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.288	-0.288	69.788	0.000
		2	0.104	0.023	78.953	0.000
		3	-0.005	0.034	78.973	0.000
		4	0.165	0.185	101.88	0.000
		5	-0.003	0.101	101.89	0.000
		6	0.110	0.129	112.04	0.000
		7	0.065	0.130	115.65	0.000
		8	0.080	0.109	121.05	0.000
		9	0.037	0.069	122.20	0.000
		10	0.042	0.022	123.70	0.000
		11	0.013	-0.028	123.84	0.000
		12	0.086	0.026	130.16	0.000
		13	0.016	-0.001	130.37	0.000
		14	0.034	-0.013	131.38	0.000
		15	0.027	-0.006	132.02	0.000
		16	0.077	0.045	137.07	0.000
		17	-0.032	-0.026	137.94	0.000
		18	0.020	-0.037	138.30	0.000
		19	0.006	-0.036	138.33	0.000
		20	0.060	0.015	141.39	0.000
		21	-0.011	-0.002	141.50	0.000
		22	0.000	-0.030	141.50	0.000
		23	0.012	-0.012	141.61	0.000
		24	0.019	0.000	141.92	0.000
		25	-0.021	-0.020	142.29	0.000
		26	-0.029	-0.054	142.99	0.000
		27	0.047	0.016	144.88	0.000
		28	0.035	0.058	145.97	0.000
		29	0.005	0.054	145.99	0.000
		30	-0.012	0.022	146.11	0.000
		31	-0.020	-0.027	146.45	0.000
		32	-0.021	-0.057	146.83	0.000
		33	0.040	0.015	148.24	0.000
		34	-0.003	0.012	148.25	0.000
		35	-0.007	-0.013	148.30	0.000
		36	-0.001	-0.015	148.30	0.000

Figure 4: Correlogram after estimation of ARIMA (4,1,1)Exponential GARCH (1,1)

e) Exponential GARCH (1,1)

The coefficient of interest is the asymmetric term. The term is positive (0.2983) and significant at 1% level. This means that at the time of computation of the results, bad news from COVID-19 has failed to significantly aggravate the behavior of the stock exchange composite index. The outbreak and the bad news of COVID-19 pandemic does not significantly determine the volatility of the Ghana Stock Exchange Composite Index.

Table 4: Estimate of EGARCH (1,1) of GSECI

Variable	Coefficient	Std. Error	t-Statistic
Constant	-1.203569**	0.503448	-2.390653
ARCH	0.505702***	0.150296	3.364698
Asymmetric	-0.03326	0.089315	-0.372384
GARCH	0.894308***	0.050997	17.53663

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R-squared	0.996476	Mean dependent var	7.779222
Adjusted R-squared	0.996472	S.D. dependent var	0.180569
Log likelihood	3162.471	Akaike info criterion	-7.530956

*Note: *, **, and *** denote statistical significance at 10%, 5%, and 1% level*

The exponential terms ($\exp^{0.03326} = 1.2156646$) indicate that for the Ghana Stock exchange composite index, the bad news of COVID-19 has a rather large symmetric effect on the volatility of the stock. The exponential term was however not significant even at 10% level. But for the insignificance of the asymmetric term, negative shocks invoke greater volatility than a positive shock. The bad news of the COVID-19 did not influence the volatility of the stock exchange.

