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# Dynamics Between Sustainable Economic Development and Macro-Economic Variables: Indian Evidence

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**Abstract**

This paper examines the relationships among selected macro-economic variables such as GDP, GCI, GCNI, SSI, CDI, CPI, and HDI from 2001 to 2022. Utilizing multiple regression analysis, the ARIMA model, co-integration, and causality techniques, the research finds a decreasing trend in economic growth over the coming years. There is a long-run equilibrium relationship among the variables, along with short-run uni-directional relationships among a few variables. The forecasted values of these macroeconomic variables, projected from the base year 2018 up to 2025, indicate that while economic growth (GDP) gradually declines, the other variables show a slow but not significant increase. This suggests that adverse economic growth may hinder the remarkable performance of other variables.

**Keywords:** gross domestic product, human development index, commitment to development index, ARIMA, VECM.

**JEL Classification** C10, C13, C53, 011.

## Introduction

Co-integration and econometric modelling have immense importance to study various macro-economic situations correctly and it provides a choice to measure the extent to which the variables under consideration are integrated. The co-integration technique is used to identify the presence of long-run economic relationship among the variables under study. In the economic literature, many co-integration techniques are available that deals with the dynamic relationship among the macro-economic variables (see, Granger 1981; Engle & Granger 1987).With this notion, this study tries to examine the dynamics among the macro-economic variables and thus, economic growth (GDP), global competitiveness index (GCI), sustainable society index (SSI), global connectedness index (GCI), commitment to development index (CDI), human development index (HDI) and corruption perception index (CPI) is considered.

These selected macro-economic variables are independent in nature but closely associated with each other that mean the impact of one variable apparently falls on others. For example, if the people of a country are deprived from their basic needs and go to bed hungry every night due to vicious chain of corruptions then it's bad impact surely falls on the society, economy, human development, country's competitiveness, commitment and connectedness that means the country has less opportunity to make herself sustainable in every aspect.

Therefore, the researchers are more prone to study such macro-economic relationship among the variables that helps to provide a better understanding among the nature of the variables. Thus, the present study takes an initiative to explore the dynamics among the selected macro-economic variables.

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## 1. Literature Review

The nexus between macro-economic variables and economic development has received immense importance in the past and its significances not slowed down in present. Many established studies have explored the probable reasons and factors for such relationship. Currently, numerous studies have established long-run equilibrium relationship along with short-run dynamics by applying appropriate econometric modelling. Generally, to inquire this association, two strands of literature is available (i) long-run association based on co-integration technique and (ii) dynamics of short-run causality. Granger's work (1981) is considered as pioneer in the field of co-integration and thereafter his work is extended by Engle & Granger (1987), Philips et al. (1990), Stock et al. (1988), Philips (1991), Johansen (1988) and Johansen & Juselius (1991) in various dimensions for empirical analysis. Roll & Ross (1986) examines the causal relationship between stock prices and macro-economic variables in United States during the period from 1953 to 1983 that reports that stock market is significantly affected by macro-economic variables (Kim, 2003). Bahmani et al. (1991) reports presence of uni-directional as well as bi-directional causalities running from stock price to foreign exchange rate based on final prediction error and F-statistic (see Roll & Ross, 1986).

Similarly, Abdalla et al. (1997) adopts the same technique which is used by Bahmani et al. (1991) to examine the same issue in selected Asian countries over a period from 1985 to 1994. Here, uni-directional causality is observed that supports the evidence of Bahmani et al. (1991). But there is no evidence of causation between foreign exchange and Philippines stock market. In the same way Granger et al. (2000) focuses on the same question which is explored by Bahmani et al. (1991) and Abdalla et al. (1997) in Asian markets during 1986 and 1997. Here, the whole study period is divided into three sub-periods and reports presence of uni-directional causality in three sub-periods in Hongkong, South Korea, Malayasia, Philippines and Taiwan markets that supports the evidences of Bahmani et al. (1997) and Abdalla et al. (1997). Moreover, the study depicts about presence of bi-directional causality between stock prices and foreign exchange rates in Indonesia, South Korea, Malaysia and Philippines markets that supports the outcome of Bahmani et al. (1991). Ranis et al. (2000) explores the impact of economic growth on human development and vice-versa by applying ordinary least square (OLS) method and reports significant result and also presence of bi-directional association between economic growth and human development. Fang et al. (2002) again considers the issue raised by Roll & Ross (1986) and observes significant relationship that supports Roll & Ross's (1986) evidence (see Bhattacharya et al., 2003; Muhammad et al., 2002; Stavarek, 2005). Similarly, Ranis (2004) concentrates on the same issue very deeply (Ranis et al., 2000) and opines that degree of freedom and capabilities may improve the economic development where human development plays an important role and also observes bi-directional relationship which is consistent with the earlier evidence of Ranis et al. (2000). Akbar (2011) tries to examine the association between economic development and the various indicators of human resources over a period from 1998 to 2010. The study reports that per capita gross domestic product in India is in growing phase but the impact of other factors of human development index on economic development is not satisfactory and also opines that the growth of human development index (HDI) is in decreasing trend.

Similarly, Terfa et al. (2011) focuses on the same topic in Nigerian context by applying error correction model and observes presence of long-run equilibrium relationship between economic development and human development index (HDI). Similarly, the same evidence of Terfa et al. (2011) is observed by Abraham & Ahmed (2011). Xia et al. (2012) examines the impact of global competitiveness index (GCI) on economic development and observes that individualism and power of distance dimensions of natural culture are the better predictor as compared to GCI and the study opines to include national culture in GCI for better prediction of economic development.

Saaed (2015) investigates the impact of foreign trade on economic development in Tunisia by considering a long study period (1977 – 2012). The study applies Granger causality test and observes uni-directional relationship between imports and exports and also exports and economic development (see Elbeydi et al., 2010; Ramos, 2001). In 2015, a panel co-integration technique is applied by Herzer & Nunnenkamp (2015) to examine the effect of income inequality on life expectancy between the developed and developing countries. The study reports that income inequality does matter on health in developed countries as compared to their counterparts and also observed that income inequality increases life expectancy in developed countries also, Sampath Kumar & Rajesh Kumar (2016) tries to establish causal relationship between export and economic development in India. Therefore, the study uses the same technique which is used by Saaed (2015) in Tunisia. It is reported that economic growth causes growth of exports where impulse response functions indicate higher reactions of export over a change in GDP (Mehrara & Firouzjaee, 2011; Kundu, 2013).

Absalyamova et al. (2016) examines the impact of corruption on Human Capital Sustainable Development Index (HCSDI) in a cross-country basis. Here, the study reports significant negative association between corruption and HCSDI that means HCSDI may be improved in the society when degree of corruption is reduced significantly. Another study by Kechagia et al., (2017) that examines the association between inflows of foreign direct investment and terrorism in five developing Asian countries over a period from 1965 to 2015 by using panel data approach. It is reported that social evils like corruption, terrorism whatever may be the case negatively affects social developments like economic growth or inflow of foreign direct investment and industrialization (Absalyamovaet al., 2016).

Similarly, Ali et al. (2017) examines the issue raised by Kechagia et al. (2017) and the evidence is same that proves that terrorism itself makes a barrier for FDI in the country. In the same way, Cinar (2017) conducts an extensive study on terrorism and economic development by considering 115 countries during a period from 2000 to 2015 (Absalyamovaet al., 2016; Kechagia et al., 2017 & Ali et al. 2017) by employing panel data approach. The study reveals that terrorism destroys economic development in the lower income countries more than three times as compared to the high-income countries. In continuation of the above studies, Evans et al., (2019) examines the impact of terrorism and militancy on few selected macro-economic variables like FDI, trade, aid and tourism in Nigeria during a period from 1980 to 2016 by using ARDL bound testing approach and Cobb-Douglas production function. It is reported that in spite of terrorism in the country, it enjoys short-run economic development due to FDI, trade, aid, remittances and tourism but in the long-run only aid and remittance positively promote economic development due to terrorism and militancy. Here, it is argued that FDI, trade and tourism are worse fully affected by terrorism activities that significantly reduce economic development. Similarly, Maja (2018) considers two factors particularly terrorism and foreign investment in tourism industry for examining the relationship of fifty countries during a period from 2000 to 2016 by employing system GMM estimator on dynamic panel data models. The study reports a different experience that FDI inflow in tourism doesn't affect by terrorism but future FDI may be dependent on arrivals of international tourists.

The impact of foreign trade on economic growth again examines by Ali et al. (2018) in Somalia over a period from 1970 to 1991. The study reports presence of uni-directional causality between export and economic development which is consistent with the outcome of Saaed (2015) and Sampathkumar & Rajeshkumar (2016) and also establishes bi-directional causality between imports and exports in the short-run. In the same year (2018), the same issue is examined by Raju in (see Ali et al., 2018) Indian context by applying Johansen-Juselius (1991) co-integration technique over a period from 2005 to 2017 and observes long-run co-integration relationship among the variables as well as short-run causality (see Ali et al., 2018; Saaed, 2015; Sampathkumar & Rajeshkumar2016). The study recommends that for sustainable economic development, both exports and economic growth play an important role. Estrada et al.(2018), tries to examine the short-run and long-run economic effect caused by terrorist activities in Turkey during a period from 1990 to 2016 and thus Terrorist Attack Vulnerability Evaluation (TAVE) model is applied. It is argued that the country has suffered a lot from terrorist attacks and therefore the application of TAVE model is highly topical in the light of the spate of terrorist and terrorist attack significantly tears down the flow of economic growth in the country.

Another study by Pradhan et al. (2021) examines the impact of financial sector and information technology on economic growth over a period from 1991 to 2018 in 20 Indian states. Here, the study applies Granger causality test to explore short-run and long-run dynamics between the selected variables and observes enough temporal causality between the variables in the short-run as well as in the long-run. Fhima et al. (2023) tries to examine the dynamics between corruption and sustainable economic development by using Seo and Shin (2016) threshold model by considering panel data set over a period from 1996 to 2019. The study reports that impact of corruption on sustainable growth in developing countries is regime-specific and depends on quality of governance. Another study by Raj et al.(2024) where it is examined the relationship between economic growth and few non-income components of Human Development Index (HDI) by considering 26 Indian states over a period from 1990 to 2019 by applying ARDL model and Dumitrescu-Hurlin panel causality techniques. The study reports bi-directional association between economic growth and the non-income components of HDI. The study also identifies the impact of education in different sectoral activities (Teker & Guner, 2016; Lonska et al., 2015).

Here, an extensively literature survey is conducted on various economic and social dimensions in different time frames which shows cause and effect relationship among the variables. Some of the studies concentrate on development of new models by which diverse socio-economic issues can be established and many of them empirically examine the impact and probable reasons for socio-economic issues by applying established models.

Decidedly, all the above studies highlight the same issues by considering different variables or exactly same variables in similar or dissimilar time horizons in various countries by taking similar or unlike data set only the differences in the ways of solving the problems. Thus, the present study is not different from the above but the uniqueness in respect of selection of long study period, types of variables considered and the way of solving the research questions in Indian context.

## 2. Research Methodology

The present study is designed to achieve the following objectives:

1. To examine the economic relationship among the variables
2. To forecast the trend of the variables
3. To examine the long run and short run equilibrium relationship
4. To observe the effect of shock

### Data & Study Period

The study considers quarterly data of GDP that represents economic growth, annual data of Global Competitiveness Index (GCI), Sustainable Society Index (SSI), Global Connectedness Index (GCNI), Commitment to Development Index (CDI), Human Development Index (HDI) and Corruption Perception Index (CPI) in Indian context. The annual data is converted into quarterly form and then in logarithm form. Here, the data is obtained from secondary sources which includes official website of World Bank[2], World Economic Forum[3]and Reserve Bank of India[4]over a period from 2001 and 2022.

### Methodology

Primarily, the study considers Cobb-Douglas production function as under:

$$Y = f(X_1, X_2) \quad (1)$$

*where*, Y (output) is a function of $X_1$ and $X_2$ (inputs).

The above production function can be written in econometric sense as under:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + e_t \quad (2)$$

After taking log on both sides, eq. (2) can be presented in its log linear form as under:

$$\log Y_t = \alpha + \beta_1 \log X_{1t} + \beta_2 \log X_{2t} + e_t \quad (3)$$

The production function of *Y* at time *t* depends on its two inputs $X_1$ and $X_2$ respectively. Now, the relationship between the variables (endogenous and exogenous) can be verified by estimating eq. (3). With this notion, it is assumed that sustainable economic growth (GDP) of an economy depends on its various macro-economic factors such as global competitiveness index (GCI), sustainable society index (SSI), global connectedness index (GCNI), commitment to development index (CDI), human development index (HDI) and corruption perception index (CPI) that can be shown as under:

$$f(GDP) = f(GCI, SSI, GCNI, CDI, HDI, CPI) \quad (4)$$

The above functional form can be written in log linear form as below:

$$\log GDP_t = \alpha + \beta_1 \log GCI_t + \beta_2 \log SSI_t + \beta_3 \log GCNI_t + \beta_4 \log CDI_t + \beta_5 \log HDI_t + \beta_6 \log CPI_t + e_t \quad (5)$$

*where*, α is the intercept and β is the slope coefficient to be estimated and e is the error term with 0 mean and constant standard deviation.

Eq. (5) represents the relationships between economic growth and selected macro-economic variables. It is assumed that global competitiveness index (GCI) is an important macroeconomic parameter that affects other variables:

[2]www.worldbank.org
[3]www.weforum.org
[4]www.rbi.org.in

$$\log GCI_t=\alpha+\beta_1\log GDP_t+\beta_2\log SSI_t+\beta_3\log GCNI_t+\beta_4\log CDI_t+\beta_5\log HDI_t+\beta_6\log CPI_t+e_t \quad (6)$$

Similarly, the sustainable society index (SSI) measures the level of sustainability in three dimensions (human wellbeing, environmental wellbeing and economic wellbeing). The positive performance of these dimensions helps to make the society sustainable in the upcoming days and it is expected that if this index is sustainable then economic development may be improved with the improvements of the other indices. But sustainable society index will not be sustainable in near future if corruption perception index is positively correlated with it that can be shown as under:

$$\log SSI_t=\alpha+\beta_1\log GCI_t+\beta_2\log GDP_t+\beta_3\log GCNI_t+\beta_4\log CDI_t+\beta_5\log HDI_t+\beta_6\log CPI_t+e_t \quad (7)$$

Likewise, Global Connectedness Index (GCNI)helps to make a linkage of a country with the rest of the world. It is assumed that if a country is well connected with the other parts of the world, then it has the scope to reduce all types of difficulties and may enhances its various opportunities for development by way of co-operation and trade. So, it is assumed that GCNI is influenced by many factors that can be written as:

$$\log GCNI_t= \alpha+\beta_1\log GCI_t+\beta_2\log GDP_t+\beta_3\log SSI_t+\beta_4\log CDI_t+\beta_5\log HDI_t+\beta_6\log CPI_t + e_t \quad (8)$$

The coefficients of the multiple regression equations (eq. 5, eq. 6, and eq. 7) are to be estimated and the goodness of fit of the models is to be determined by $R^2$ statistics. The $R^2$ statistic for *k* variable model may be shown as under:

$$R^2 = \frac{\hat{\beta}_1\sum X_{1i}y_i + \hat{\beta}_2\sum X_{2i}y_i + \ldots\ldots + \hat{\beta}_k\sum X_{ki}y_i}{\sum y_i^2} \quad (9)$$

$$\text{or } R^2 = 1-\frac{RSS}{TSS} \quad (10)$$

*where*, RSS is the residual sum of squares and TSS is the total sum of squares.

The variance and co-variance matrices of the residuals of the multiple regression models are corrected for auto-correlation (D-W), heteroskedasticity (N-W) and multi-collinearity (correlation matrix). distribution of the time series data is checked by applying Jarque-Bera (J-B) test statistic:

$$J-B = n\left[\frac{S^2}{6}+\frac{(k-3)^2}{24}\right] \quad (11)$$

*where*, *n* is the number of observations; *S* and *k* are skewness and kurtosis respectively.

Similarly, the stationarity of the time series data is also verified by applying the non-parametric ADF and P-P test statistics as under:

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum_{i=1}^{m}\gamma_i\Delta Y_{t-i} + e_t \quad (12)$$

The testable hypothesis is as follows:

$H_0$: $\delta = 0$ (non-stationary for $Y_t$)

$H_a$: $\delta \neq 0$ (stationary for $Y_t$)

Basically, the time series model is constructed for forecasting purposes. Forecasting means quantitative anticipation about possible future occurrences. The anticipation regarding future outcomes can be made by extrapolating the model beyond the period over which it is estimated. The study considers selected economic indicators for forecasting sustainable economic development. If these indicators perform consistently well then, their effects certainly fall on economic development. There are many econometric techniques for economic forecasting but the study applies Autoregressive Integrated Moving Average (ARIMA), popularly known as Box-Jenkins (1976) methodology.

Thus, the macro-economic variables will be forecasted for seven years (2029) beyond 2022. Before proceed to ARIMA, it is assumed that the underlying time series are stationary. If the time series is differenced by d times to make the series stationary then ARIMA (p,d,q) technique may be applied where p is the number of autoregressive terms, d is the operator and q denotes number of moving average terms. Thus, for best forecast optimal parameters must be chosen. An ARIMA model contains both the properties of autoregressive (AR) and moving average (MA). The study starts with AR(p) model as under:

$$Y_t = \alpha + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_p Y_{t-p} + \ldots + e_t \quad (13)$$

Similarly, the MA process is a linear combination of white noise process. Here, $Y_t$ depends on the current and previous values of the error terms. Now, MA(q) model may be presented as under:

$$Y_t = e_t + \beta_1 e_{t-1} + \beta_2 e_{t-2} + \ldots + \beta_q e_{t-q} \quad (14)$$

The ARIMA (p,d,q) model has both the characteristics of AR(p) and MA(q) process that can be shown as under:

$$Y_t = \alpha + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots.. + \alpha_p Y_{t-p} + \beta_1 e_{t-1} + \beta_2 e_{t-2} + \ldots.. + \beta_q e_{t-q} + e_t \quad (15)$$

If the series is integrated of order d then the original time series will be ARIMA(p,d,q) process. Here, ACF and PACF are used to identify the superior model for forecasting. The following chart shows the pattern:

Table 1. ARIMA (p,d,q) process

| Model | ACF | PACF |
|---|---|---|
| ARIMA(p,d,0) | Dies down | Cuts off after lag p |
| ARIMA(0,d,q) | Cuts off after lag q | Dies down |
| ARIMA(p,d,q) | Dies down | Dies down |

To judge the adequacy of the ARIMA model, diagnostic checking is carried out by applying Box-Pierce *Q* statistic and Ljung-Box (LB) statistics respectively. The *Q* statistic is presented as follows:

$$Q = n\sum_{k=1}^{m} \hat{\rho}k^2 \quad (16)$$

*where*, *n* is sample size, *m* is lag length, $\hat{\rho}k$ indicates sample autocorrelation of the residuals at lag *k*. The null hypothesis ($H_0$: $\rho k = 0$) is rejected if the *Q* statistics exceeds the critical value.