f) EGARCH Diagnostics

Table 5: Diagnostic test of Appropriateness

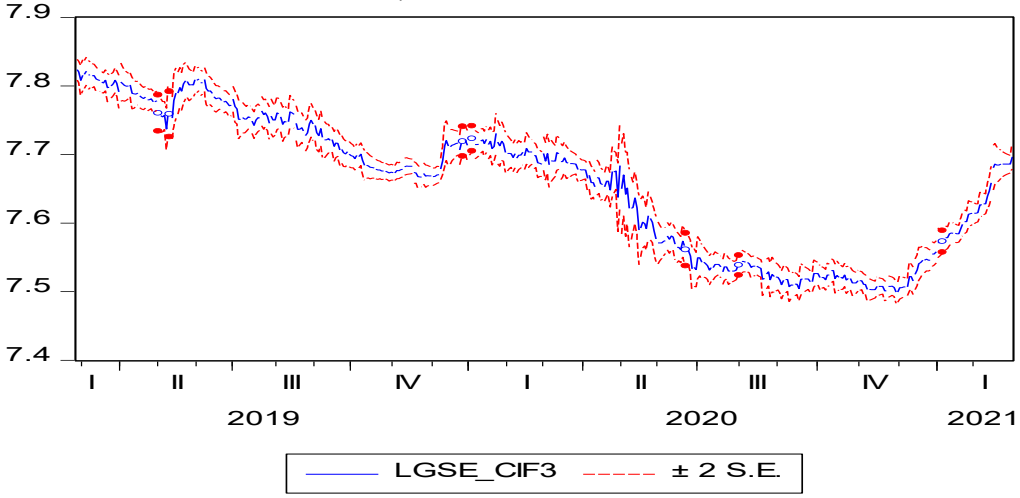
Logged GSECI	Normal Gaussian	Student t's	GED	Student's twith fixed df
Significant Coefficient s	All*	2	2	3
ARCH Significance	Yes	Yes	Yes	Yes
GARCH Significance	Yes	Yes	Yes	Yes
Log-likelihood	2758.957	3074.970	3162.471*	3020.470
Adj R^2	0.996443	0.996469	0.996472*	0.996472
Schwarz IC	-6.536429	-7.282604	-7.491437*	-7.160566
Heteroscedasticity	No	No	No	No
Autocorrelation	Yes	Yes	Yes	Yes

*Note: * represents the best modelSource: Authors computation*

In choosing the preferred model, we depend on the four different error constructs in Table 5 above. The model must be parsimonious. Thus, the ARCH and GARCH coefficients must be statistically significant. The generalized error model has the highest adjusted R-square and the log-likelihood ratio. The Generalized Error Distribution (GED) model also the lowest SIC information criterion which gives the heaviest penalties for loss of degrees of freedom. All the models have the same results for test of heteroscedasticity and serial correlation. The reasonable tradeoff is to choose the generalized error distribution model.

From the GARCH (1,1) model in Table 4, both the GARCH and ARCH models are positive and significant at one 1% level. The residual test reveals that the model passes the residual test since the F-statistic is not significant at 1% level. From Table 5, there is no evidence of heteroscedasticityin the residuals.

Using the correlogram Q-statistics, there existed no serial correlation in the residuals. The ACF and the PACF lie within the confidence intervals as shown in Figure 2. There exist no probability values of the Q-statistics below the alpha level of 1% indicating that there is no serial correlation. Evidence of serial correlation here is when the p-values of the Q-statistics is are statistically significant.



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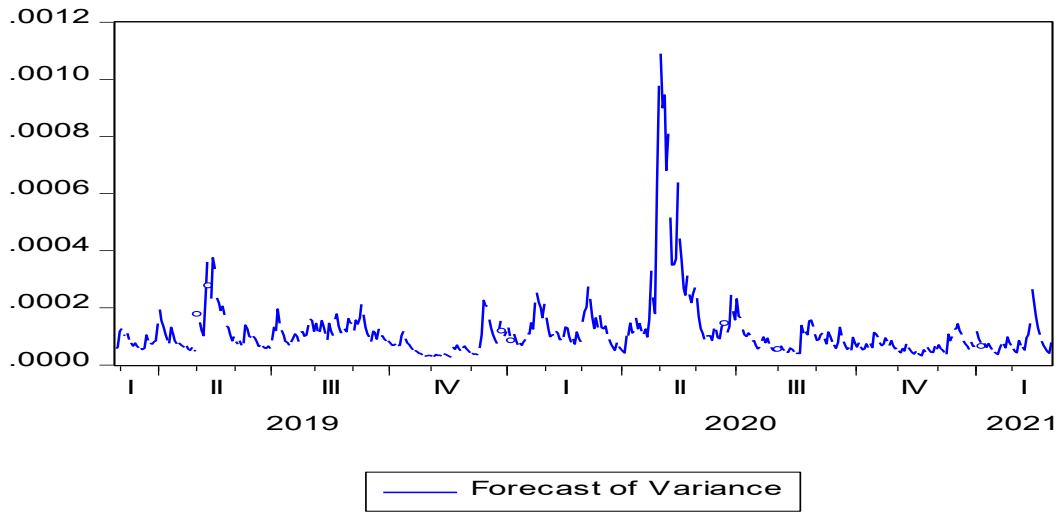

Figure 6: Static Plot of Forecast

g) EGARCH Forecast of GSECI

Not much information was obtained from the dynamic forecast of using the EGARCH model. As a result, a static forecast was used and the results are shown in Figure 5. We can conclude from the plot that the return of GSECI is stable but shows intense volatility. Thought it is sown that return on the composite index will be stable over time, there is exist turbulence throughout the period and we can predict that volatility may occur for the outer days, months, and years.