In the same way, the LB statistic may be represented as under:

$$LB = n(n+2)\sum_{k=1}^{m}\left(\frac{\hat{\rho}^2 k}{n-k}\right) \sim \chi^2 m \quad (17)$$

The null hypothesis is rejected if the computed LB statistic exceeds the $\chi^2_\alpha(m,p,q)$ value. There is some formal criterion (AIC or SBIC) which are used to identify the best performing model. In a nutshell, the BJ or ARIMA forecasting process goes through the following steps:

- Identification of the model;
- Estimation;
- Diagnostic checking (if the estimated residuals are white noise, then follow the next step otherwise return back to the first step);
- Forecasting.

The study uses multiple regression technique to explain the variation of the dependent variable by considering independent variables. Sometimes, regression equation may fall in a situation of spurious regression results and such type of problem can be handled in two ways namely introducing trend term in the regression model and by applying differencing technique. In simultaneous equation model, it is assumed that some variables are treated as dependent and others are independent. This subjective selection of variables is criticized by Christopher (1980) and he argues that if there is simultaneity among the variables then classification of variables is unnecessary.

So, all the variables are to be treated in the same light. It is generally assumed that time series often have either deterministic or stochastic trends. Most of the macro-economic time series variables follow stochastic trends called non-stationary or unit root process and the variables are linked by a long-run equilibrium relationship. Under some circumstances, the variables under consideration may drift away from equilibrium for a while but economic forces or sometimes government interventions may be expected to restore equilibrium. Here the variables under consideration have long run equilibrium relationship. If there is actually a long run association between $Y_t$ and $X_t$ then the variables will rise overtime (they are trended) but there is a common trend that links them together. When the concept of equilibrium is applied to I(1) variables then co-integration occurs i.e. co-integration is defined as a certain stationary linear combination of multiple I(1) variables.

In the context of co-integration analysis choosing of optimal lag is very much important because multivariate co-integration analysis is sensitive to lag length selection. There are many criterions but the study is restricted to use AIC, BIC and HQIC. For a multivariate VAR with *k* variables, *T* observations, constant term and lag length *p* the information criteria may be written as under:

$$AIC(p) = \ln\left|\sum\nolimits^{-}(p)\right| + \frac{2}{T}(k^2 p) \tag{18}$$

$$SBIC(p) = \ln\left|\sum\nolimits^{-}(p)\right| + \frac{\ln(T)}{T}(k^2 p) \tag{19}$$

$$HQIC(p) = \ln\left|\sum\nolimits^{-}(p)\right| + \frac{2\ln T}{T}(k^2 p) \tag{20}$$

*where*, $\sum$is the quasi-maximum likelihood estimate of the innovation co-variance matrix Σ (Sin & White 1996).

The lag order estimate $\hat{p}$ is chosen to minimize the value of the criterion function {ρ:1 ≤ ρ ≤ ρ} where $\overline{\rho} \geq \rho_0$ (Paulsen & Tjostheim, 1985). Similarly, the order of integration which is an important assumption for co-integration analysis is fixed by testing unit root of the selected variables. To avoid non-stationarity, differencing technique is used to make the series stationary and if the series is stationary after differencing one time then the series is integrated of order one but some linear combination is I(0).The idea of co-integration is first introduced by Granger (1981) and later it is extended by Engle and Granger (1987) and also Johansen (1988). Here, Johansen and Juselious (1990) co-integration test is applied because it treats all variables as endogenous and it allows for testing long-run parameters and it may be presented in a matrix notation:

$Z_t$ = [GDP, GCI, GCNI, CDI, SSI, HDI, CPI] (21)

According to VAR(p) framework, it can be shown as:

$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \ldots\ldots + A_p Z_{t-p} + e_t$ (22)

Eq. 22 (VAR) may be transformed into a VECM framework as under:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \ldots\ldots + \Gamma_{p-1} \Delta Z_{t-(p-1)} + \Pi Z_{t-1} + e_t \tag{23}$$

Here, the matrix $\Pi$ contains information about long-run relationships and may be decomposed as under:

$$\Pi = \alpha\beta' \tag{24}$$

*where*: α is the speed of adjustment towards equilibrium coefficients while β' is the long run matrix of coefficient and $\beta' Z_{t-1}$ is equivalent to the error correction term (ECM).

It is assumed that p = 2 (two lag terms) and the model becomes as under:

$$\begin{vmatrix}\Delta GDP_t\\ \Delta GCI_t\\ \Delta GCNI_t\\ \Delta CDI_t\\ \Delta SSI_t\\ \Delta HDI_t\\ \Delta CPI_t\end{vmatrix} = \Gamma_1 \begin{vmatrix}\Delta GDP_t\\ \Delta GCI_t\\ \Delta GCNI_t\\ \Delta CDI_t\\ \Delta SSI_t\\ \Delta HDI_t\\ \Delta CPI_t\end{vmatrix} + \Pi \begin{vmatrix}\Delta GDP_{t-1}\\ \Delta GCI_{t-1}\\ \Delta GCNI_{t-1}\\ \Delta CDI_{t-1}\\ \Delta SSI_{t-1}\\ \Delta HDI_{t-1}\\ \Delta CPI_{t-1}\end{vmatrix} + e_t \quad (25)$$

*Or*

$$\begin{vmatrix}\Delta GDP_t\\ \Delta GCI_t\\ \Delta GCNI_t\\ \Delta CDI_t\\ \Delta SSI_t\\ \Delta HDI_t\\ \Delta CPI_t\end{vmatrix} = \Gamma_1 \begin{vmatrix}\Delta GDP_t\\ \Delta GCI_t\\ \Delta GCNI_t\\ \Delta CDI_t\\ \Delta SSI_t\\ \Delta HDI_t\\ \Delta CPI_t\end{vmatrix} + \Pi \begin{vmatrix}\alpha_{11} & \alpha_{12}\\ \alpha_{21} & \alpha_{22}\\ \alpha_{31} & \alpha_{32}\\ \alpha_{41} & \alpha_{42}\\ \alpha_{51} & \alpha_{52}\\ \alpha_{61} & \alpha_{62}\\ \alpha_{71} & \alpha_{72}\end{vmatrix} \begin{vmatrix}\beta_{11} & \beta_{21} & \beta_{31} & \beta_{41} & \beta_{51} & \beta_{61} & \beta_{71}\\ \beta_{12} & \beta_{22} & \beta_{32} & \beta_{42} & \beta_{52} & \beta_{62} & \beta_{72}\end{vmatrix} \begin{vmatrix}\Delta GDP_{t-1}\\ \Delta GCI_{t-1}\\ \Delta GCNI_{t-1}\\ \Delta CDI_{t-1}\\ \Delta SSI_{t-1}\\ \Delta HDI_{t-1}\\ \Delta CPI_{t-1}\end{vmatrix} + e_t \quad (26)$$

The error correction term (ECM) of the first equation (i.e., for $\Delta GDP_t$) may be written as follows:

$$\Pi_1 Z_{t-1} = ([\alpha_{11}\beta_{11}+\alpha_{12}\beta_{12})(\alpha_{11}\beta_{21}+\alpha_{12}\beta_{22})(\alpha_{11}\beta_{31}+\alpha_{12}\beta_{32})(\alpha_{11}\beta_{41}+\alpha_{12}\beta_{42})(\alpha_{11}\beta_{51}+\alpha_{12}\beta_{52})(\alpha_{11}\beta_{61}+\alpha_{12}\beta_{62})(\alpha_{11}\beta_{71}+\beta_{12}\beta_{72}) \begin{vmatrix}GDP_{t-1}\\ GCI_{t-1}\\ GCNI_{t-1}\\ CDI_{t-1}\\ SSI_{t-1}\\ HDI_{t-1}\\ CPI_{t-1}\end{vmatrix} \quad (27)$$

*Or*

$$\Pi_1 Z_{t-1} = \alpha_{11}(\beta_{11}GDP_{t-1} + \beta_{21}GCI_{t-1} + \beta_{31}GCNI_{t-1} + \beta_{41}CDI_{t-1} + \beta_{51}SSI_{t-1} + \beta_{61}HDI_{t-1} + \beta_{71}CPI_{t-1}) + \alpha_{12}(\beta_{12}GDP_{t-1} + \beta_{22}GCI_{t-1} + \beta_{32}GCNI_{t-1} + \beta_{32}GCI_{t-1} + \beta_{42}SSI_{t-1} + \beta_{52}HDI_{t-1} + \beta_{62}HDI_{t-1} + \beta_{72}CPI_{t-1}) \quad (28)$$

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Eq. (28) indicates two co-integrating vectors with their respective speed of adjustment terms $\alpha_{11}$ and $\alpha_{12}$.Similarly, the ECT for other equations can be extracted. The VAR model contains k variables in first differenced from the left-hand side and p-1 lags in differenced from on the right-hand side each with a Γ coefficient matrix. The Johansen test concentrates on examination of the Π matrix (long run coefficient matrix). The test for co-integration between the Z variables is computed by looking at the rank of Π matrix through eigen values. The rank of a matrix is equal to the number of its characteristic's roots (eigen values) which are different from 0. The eigen values are denoted by $\lambda_i$ that put in ascending order $\lambda_1 \geq \lambda_2 \geq ...\lambda_n$. If the variables are not co-integrated then rank of Π is not significantly different from 0 ($\lambda_i \approx 0$ $\forall_i$). The test statistic incorporates ln(1 - $\lambda_i$) rather than $\lambda_i$ themselves but still when $\lambda_i = 0$, ln(1 - $\lambda_i$) = 0. If the eigen value i is non zero then ln(1 - $\lambda_i$) < 0 $\forall_i$> 1 i.e. for Π have a rank of 1 and then the largest eigen value is significantly non zero.

In general, there are two test statistics are available to test co-integration under the Johansen approach:

$$\lambda_{tarce}(r) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i) \quad (29)$$

$$\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1}), \quad (30)$$

*where*: *r* is the number of co-integrating vectors and $\hat{\lambda}_i$ is the estimated $i^{th}$ order Eigen value from Π matrix. A significantly non zero Eigen value indicates a significant co-integrating vector. $\lambda_{trace}$ is a joint test where the null hypothesis is the number of co-integrating vectors is less than or equal to *r* against an unspecified alternative that there is more than *r*.

Whereas, $\lambda_{max}$ conducts separate tests on each Eigenvalue and the null hypothesis is the number of co-integrating vectors is r against an alternative $r_{t+1}$. The critical values for both the statistics are provided by Johansen and Juselious (1990). If the test statistic is greater than the critical value then null hypothesis is rejected meaning that presence of r co-integrating vectors against the alternative hypothesis r+1 (for $\lambda_{trace}$) or more than r ($\lambda_{max}$). The test is conducted under the null hypothesis as under:

$H_0$: r = 0 vs $H_a$: 0 < r ≤ n;

$H_0$: r = 1 vs $H_a$: 1 < r ≤ n;

$H_0$: r = 2 vs $H_a$: 2 < r ≤ n;

$H_0$: r = n-1 vs $H_a$: r = n.

It is assumed that the variables under consideration are co-integrated that means they share a common stochastic trend and grow proportionately (long run equilibrium relationship) that influence to formulate error correction model (ECM). It also (VECM) helps to examine the dynamic relationship among the variables and also helps to identify the direction of causality (see Engle & Granger 1987). VECM helps to distinguish between short run and long run causalities and the ECT helps to adjust the short run relationship into a long run with a steady adjustment process. The VECM frameworks of the variables are as under:

$$\Delta \ln GDP_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta \ln GCI_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta \ln GCNI_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta \ln CDI_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta \ln SSI_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta \ln HDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta \ln CPI_{t-i} + \delta ECT_{t-i} + e_{it} \quad (31)$$

$$\Delta \ln GCI_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta \ln GCI_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta \ln GCNI_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta \ln CDI_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta \ln SSI_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta \ln HDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta \ln CPI_{t-i} + \delta ECT_{t-i} + e_{it} \quad (32)$$

$$\Delta \ln GCNI_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta \ln GCI_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta \ln GCNI_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta \ln CDI_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta \ln SSI_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta \ln HDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta \ln CPI_{t-i} + \delta ECT_{t-i} + e_{it} \quad (33)$$

$$\Delta \ln CDI_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta \ln GCI_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta \ln GCNI_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta \ln CDI_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta \ln SSI_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta \ln HDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta \ln CPI_{t-i} + \delta ECT_{t-i} + e_{it} \quad (34)$$

$$\Delta \ln SSI_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta \ln GCI_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta \ln GCNI_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta \ln CDI_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta \ln SSI_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta \ln HDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta \ln CPI_{t-i} + \delta ECT_{t-i} + e_{it} \quad (35)$$

$$\Delta \ln HDI_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta \ln GCI_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta \ln GCNI_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta \ln CDI_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta \ln SSI_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta \ln HDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta \ln CPI_{t-i} + \delta ECT_{t-i} + e_{it} \quad (36)$$

$$\Delta \ln CPI_t = \alpha_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta \ln GCI_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta \ln GCNI_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta \ln CDI_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta \ln SSI_{t-i} + \sum_{i=1}^{k} \beta_6 \Delta \ln HDI_{t-i} + \sum_{i=1}^{k} \beta_7 \Delta \ln CPI_{t-i} + \delta ECT_{t-i} + e_{it} \quad (37)$$

*where*: *xi*, *α* is the constant term of all the equations; $\beta^s$ are the estimated coefficients for short run relationships; $\delta^s$ are the estimated error correction terms which represents the speed of adjustments from short run to the long run equilibrium states.

The study also uses impulse response function (IRF) to show the effects of an exogenous shock on the whole process over time (Sims et al., 1990). The idea is to look into the adjustment of the endogenous variables and to detect the dynamic relationships among the contemporaneous values of the variables overtime after a hypothetical shock at time *t*. This adjustment is compared with the time series process without any shock and then examines the differences. The IRF helps to identify the impact of shocks on variables overtime in a VAR framework. Diagnostic checking is one of the important mechanisms for model suitability. Most of the models checking tools are based on residuals. The study uses serial correlation, heteroskedasticity and normality tests for judging the suitability of the models and thus the following hypotheses are formulated:

$H_0$: No serial correlation;

$H_0$: No ARCH effect;

$H_0$: Residuals are normally distributed.

Similarly, parameters stability throughout the sample period is a key assumption of any econometric model. The study uses recursive residuals test (CUSUM) to check the validity of this assumption. This test is based on (see Brown et. al. 1975) the cumulative sum of recursive residuals. If the plot of cumulative sum goes beyond the area between the two critical lines, then structural break is found (instability). The CUSUM test statistic is as under:

$$Wt = \sum_{j=k+1}^{T} \frac{W_t}{\hat{\sigma}} \qquad j = k+1,.....T \tag{38}$$

with, $\hat{\sigma}_2 = \dfrac{\sum_{j=k+1}^{T}(w_t - \overline{w})^2}{T-K-1}$ and $\overline{W} = \dfrac{\sum_{T-k}^{T} w_t}{T-k}$,

*where*: $W$ is recursive test statistic; $\sigma$ is standard error of the regression fitted to all $T$ periods; $k$ is the number of coefficients to be estimated.

## 3. Results & Analysis

Table 2 presents the descriptive statistics of the selected macro-economic variables. It is observed that the time series data of the macro-economic variables are negatively skewed that means long left tail as compared to the right one except GCI and CDI. Moreover, the JB statistics of the variables are very small and the probability of obtaining such statistics under the normality assumption is not significantly zero that means acceptance of the null hypothesis ($H_0$: Normally distributed).

Table 2. Descriptive statistics

| Var. | OB | Mean | Median | Max | Min | St.Dev | Skew. | Kurt. | JB | Prob. |
|---|---|---|---|---|---|---|---|---|---|---|
| GDP | 88 | 6.1422 | 6.2394 | 6.3567 | 5.7191 | 0.1970 | -0.8936 | 2.4589 | 2.7606 | 0.2515 |
| GCI | 88 | 0.6349 | 0.6335 | 0.6618 | 0.6159 | 0.0130 | 0.6986 | 2.6075 | 1.6675 | 0.4344 |
| GCNI | 88 | 1.6809 | 1.6989 | 1.7242 | 1.6127 | 0.0377 | -0.5766 | 1.6607 | 2.4727 | 0.2904 |
| HDI | 88 | 1.7551 | 1.7551 | 1.8123 | 1.6937 | 0.0380 | -0.1267 | 1.7860 | 1.2174 | 0.5440 |
| CDI | 88 | 0.7045 | 0.6996 | 0.7299 | 0.6848 | 0.0135 | 0.3534 | 1.8539 | 1.4354 | 0.4878 |
| CPI | 88 | 1.5298 | 1.5315 | 1.6232 | 1.4313 | 0.0632 | -0.2215 | 1.8180 | 1.2614 | 0.5322 |
| SSI | 88 | 0.6989 | 0.7024 | 0.7299 | 0.6551 | 0.0200 | -0.5512 | 2.5889 | 1.0961 | 0.5781 |

Source: Author's own calculation

Table 3 provides result of stationarity based on two approaches particularly ADF and P-P test. It is found that the variables are not stationary at level form but after first difference the variables become stationary. Although, ADF test itself assumes that there is no relationship among the variables but P-P test gives some extent space for interrelationship among the variables. So, P-P test is used to confirm the result of ADF test and it is confirmed that the series is I(1) or integrated at same order and thus, ECM may be developed and estimated.

Table 3. Unit Root Test and order of integration

| Var. | ADF Test | | | | Philips-Perron Test | | | | Order of Integration |
|---|---|---|---|---|---|---|---|---|---|
| | Level | | 1stDif. | | Level | | 1stDif. | | |
| | t-stat. | Prob. | t-stat. | Prob. | t-stat. | Prob. | t-stat. | Prob. | |
| lnGDP | -1.9216 | 0.3075 | -3.3255* | 0.0289 | -1.7183 | 0.4132 | -3.9812* | 0.0006 | I(1) |
| lnGCI | 0.0720 | 0.9525 | -4.6219* | 0.0026 | -0.9354 | 0.7523 | -3.4118* | 0.0253 | I(1) |
| lnGCNI | -1.7040 | 0.4126 | -5.1571* | 0.0008 | -1.7325 | 0.3993 | -5.1592* | 0.0008 | I(1) |
| lnHDI | -1.1371 | 0.6769 | -3.8461* | 0.0108 | -1.9259 | 0.3139 | -3.8461* | 0.0108 | I(1) |
| lnCDI | -1.9840 | 0.2904 | -5.3955* | 0.0005 | -1.9171 | 0.3176 | -5.3718* | 0.0005 | I(1) |
| lnCPI | -1.5689 | 0.3126 | -4.5124* | 0.0007 | -0.7829 | 0.7998 | -4.5965* | 0.0025 | I(1) |
| lnSSI | -0.6969 | 0.8234 | -3.1388* | 0.0432 | -0.5731 | 0.8538 | -5.2521* | 0.0007 | I(1) |

Note: *significant at 5% level. Source: Author's own calculation

The estimated result of regression eq. (5) where GDP is the dependent variable is presented in Table 3. It is found that the coefficients of the independent variables are not statistically significant that means they cannot influence GDP but jointly they can on the basis of *F*-statistic. It is also observed that the residuals are free from autocorrelation and heteroskedasticity (Table 5) and they are normally distributed and also absence from multicollinearity (Table 6) problem because the simple correlation between the variables doesn't exceed 0.90 in all cases and thus it may be argued that the result is acceptable.