Volatility towards the end of the years still shows high volatility. Volatility during the period of COVID-19 was intense in the second quarter of 2020. Volatility was very severe from May to June but slowed in July and become extremely high and slowed towards the end of August 2020. The volatility measures the risky involve when an investor holds an asset in such a stock exchange market.

V. Conclusion

The study found that the GSECI data is non-stationary for the period October, 2018 to February 2021. It becomes stationary after first differencing of the original GSECI data. After the comparison made with several tentative models, ARIMA (4,1,1) is found to be ideal for the study.The period of bad news of the COVID-19 adds to the declining trend of the composite index whose volatility begun to subsides towards the end of August, 2020 with some slight turbulence in the first two months of 2021. This might be due to the rising in the COVID-19 case count which hit Ghana after the 2020 General Election on 7th December. The high volatility of the composite indexin the EGARCH shows that investors should be careful of the risky nature of the assets since it isvery irrational to invest in assets that will not provide a sure profit. However, since the volatility is beginning to slow in the early 2021, investors can be ready to make informed decisions on the index.

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Appendix 1: Check for stationary of GSECI using Correlogram

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.998	0.998	838.91	0.000
		2	0.997	0.245	1677.2	0.000
		3	0.996	-0.037	2514.4	0.000
		4	0.995	-0.031	3350.5	0.000
		5	0.993	-0.162	4184.4	0.000
		6	0.991	-0.074	5016.4	0.000
		7	0.989	-0.105	5845.7	0.000
		8	0.986	-0.106	6672.0	0.000
		9	0.984	-0.088	7494.8	0.000
		10	0.981	-0.053	8313.9	0.000
		11	0.978	-0.025	9129.2	0.000
		12	0.975	-0.003	9940.4	0.000
		13	0.972	-0.059	10747.	0.000
		14	0.968	-0.024	11549.	0.000
		15	0.965	-0.014	12346.	0.000
		16	0.961	-0.007	13138.	0.000
		17	0.957	-0.040	13924.	0.000
		18	0.953	0.036	14706.	0.000
		19	0.950	0.031	15482.	0.000
		20	0.946	0.029	16252.	0.000
		21	0.942	-0.013	17017.	0.000
		22	0.937	0.006	17776.	0.000
		23	0.933	0.028	18529.	0.000
		24	0.929	0.009	19277.	0.000
		25	0.925	-0.009	20018.	0.000
		26	0.921	0.017	20754.	0.000
		27	0.917	0.045	21485.	0.000
		28	0.913	-0.024	22210.	0.000
		29	0.908	-0.057	22929.	0.000
		30	0.904	-0.041	23641.	0.000
		31	0.900	-0.007	24348.	0.000
		32	0.895	0.037	25049.	0.000
		33	0.891	0.057	25745.	0.000
		34	0.887	-0.016	26435.	0.000
		35	0.883	-0.015	27119.	0.000
		36	0.879	0.008	27797.	0.000

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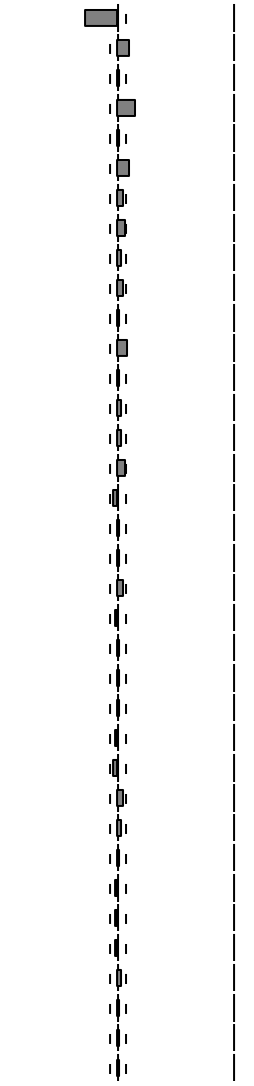
Appendix 2: Check for stationary of Differenced GSECI using Correlogram