Table 4. Estimated regression coefficients of eq. (5)

| Const. | GCI | SSI | GCNI | CDI | HDI | CPI | D-W | $R^2$ | F-stat |
|---|---|---|---|---|---|---|---|---|---|
| -0.6179 (0.6414) | -4.6791 (0.0832) | 5.8607 (0.0348) | 2.1704 (0.0707) | 2.3400 (0.190) | -0.2887 (0.8944) | 0.5520 (0.5399) | 2.017 | 0.938 | 30.3443 (0.00001) |

Source: Author's own calculation

Table 5. Diagnostic checking of eq. (5)

| Dep. Var. | Serial Corr. Test | | Heteroskedasticity Test | | Normality Test | |
|---|---|---|---|---|---|---|
| | Observed*$R^2$ | Prob. | Observed*$R^2$ | Prob. | J-B Stat. | Prob. |
| GDP | 3.5530 | 0.1692 | 5.5265 | 0.4783 | 1.6076 | 0.4476 |

Source: Author's own calculation

Table 6. Test of multicollinearity. Pearson correlation matrix

| Variable | GCI | SSI | GCNI | CDI | HDI | CPI |
|---|---|---|---|---|---|---|
| GCI | 1.0000 | 0.8603 | 0.6426 | 0.4902 | 0.8279 | 0.8215 |
| SSI | 0.8603 | 1.0000 | 0.8383 | 0.6144 | 0.8318 | 0.8226 |
| GCNI | 0.6426 | 0.8383 | 1.0000 | 0.7279 | 0.8985 | 0.8007 |
| CDI | 0.4902 | 0.6144 | 0.7279 | 1.0000 | 0.7393 | 0.6749 |
| HDI | 0.8279 | 0.8318 | 0.8985 | 0.7393 | 1.0000 | 0.8525 |
| CPI | 0.8215 | 0.8226 | 0.8007 | 0.6749 | 0.8525 | 1.0000 |

Source: Author's own calculation

The estimated result of regression eq. (6) where GCI is the dependent variable is presented in Table 7. It is observed that the coefficient of Sustainability Society Index (SSI) is positively significant that means if the component of SSI (Human wellbeing, Environmental Wellbeing and Economic wellbeing) increases then competitiveness of a country (GCI) will be increased and vice-versa. But the coefficients of the remaining variables are not significant and their influence towards GCI is not remarkable but all the independent variables jointly influence the GCI. Finally, the following tests (Table 8 and Table 9) of residuals are applied to check the adequacy of the regression eq. (6). It is found from Table 8 and Table 9that the estimated regression model is free from autocorrelation, heteroskedasticity and multicollinearity which are desirable and the residuals are normally distributed which is acceptable.

Table 7. Estimated regression coefficients of eq. (6)

| Const. | GDP | SSI | GCNI | CDI | HDI | CPI | D-W | $R^2$ | F-stat |
|---|---|---|---|---|---|---|---|---|---|
| -0.1099 (0.413) | -0.0489 (0.083) | 0.6406 (0.022) | -0.0484 (0.712) | 0.0480 (0.799) | 0.2585 (0.230) | -0.0182 (0.843) | 1.9244 | 0.9031 | 11.5444 (0.0002) |

Source: Author's own calculation

Table 8. Diagnostic checking of eq. (6)

| Dep. Var. | Serial Corr. Test | | Heteroskedasticity Test | | Normality Test | |
|---|---|---|---|---|---|---|
| | Observed*$R^2$ | Prob. | Obs*$R^2$ | Prob. | J-B Stat. | Prob. |
| GCI | 3.6518 | 0.1611 | 7.6458 | 0.2652 | 0.6855 | 0.7098 |

Source: Author's own calculation

Table 9. Test of multicollinearity. Pearson correlation matrix

| Var. | GDP | SSI | GCNI | CDI | HDI | CPI |
|---|---|---|---|---|---|---|
| GDP | 1.0000 | 0.8889 | 0.8257 | 0.7568 | 0.8049 | 0.8614 |
| SSI | 0.8889 | 1.0000 | 0.8383 | 0.6144 | 0.8318 | 0.8226 |
| GCNI | 0.8257 | 0.8383 | 1.0000 | 0.7279 | 0.8985 | 0.8007 |
| CDI | 0.7568 | 0.6144 | 0.7279 | 1.0000 | 0.7393 | 0.6749 |
| HDI | 0.8049 | 0.8318 | 0.8985 | 0.7393 | 1.0000 | 0.8525 |
| CPI | 0.8614 | 0.8226 | 0.8001 | 0.6749 | 0.8525 | 1.0000 |

Source: Author's own calculation

Similarly, the estimated result of regression eq. (7) where GCNI is considered as the dependent variable is presented in Table 10. It is observed that the coefficient of Human Development Index (HDI) is positively significant that means the indicators of HDI (life expectancy index, education index and GNI index) significantly influence GCNI positively. However, the coefficients of the remaining variables are not statistically significant and their impact towards GCNI is not notable but together they can influence the GCNI as the probability value of F-statistic is statistically significant. Finally, the following tests of the residuals are applied to check the adequacy of the regression eq. (7) which is presented in Table 11 and Table 12. It is found that the regression model is free from autocorrelation, heteroskedasticity and multicollinearity which is desirable and also the residuals are normally distributed which is expected.

Table 10. Estimated regression coefficients of eq. 7

| Const. | GDP | SSI | GCI | CDI | HDI | CPI | D-W | $R^2$ | F-stat |
|---|---|---|---|---|---|---|---|---|---|
| -0.0176 (0.953) | 0.1137 (0.070) | -0.0184 (0.979) | -0.2423 (0.7124) | -0.0982 (0.816) | 1.0000 (0.025) | -0.3397 (0.081) | 2.0370 | 0.911 | 20.6658 (0.0001) |

Source: Author's own calculation

Table 11. Diagnostic checking of eq.(7)

| Dep. Var. | Serial Corr. Test | | Heteroskedasticity Test | | Normality Test | |
|---|---|---|---|---|---|---|
| | Obs*$R^2$ | Prob. | Observed*$R^2$ | Prob. | J-B Stat. | Prob. |
| GCNI | 0.5212 | 0.7706 | 2.2349 | 0.8969 | 3.9299 | 0.1402 |

Source: Author's own calculation

Table 12. Test of multicollinearity. Pearson correlation matrix

| Variable | CDI | CPI | GCI | GDP | HDI | SSI |
|---|---|---|---|---|---|---|
| CDI | 1.0000 | 0.6749 | 0.4902 | 0.7568 | 0.7393 | 0.6144 |
| CPI | 0.6749 | 1.0000 | 0.8215 | 0.8614 | 0.8525 | 0.8226 |
| GCI | 0.4902 | 0.8215 | 1.0000 | 0.6488 | 0.8279 | 0.8603 |
| GDP | 0.7568 | 0.8614 | 0.6488 | 1.0000 | 0.8049 | 0.8889 |
| HDI | 0.7393 | 0.8525 | 0.8279 | 0.8049 | 1.0000 | 0.8318 |
| SSI | 0.6144 | 0.8226 | 0.8603 | 0.8889 | 0.8318 | 1.0000 |

Source: Author's own calculation

Table 13 shows the estimated coefficients of the appropriate ARIMA model among so many options based on lowest AIC and SIC criterion. The estimated coefficient of the AR(1) term of CPI and the MA(1) terms of SSI and CPI are statistically significant because the probability values are practically zero that means rejection of null hypothesis (($H_0$: AR(1) & MA(1) = 0)) and indicates that the past performance of CPI and SSI strongly don't happen in future. Here, all the ARIMA models are free from the autocorrelation problem as depicted by the DW values.

Table 13. Estimated Results of ARIMA(p,d,q) Model

| Variable | AR | Prob. | MA | Prob. | $R^2$ | AIC | SIC | D-W |
|---|---|---|---|---|---|---|---|---|
| GDP (1,4)(0,0) | -0.2386 | 0.3958 | -0.9285 | 0.9996 | 0.5249 | -7.3117 | -7.0868 | 2.051 |
| GCI (4,4)(0,0) | -0.3154 | 0.5124 | 0.9999 | 0.9999 | 0.7914 | -10.2431 | -9.9244 | 1.947 |
| GCNI (0,3)(0,0) | - | - | 0.9999 | 0.9995 | 0.7538 | -10.3729 | -10.2135 | 1.982 |
| SSI (0,3)(0,0) | - | - | 0.5270 | 0.0002 | 0.5438 | -9.6278 | -9.46851 | 1.917 |
| CDI (0,3)(0,0) | - | - | 0.9999 | 0.9993 | 0.7480 | -10.2866 | -10.1273 | 2.008 |
| HDI (0,3)(0,0) | - | - | 0.8178 | 0.9993 | 0.6490 | -14.5791 | -14.4198 | 2.150 |
| CPI (1,4)(0,0) | 0.8502 | 0.0000 | -0.9999 | 1.000 | 0.7593 | -8.6036 | -8.3805 | 1.894 |

Source: Author's own calculation

Table 14 presents the forecasted value of the macroeconomic variables beyond the base year (2018). It is found that the economic growth (GDP) decreases slowly year after year. But in other cases, the forecasted values of all the macroeconomic variables are increased in a slow pace but the change is not very significant. So, it may be argued that due to adverse economic growth the other variables cannot perform remarkably.