		AC	PAC	Q-Stat	Prob
1		-0.288	-0.288	69.788	0.000
2		0.104	0.023	78.953	0.000
3		-0.005	0.034	78.973	0.000
4		0.165	0.185	101.88	0.000
5		-0.003	0.101	101.89	0.000
6		0.110	0.129	112.04	0.000
7		0.065	0.130	115.65	0.000
8		0.080	0.109	121.05	0.000
9		0.037	0.069	122.20	0.000
10		0.042	0.022	123.70	0.000
11		0.013	-0.028	123.84	0.000
12		0.086	0.026	130.16	0.000
13		0.016	-0.001	130.37	0.000
14		0.034	-0.013	131.38	0.000
15		0.027	-0.006	132.02	0.000
16		0.077	0.045	137.07	0.000
17		-0.032	-0.026	137.94	0.000
18		0.020	-0.037	138.30	0.000
19		0.006	-0.036	138.33	0.000
20		0.060	0.015	141.39	0.000
21		-0.011	-0.002	141.50	0.000
22		0.000	-0.030	141.50	0.000
23		0.012	-0.012	141.61	0.000
24		0.019	0.000	141.92	0.000
25		-0.021	-0.020	142.29	0.000
26		-0.029	-0.054	142.99	0.000
27		0.047	0.016	144.88	0.000
28		0.035	0.058	145.97	0.000
29		0.005	0.054	145.99	0.000
30		-0.012	0.022	146.11	0.000
31		-0.020	-0.027	146.45	0.000
32		-0.021	-0.057	146.83	0.000
33		0.040	0.015	148.24	0.000
34		-0.003	0.012	148.25	0.000
35		-0.007	-0.013	148.30	0.000
36		-0.001	-0.015	148.30	0.000

Appendix 1

Date	Forecast Value	Date	Forecast Value	Date	Forecast Value
2/17/2020	2180.90	8/17/2020	1828.78	2/15/2021	1509.79
2/18/2020	2179.02	8/18/2020	1826.32	2/16/2021	1507.34
2/19/2020	2179.02	8/19/2020	1823.87	2/17/2021	1504.88
2/20/2020	2178.41	8/20/2020	1821.41	2/18/2021	1502.43
2/21/2020	2177.87	8/21/2020	1818.96	2/19/2021	1499.98
2/24/2020	2160.90	8/24/2020	1816.51	2/22/2021	1497.52
2/25/2020	2160.52	8/25/2020	1814.05	2/23/2021	1495.07
2/26/2020	2158.85	8/26/2020	1811.60	2/24/2021	1492.61
2/27/2020	2159.61	8/27/2020	1809.15	2/25/2021	1490.16
2/28/2020	2159.38	8/28/2020	1806.69	2/26/2021	1487.71
3/2/2020	2132.72	8/31/2020	1804.24	3/1/2021	1485.25

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3/3/2020	2143.09	9/1/2020	1801.79	3/2/2021	1482.80
3/4/2020	2119.40	9/2/2020	1799.33	3/3/2021	1480.35
3/5/2020	2119.40	9/3/2020	1796.88	3/4/2021	1477.89
3/6/2020	2106.95	9/4/2020	1794.42	3/5/2021	1475.44
3/9/2020	2135.24	9/7/2020	1791.97	3/8/2021	1472.98
3/10/2020	2134.04	9/8/2020	1789.52	3/9/2021	1470.53
3/11/2020	2116.74	9/9/2020	1787.06	3/10/2021	1468.08
3/12/2020	2113.70	9/10/2020	1784.61	3/11/2021	1465.62
3/13/2020	2106.58	9/11/2020	1782.16	3/12/2021	1463.17
3/16/2020	2124.62	9/14/2020	1779.70	3/15/2021	1460.72
3/17/2020	2124.62	9/15/2020	1777.25	3/16/2021	1458.26
3/18/2020	2097.14	9/16/2020	1774.79	3/17/2021	1455.81
3/19/2020	2154.44	9/17/2020	1772.34	3/18/2021	1453.35
3/20/2020	2152.63	9/18/2020	1769.89	3/19/2021	1450.90
3/23/2020	2155.90	9/21/2020	1767.43	3/22/2021	1448.45
3/24/2020	2074.91	9/22/2020	1764.98	3/23/2021	1445.99
3/25/2020	2172.70	9/23/2020	1762.53	3/24/2021	1443.54
3/26/2020	2100.74	9/24/2020	1760.07	3/25/2021	1441.09
3/27/2020	2143.90	9/25/2020	1757.62	3/26/2021	1438.63
3/30/2020	2083.72	9/28/2020	1755.16	3/29/2021	1436.18
3/31/2020	2102.74	9/29/2020	1752.71	3/30/2021	1433.72
4/1/2020	2041.96	9/30/2020	1750.26	3/31/2021	1431.27
4/2/2020	2042.05	10/1/2020	1747.80	4/1/2021	1428.82
4/3/2020	2043.60	10/2/2020	1745.35	4/2/2021	1426.36
4/6/2020	2073.21	10/5/2020	1742.90	4/5/2021	1423.91
4/7/2020	2043.11	10/6/2020	1740.44	4/6/2021	1421.46
4/8/2020	1977.63	10/7/2020	1737.99	4/7/2021	1419.00
4/9/2020	1983.83	10/8/2020	1735.53	4/8/2021	1416.55