Table 14. Forecasted value of the macroeconomic variables 7 years ahead

| Var. | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|
| GDP | 6.142270 | 6.131483 | 6.119277 | 6.105798 | 6.091175 | 6.075526 | 6.058956 |
| GCI | 0.659606 | 0.661824 | 0.664042 | 0.666260 | 0.668478 | 0.670696 | 0.672914 |
| GCNI | 1.719876 | 1.725592 | 1.731307 | 1.737023 | 1.742738 | 1.748454 | 1.754170 |
| SSI | 0.729325 | 0.732547 | 0.735770 | 0.738992 | 0.742214 | 0.745436 | 0.748658 |
| CDI | 0.705631 | 0.706742 | 0.707575 | 0.708964 | 0.710074 | 0.711185 | 0.712296 |
| HDI | 1.816967 | 1.823548 | 1.830128 | 1.836709 | 1.843290 | 1.849870 | 1.856451 |
| CPI | 1.633506 | 1.644297 | 1.655088 | 1.665879 | 1.676670 | 1.687451 | 1.698252 |

Source: Author's own calculation

Table 15 presents the pattern of forecast. It is observed that the Root Mean Squared Error (RMSE) of the estimated ARIMA model for each variable is found to be lower based on AIC and SIC criterion. Generally, the forecast will be satisfactory if the bias and variance proportions are small so that most of the bias is concentrated on the covariance proportion. The bias proportion means how far the mean of the forecast is from the mean of the actual series. Similarly, the variance proportion conveys how far the variation of the forecast is from the variation of the actual series and finally, covariance proportion measures the remaining unsystematic forecasting error. It is observed that the bias and variance proportions of the macro-economic variables are lower than the covariance proportions in all the cases that mean forecast is satisfactory.

Table 15. Whether forecast is satisfactory or not

| Var. | RMSE | MAE | MAPE | TIC | Bias Prop. | Var. Prop. | Covar. Prop. |
|---|---|---|---|---|---|---|---|
| GDP | 0.105754 | 0.088571 | 1.413572 | 0.008643 | 0.277563 | 0.081026 | 0.641411 |
| GCI | 0.007797 | 0.005438 | 0.857489 | 0.006114 | 0.174806 | 0.005808 | 0.819385 |
| GCNI | 0.024045 | 0.018243 | 1.074744 | 0.007184 | 0.358310 | 0.048953 | 0.392737 |
| SSI | 0.007186 | 0.005687 | 0.820554 | 0.005143 | 0.017966 | 0.060223 | 0.921811 |
| CDI | 0.013635 | 0.010710 | 1.499698 | 0.009739 | 0.370803 | 0.252095 | 0.577102 |
| HDI | 0.003267 | 0.002961 | 0.168445 | 0.000931 | 0.323665 | 0.115791 | 0.560544 |
| CPI | 0.018366 | 0.012125 | 0.797821 | 0.005997 | 0.026598 | 0.004068 | 0.959334 |

Source: Author's own calculation

Choosing of optimal lag length is a pre-condition for co-integration analysis otherwise, the model may be mis-specified if the lag length is too small and also over parameterized if the number of lag is too large (see Wooldridge, 2009, p. 576). There are many techniques for choosing optimal lag length. Here, the study applies AIC, SBIC and HQIC. Here, the symbol of '*' is the target or guideline to choose the best possible lag for a particular model. It is observed that the position of '*' is at lag length one in all cases which indicates optimal.

Table 16. Optimal lag order selection

| Variable | Lags | AIC | SBIC | HQIC |
|---|---|---|---|---|
| lnGDP | 1 | -3.473924* | -3.37499* | -3.460283* |
| LnGCI | 1 | -7.103027* | -7.004097* | -7.089386* |
| LnGCNI | 1 | -5.414231* | -5.315301 | -5.400590* |
| LnCDI | 1 | -6.421245* | -6.322315* | -6.407604* |
| LnSSI | 1 | -6.870354* | -6.771424* | -6.856713* |
| LnHDI | 1 | -9.891501* | -9.792571* | -9.877860* |
| LnCPI | 1 | -4.608937* | -4.510007* | -4.595296* |

Note: *indicates lag order selection criterion. Source: Author's own calculation

After satisfying all the pre-conditions, Johansen co-integration test is applied to find out the number of co-integrating equation/s or vector/s. Here, trace statistic and max Eigen value are used and found that both the test statistics produce same results and thus, reject the null hypotheses at 5% level of significance that means at least one co-integrating equations in the system. Hence, the selected macro-economic variables are co-integrated with a long-run relationship and thus, vector error correction model (VECM) is appropriate and applied in this study.

Table 17. Johansen co-integration test

| Hypothesized no. of CEs | Eigen value | Rank test (Trace statistic) | | | Rank test (Max Eigen value) | | |
|---|---|---|---|---|---|---|---|
| | | Trace stat. | Critical value | Prob. | Max-Eigen value | Critical value | Prob. |
| None* | 0.79947 | 249.0621 | 125.615 | 0.0000 | 109.2647 | 46.23142 | 0.0000 |
| At most 1 | 0.43678 | 139.7974 | 95.7536 | 0.0000 | 39.03790 | 40.07757 | 0.0652 |

Note: Trace test & Max-Eigen value indicate one co-integrating eqs. at 0.05 levels; *denotes rejection of null hypothesis at 0.05
Source: Author's own calculation.

The next step is to examine the long-run equilibrium relationship based on VECM framework. The result is presented in Table 18along with the error correction term (ECT). It is observed that the coefficient of the lagged error correction term where GCI is the dependent variable is positive and significant that implies that the process is not converging in the long-run and there is some instability. Usually, this means that there are some specification problems with the model itself, or maybe there are some data issues or it could also be an indication of structural changes. In the same way, it is found that the error correction term of GDP, SSI and CDI (dependent variables respectively) are negative and statistically significant that means presence of long-run causality running from the exogenous variables and the direction of causality is unidirectional.

Table 18. Vector error correction estimates (Long-Run Causality)

| Dep. Var. | Error Correction Term (Long Run Coefficient) | t-statistic | Probability |
|---|---|---|---|
| GDP | -0.880328 | -2.16196* | 0.0067 |
| GCI | 0.184893 | 2.71723* | 0.0093 |
| GCNI | -0.340518 | -1.60506 | 0.1155 |
| SSI | -0.316564 | -3.87500* | 0.0003 |
| CDI | -0.417289 | -3.51273* | 0.0010 |
| HDI | 0.024548 | 1.09095 | 0.2811 |
| CPI | -0.121102 | -0.41511 | 0.6800 |

Note: *significance at 5% level
Source: Author's own calculation

It is confirmed that long-run association exists among the variables when GDP, SSI and CDI, are considered as the dependent variable and thus, it is expected that there must be presence of some short-run relationships and observed that short-run unidirectional relationships exist between HDI and CPI; HDI and GCI and finally, SSI and GCI because the probability values in those cases are less than five percent meaning that the null hypotheses of no short-run causal relationships are rejected. But, in other cases short run causal relationship between the variables is absent.

Table 19. Granger short run causality

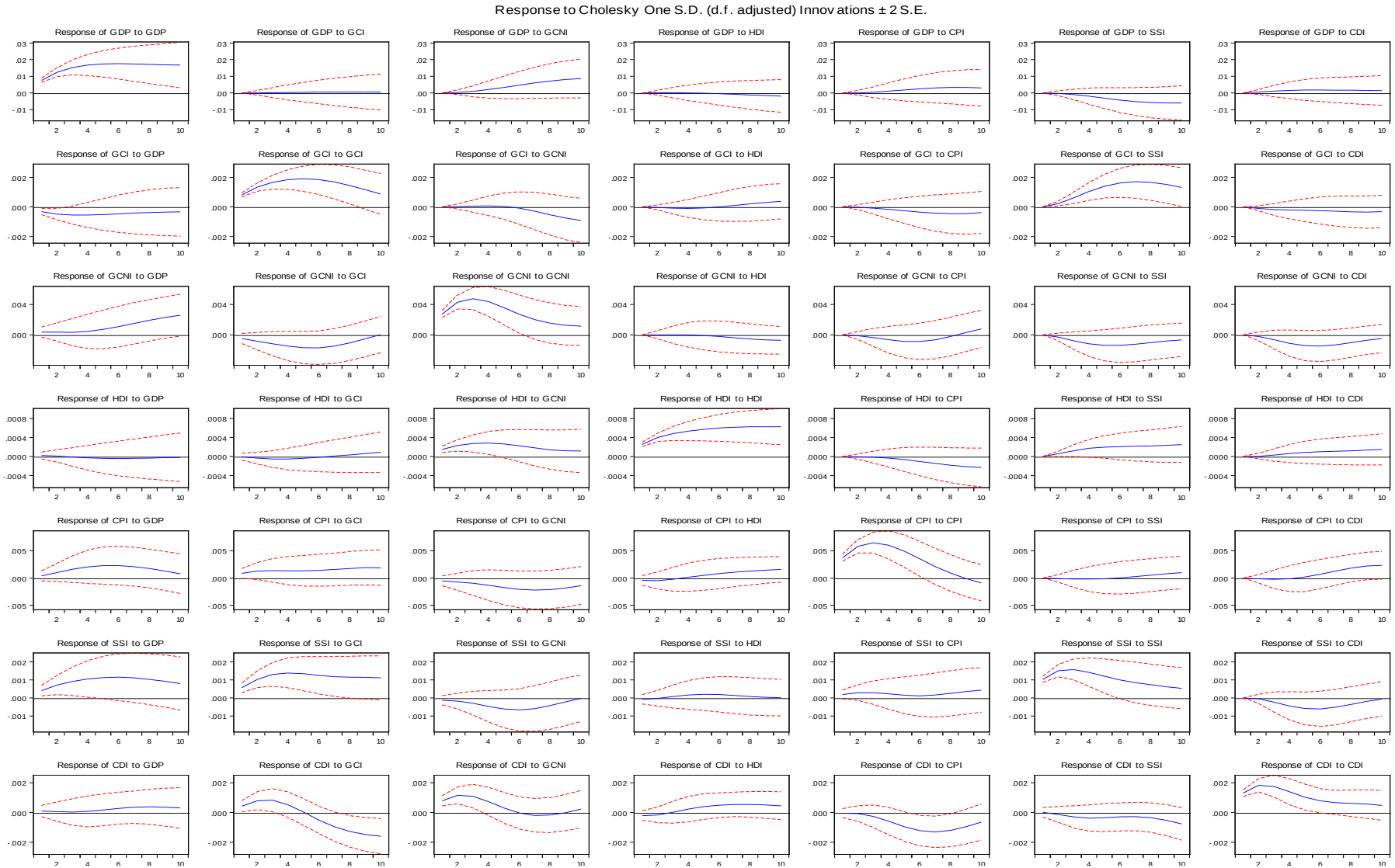
| Null Hypothesis ($H_0$) | F-statistic | Probability | Decision |
|---|---|---|---|
| CPI doesn't Granger Cause CDI | 0.56868 | 0.5691 | Don't reject $H_0$ |
| CDI doesn't Granger Cause CPI | 2.10348 | 0.1303 | Don't reject $H_0$ |
| GCI doesn't Granger Cause CDI | 0.16183 | 0.8509 | Don't reject $H_0$ |
| CDI doesn't Granger Cause GCI | 1.20601 | 0.3060 | Don't reject $H_0$ |
| GCNI doesn't Granger Cause CDI | 2.65486 | 0.0779 | Don't reject $H_0$ |
| CDI doesn't Granger Cause GCNI | 0.81643 | 0.4465 | Don't reject $H_0$ |
| GDP doesn't Granger Cause CDI | 3.04017 | 0.0547 | Don't reject $H_0$ |
| CDI doesn't Granger Cause GDP | 0.06471 | 0.9347 | Don't reject $H_0$ |
| HDI doesn't Granger Cause CDI | 2.08223 | 0.1329 | Don't reject $H_0$ |
| CDI doesn't Granger Cause HDI | 0.14278 | 0.8672 | Don't reject $H_0$ |
| SSI doesn't Granger Cause CDI | 0.58583 | 0.5596 | Don't reject $H_0$ |
| CDI doesn't Granger Cause SSI | 0.38927 | 0.6791 | Don't reject $H_0$ |
| GCNI doesn't Granger Cause CPI | 0.95602 | 0.3898 | Don't reject $H_0$ |
| CPI doesn't Granger Cause GCNI | 2.00208 | 0.1433 | Don't reject $H_0$ |

| Null Hypothesis ($H_0$) | F-statistic | Probability | Decision |
|---|---|---|---|
| GDP doesn't Granger Cause CPI | 1.26003 | 0.2905 | Don't reject $H_0$ |
| CPI doesn't Granger Cause GDP | 0.15661 | 0.8554 | Don't reject $H_0$ |
| HDI doesn't Granger Cause CPI | 5.52857 | 0.0061* | Reject $H_0$ |
| CPI doesn't Granger Cause HDI | 0.19033 | 0.8271 | Don't reject $H_0$ |
| SSI doesn't Granger Cause CPI | 0.86324 | 0.4266 | Don't reject $H_0$ |
| CPI doesn't Granger Cause SSI | 1.87145 | 0.1621 | Don't reject $H_0$ |
| GCNI doesn't Granger Cause GCI | 1.44711 | 0.2427 | Don't reject $H_0$ |
| GCI doesn't Granger Cause GCNI | 0.83825 | 0.4371 | Don't reject $H_0$ |
| GDP doesn't Granger Cause GCI | 1.86596 | 0.1629 | Don't reject $H_0$ |
| GCI doesn't Granger Cause GDP | 0.27170 | 0.7629 | Don't reject $H_0$ |
| HDI doesn't Granger Cause GCI | 3.38074 | 0.0401* | Reject $H_0$ |
| GCI doesn't Granger Cause HDI | 0.11873 | 0.8882 | Don't reject $H_0$ |
| SSI doesn't Granger Cause GCI | 4.67226 | 0.0127 | Reject $H_0$ |
| GCI doesn't Granger Cause SSI | 0.68215 | 0.5091 | Don't reject $H_0$ |
| GDP doesn't Granger Cause GCNI | 4.39420 | 0.0162* | Reject $H_0$ |
| GCNI doesn't Granger Cause GDP | 0.61767 | 0.5423 | Don't reject $H_0$ |
| HDI doesn't Granger Cause GCNI | 1.58736 | 0.2123 | Don't reject $H_0$ |
| GCNI doesn't Granger Cause HDI | 0.12031 | 0.8868 | Don't reject $H_0$ |
| SSI doesn't Granger Cause GCNI | 2.71558 | 0.0737 | Don't reject $H_0$ |
| GCNI doesn't Granger Cause SSI | 0.21353 | 0.8083 | Don't reject $H_0$ |
| HDI doesn't Granger Cause GDP | 0.21904 | 0.8039 | Don't reject $H_0$ |
| GDP doesn't Granger Cause HDI | 0.58599 | 0.5595 | Don't reject $H_0$ |
| SSI doesn't Granger Cause GDP | 0.51947 | 0.5973 | Don't reject $H_0$ |
| GDP doesn't Granger Cause SSI | 0.44117 | 0.6452 | Don't reject $H_0$ |
| SSI doesn't Granger Cause HDI | 1.09458 | 0.3408 | Don't reject $H_0$ |
| HDI doesn't Granger Cause SSI | 2.35880 | 0.1026 | Don't reject $H_0$ |

Note: *significance at 5% level
Source: Author's own calculation

Generally, impulse response function (IRF) identifies the responsiveness of the dependent variables in the VAR system when a positive standard deviation shock is given to the error term. This positive standard deviation shock is given to the following equations: eq. (31), eq. (32), eq. (33), eq. (34), eq. (35), eq. (36), eq. (37) and the reaction is presented in Figure 1. It is assumed that the change in residuals certainly brings a change in the variables in VECM framework. Here, seven macro-economic variables are considered in the VAR system and thus forty-nine impulse response functions are generated. Cholesky adjusted method is chosen for ordering of all the endogenous variables and finally IRF is applied to VECM (restricted VAR) to observe the responses for 10 years periods. Here, the straight line is zero (0) and the blue line indicates reaction towards positive standard deviation shock. It is observed that the direction of the blue line sometime lies above the straight line and sometimes below the straight line and occasionally it is straight line (0). It is also found that from time to time the blue line crosses the straight line from positive horizon to negative and then again at positive sphere and vice-versa. The own shock to GDP in eq. (31) is positive after 10 years but in other cases when a positive standard deviation shock is given to GDP the responses of the other variables are found to be positive and sometime negative for ten years. So, the positive standard deviation shocks to the dependent variables of the remaining equations under the VECM system (eq. 32 to eq. 37) exhibit a mix picture about their behaviour.

Figure 1. Impulse response function



The adequacy of the VECM model depends on some specific tests which are based on residuals. Firstly, Breusch-Godfrey test is carried out to check serial correlation and found absence of serial correlation which is enviable. Secondly, heteroskedasticity test is applied and found nonexistence of heteroskedasticity which is desirable. Finally, J-B test of normality is applied and found presence of normality in the distribution of residuals which is good enough. Lastly, it may be said that the VECM model is adequate and the results are acceptable in all respects.

Table 20. VECM test for serial correlation, heteroskedasticity and normality

| Dependent Variable | B-G LM test | | B-P-G Het. Test | | Normality test | |
|---|---|---|---|---|---|---|
| | Obs*$R^2$ | Probability | Obs*$R^2$ | Probability | J-B statistic | Probability |
| GCI | 3.055653 | 0.2170 | 11.02184 | 0.9983 | 1.6675 | 0.4344 |
| GCNI | 28.72331 | 0.0000 | 20.25491 | 0.8550 | 2.4727 | 0.2904 |
| SSI | 8.470638 | 0.0145 | 17.91886 | 0.9282 | 1.0961 | 0.5781 |
| CDI | 4.435789 | 0.1088 | 17.64429 | 0.9348 | 1.4354 | 0.4878 |
| GDP | 6.868956 | 0.0322 | 18.79730 | 0.9043 | 2.7606 | 0.2515 |
| CPI | 14.99488 | 0.0006 | 20.63063 | 0.8404 | 1.2614 | 0.5322 |
| HDI | 15.19841 | 0.0005 | 31.02765 | 0.3159 | 1.2174 | 0.5440 |

Source: Author's own calculation

At the end, CUSUM test is applied by taking into consideration the residuals to check the stability of the long-run coefficient together with the short-run dynamics (see Pearson & Pearson 1997). It is observed that the CUSUM plot (blue line) lies between the critical bounds (within two red lines) meaning that VECM model is stable and there is absence of structural break.