Date	Forecast Value	Date	Forecast Value	Date	Forecast Value
4/10/2020	2000.80	10/9/2020	1733.08	4/9/2021	1414.09
4/13/2020	1996.79	10/12/2020	1730.63	4/12/2021	1411.64
4/14/2020	1981.93	10/13/2020	1728.17	4/13/2021	1409.19
4/15/2020	2019.68	10/14/2020	1725.72	4/14/2021	1406.73
4/16/2020	2011.97	10/15/2020	1723.27	4/15/2021	1404.28
4/17/2020	2000.12	10/16/2020	1720.81	4/16/2021	1401.83
4/20/2020	1975.81	10/19/2020	1718.36	4/19/2021	1399.37
4/21/2020	1952.12	10/20/2020	1715.90	4/20/2021	1396.92
4/22/2020	1941.03	10/21/2020	1713.45	4/21/2021	1394.47
4/23/2020	1941.03	10/22/2020	1711.00	4/22/2021	1392.01
4/24/2020	1941.03	10/23/2020	1708.54	4/23/2021	1389.56
4/27/2020	1946.14	10/26/2020	1706.09	4/26/2021	1387.10
4/28/2020	1947.54	10/27/2020	1703.64	4/27/2021	1384.65

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4/29/2020	1960.63	10/28/2020	1701.18	4/28/2021	1382.20
4/30/2020	1951.41	10/29/2020	1698.73	4/29/2021	1379.74
5/1/2020	1960.61	10/30/2020	1696.27	4/30/2021	1377.29
5/4/2020	1958.06	11/2/2020	1693.82	5/3/2021	1374.84
5/5/2020	1937.65	11/3/2020	1691.37	5/4/2021	1372.38
5/6/2020	1928.66	11/4/2020	1688.91	5/5/2021	1369.93
5/7/2020	1928.66	11/5/2020	1686.46	5/6/2021	1367.47
5/8/2020	1922.27	11/6/2020	1684.01	5/7/2021	1365.02
5/11/2020	1946.08	11/9/2020	1681.55	5/10/2021	1362.57
5/12/2020	1933.65	11/10/2020	1679.10	5/11/2021	1360.11
5/13/2020	1921.29	11/11/2020	1676.64	5/12/2021	1357.66
5/14/2020	1919.85	11/12/2020	1674.19	5/13/2021	1355.21
5/15/2020	1904.24	11/13/2020	1671.74	5/14/2021	1352.75
5/18/2020	1869.20	11/16/2020	1669.28	5/17/2021	1350.30
5/19/2020	1872.79	11/17/2020	1666.83	5/18/2021	1347.84
5/20/2020	1866.90	11/18/2020	1664.38	5/19/2021	1345.39
5/21/2020	1899.90	11/19/2020	1661.92	5/20/2021	1342.94
5/22/2020	1899.34	11/20/2020	1659.47	5/21/2021	1340.48
5/25/2020	1887.65	11/23/2020	1657.01	5/24/2021	1338.03
5/26/2020	1887.65	11/24/2020	1654.56	5/25/2021	1335.58
5/27/2020	1884.03	11/25/2020	1652.11	5/26/2021	1333.12
5/28/2020	1877.53	11/26/2020	1649.65	5/27/2021	1330.67
5/29/2020	1865.69	11/27/2020	1647.20	5/28/2021	1328.21
6/1/2020	1872.77	11/30/2020	1644.75	5/31/2021	1325.76
6/2/2020	1872.77	12/1/2020	1642.29	6/1/2021	1323.31
6/3/2020	1881.45	12/2/2020	1639.84	6/2/2021	1320.85
6/4/2020	1881.45	12/3/2020	1637.38	6/3/2021	1318.40