Figure 2. CUSUM test of GCI

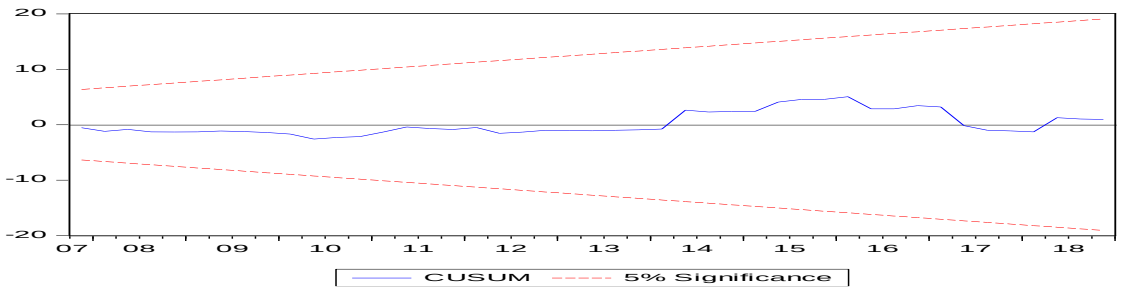



Figure 3. CUSUM test of GCNI

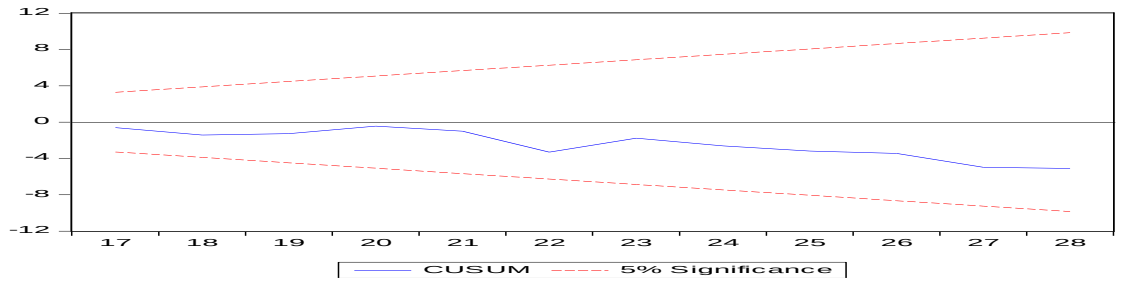



Figure 4. CUSUM test of CPI

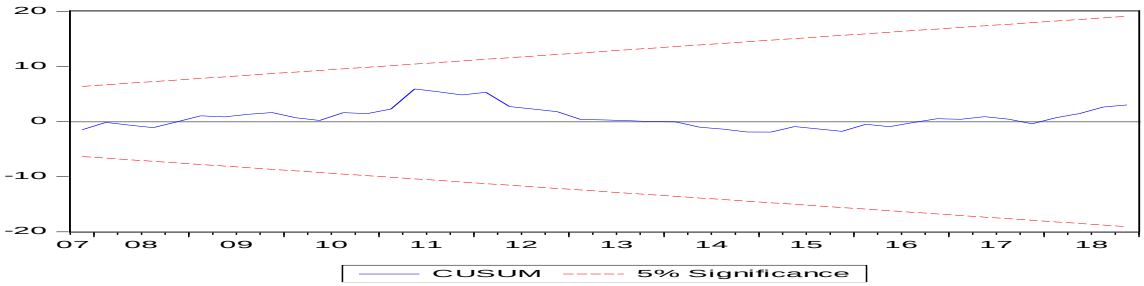


Figure 5. CUSUM test of GCNI

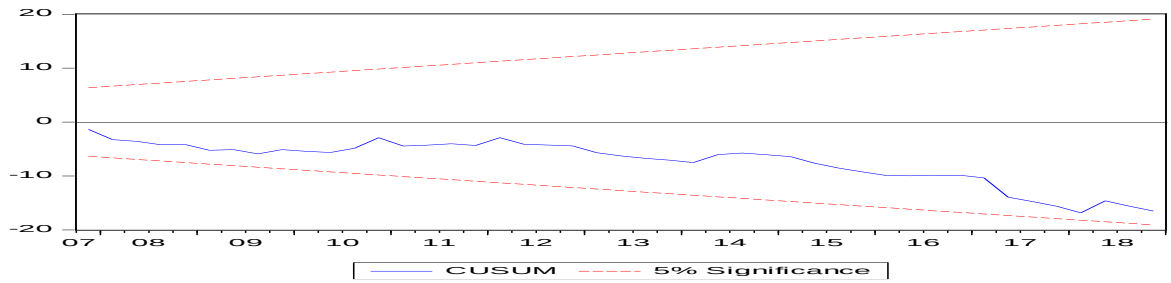



Figure 6. CUSUM test of GDP

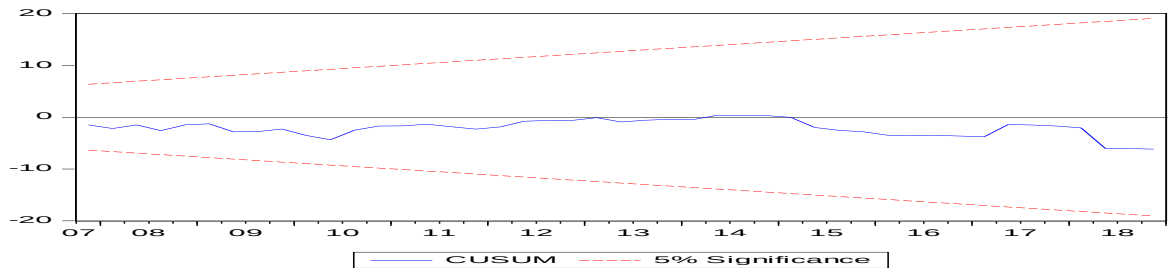



Figure 7. CUSUM test of HDI

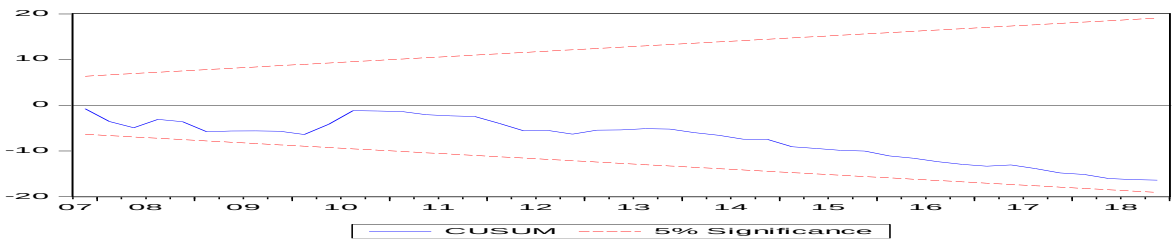
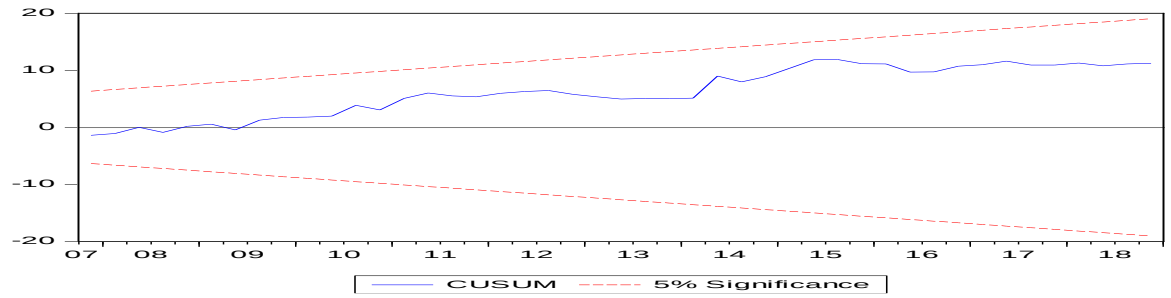



Figure 8. CUSUM test of SSI




## Conclusion

This study examines the dynamics of selected macro-economic variables under the VAR system. It is found that economic growth is not impacted by other variables in a statistically significant way but jointly it is influenced. Similarly, the global competitiveness index is statistically significantly influenced by the sustainable society index that means if the society in the near future becomes sustainable then obviously competitiveness of a nation will increase if government takes necessary policies. In the same fashion, the human development index has the capability to influence global connectedness index in a positive and significant way that means if the government and other agencies give proper attention and take necessary actions for the betterment of the components of the HDI then certainly global connectedness will be enhanced globally. The forecast of the macro-economic variables is satisfactory based on various results but one thing is that the forecasted value of the economic growth is decreased in slow pace due to economic volatility and may be for covid-19, recession and stagnation of the industrial growth around the world. Similarly, the forecast of the other variables is not too much satisfactory and the growth is very insignificant due to present adverse economic condition prevailing in all the economies and thus,

ministerial meeting with the economists, academicians, industrialists as well as the professionals all over the world is urgent to find out a new lane to overcome this problem. The study confirms about long-run equilibrium relationship among the co-integrating variables and undoubtedly there are also evidences of short-run uni-directional relationships. Impulse response function (IRF) tools are used to check the fluctuation of variances after putting positive standard deviation shock to the endogenous variable and then adequacy of the VECM model is checked and finally, CUSUM test confirms about model stability. Although, research in this area is scanty. More attention is needed by the researchers, government, scientists, policy makers to shave the earth and make it sustainable. The Earth doesn't support to make more money by exploiting the society and destroying the eco-system for itself but it encourages behavioural change of the human beings to control their greedy eyes. Otherwise, sustainability is not possible and very soon the survival will be the main issue, presently we are experiencing this issue.

## Credit Authorship Contribution Statement

Subrata Roy is responsible for the conceptualization and design of the study. He conducted the statistical and econometrical analysis using regression equation and VECM technique. R.S. interprets the results and writes the initial draft of the manuscripts. He also handles the revisions based on feedback from peer reviewers and makes substantial contributions to the final manuscript.

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## Conflict of Interest Statement

The author declares that the research is conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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