Date	Forecast Value	Date	Forecast Value	Date	Forecast Value
6/5/2020	1881.45	12/4/2020	1634.93	6/4/2021	1315.95
6/8/2020	1874.21	12/7/2020	1632.48	6/7/2021	1313.49
6/9/2020	1861.24	12/8/2020	1630.02	6/8/2021	1311.04
6/10/2020	1874.62	12/9/2020	1627.57	6/9/2021	1308.58
6/11/2020	1874.62	12/10/2020	1625.12	6/10/2021	1306.13
6/12/2020	1862.77	12/11/2020	1622.66	6/11/2021	1303.68
6/15/2020	1862.77	12/14/2020	1620.21	6/14/2021	1301.22
6/16/2020	1862.77	12/15/2020	1617.75	6/15/2021	1298.77
6/17/2020	1862.77	12/16/2020	1615.30	6/16/2021	1296.32
6/18/2020	1865.79	12/17/2020	1612.85	6/17/2021	1293.86
6/19/2020	1877.64	12/18/2020	1610.39	6/18/2021	1291.41
6/22/2020	1877.64	12/21/2020	1607.94	6/21/2021	1288.95
6/23/2020	1889.49	12/22/2020	1605.49	6/22/2021	1286.50
6/24/2020	1889.49	12/23/2020	1603.03	6/23/2021	1284.05

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6/25/2020	1887.67	12/24/2020	1600.58	6/24/2021	1281.59
6/26/2020	1886.40	12/25/2020	1598.13	6/25/2021	1279.14
6/29/2020	1883.45	12/28/2020	1595.67	6/28/2021	1276.69
6/30/2020	1873.39	12/29/2020	1593.22	6/29/2021	1274.23
7/1/2020	1876.41	12/30/2020	1590.76	6/30/2021	1271.78
7/2/2020	1876.41	12/31/2020	1588.31	7/1/2021	1269.32
7/3/2020	1876.41	1/1/2021	1585.86	7/2/2021	1266.87
7/6/2020	1872.85	1/4/2021	1583.40	7/5/2021	1264.42
7/7/2020	1870.50	1/5/2021	1580.95	7/6/2021	1261.96
7/8/2020	1840.68	1/6/2021	1578.50	7/7/2021	1259.51
7/9/2020	1843.10	1/7/2021	1576.04	7/8/2021	1257.06
7/10/2020	1854.94	1/8/2021	1573.59	7/9/2021	1254.60
7/13/2020	1861.19	1/11/2021	1571.13	7/12/2021	1252.15
7/14/2020	1839.40	1/12/2021	1568.68	7/13/2021	1249.69
7/15/2020	1853.66	1/13/2021	1566.23	7/14/2021	1247.24
7/16/2020	1848.55	1/14/2021	1563.77	7/15/2021	1244.79
7/17/2020	1847.04	1/15/2021	1561.32	7/16/2021	1242.33
7/20/2020	1846.59	1/18/2021	1558.87	7/19/2021	1239.88
7/21/2020	1838.55	1/19/2021	1556.41	7/20/2021	1237.43
7/22/2020	1826.26	1/20/2021	1553.96	7/21/2021	1234.97
7/23/2020	1838.11	1/21/2021	1551.50	7/22/2021	1232.52
7/24/2020	1840.07	1/22/2021	1549.05	7/23/2021	1230.06
7/27/2020	1840.07	1/25/2021	1546.60	7/26/2021	1227.61
7/28/2020	1821.21	1/26/2021	1544.14	7/27/2021	1225.16
7/29/2020	1825.74	1/27/2021	1541.69	7/28/2021	1222.70
7/30/2020	1825.28	1/28/2021	1539.24	7/29/2021	1220.25

Date	Forecast Value	Date	Forecast Value	Date	Forecast Value
7/31/2020	1827.80	1/29/2021	1536.78	7/30/2021	1217.80
8/3/2020	1827.80	2/1/2021	1534.33	8/2/2021	1215.34
8/4/2020	1815.77	2/2/2021	1531.87	8/3/2021	1212.89
8/5/2020	1840.70	2/3/2021	1529.42	8/4/2021	1210.44
8/6/2020	1841.38	2/4/2021	1526.97	8/5/2021	1207.98
8/7/2020	1841.38	2/5/2021	1524.51	8/6/2021	1205.53
8/10/2020	1841.38	2/8/2021	1522.06	8/9/2021	1203.07
8/11/2020	1841.38	2/9/2021	1519.61	8/10/2021	1200.62
8/12/2020	1834.47	2/10/2021	1517.15	8/11/2021	1198.17
8/13/2020	1834.47	2/11/2021	1514.70	8/12/2021	1195.71
8/14/2020	1831.16	2/12/2021	1512.24	8/13/2021	1193.26

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