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The Dynamic Relationship between Innovation Index and Macroeconomic Instruments in the United States

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ABSTRACT : Innovation growth is a fundamental instrument that drives a country's economic growth, and economic growth is best quantified using important macroeconomic measures that reflect the economic growth and development of the country. The sole objective of this research study is to investigate the dynamic link between the innovation index and macroeconomic instruments in the United States. Secondary data was extracted from World Bank data publications (data.worldbank.org) and theglobaleconomy.com for the period under consideration, 1991 to 2021, for macroeconomic instruments and innovation index respectively in the United States. The unit root test was employed which indicates that the innovation and macroeconomic variables are stationary after the first difference which suggests that further econometric models can be applied to constitute the dynamic association. The dynamic relationship is explored using different econometric models such as the regression model which indicate that there is a significant linear relationship between innovation and macroeconomic instruments, vector autoregression (Var model) shows that there is a short-run relationship between innovation and macroeconomic instruments while Johansen cointegration shows that there is a long-run relationship between them and impulse response function reveals that there is a positive response of innovation index to GDP and GDP growth shocks which indicate that there is a positive relationship between the US innovation index and macroeconomic tools. This suggests that innovation growth in the united states contributed immensely to her growth and development. Consequently, there is a need for the US government to continually inject sustainable policy that is capable of accommodating global economic crisis into the system that will promote innovation growth for sustainable economic growth and development.

Keywords*: Innovation Index, Macroeconomic instruments, Multiple regression model. Unit root test, Var model, Johansen cointegration, Impulse response*

I. INTRODUCTION

The process of developing fresh ideas and putting them into practice to enhance current products and services or to boost the effectiveness of manufacturing processes is known as innovation (European Central Bank, 2017). An effective accelerator that will speed up a country's economic development is the growth of its innovative capacity. The United States as a whole had the highest innovation index in 2019 with 61.7%, but due to the COVID-19 pandemic, that number fell to 60.6% in 2020. (Globaleconomy.com, 2022; World health organization, 2022). It is important to note that innovation is a vital tool that enables activities that develop the nation's human capital, infrastructure, and research, all of which make significant contributions to the nation's economic prosperity. This is something that needs to be thought about. To assess a nation's economic development, key macroeconomic indicators are used, including the growth of its gross domestic product, inflation rate, unemployment rate, and gross domestic product (World Bank, 2022). As a direct result of the decline in the innovation index, which has harmed the nation's economy, the United States of America is currently dealing with high inflation as well as a high unemployment rate. The economic indicators, which show that inflation has unexpectedly risen to 4.7%, the unemployment rate has unexpectedly reached 8.1% in 2020, and gross domestic growth has unexpectedly fallen in 2020, make this abundantly clear (World bank, 2021).

Meanwhile, the United States of America's innovation index rose from 60.6% in 2020 to 61.3% in 2021, which also helped the country's GDP grow significantly from 20.89 trillion dollars in 2020 to 23 trillion dollars in 2021. This supports the hypothesis that the rate of growth of a country's innovative sector has a significant impact on its macroeconomic indicators.

The increase in innovation in the United States, according to economists, accounts for 50% of the country's GDP growth each year (Fraser, 2021; World bank, 2021). Technology development, the human capital index, and research performance are all primarily influenced by innovation performance (World bank, 2022). The United States has consistently performed well in the area of innovation because the government is interested in

encouraging people to develop good ideas that can boost the economy. In California and other states across the nation, this is something that stands out.

Numerous different types of studies have shown that innovation and macroeconomic tools have a positive relationship (Raghupathi and Raghupathi, 2017; World Bank, 2021). The findings of a study conducted by Raghupathi and Raghupathi (2017) indicate that a key element in the growth of the economy is the development of innovative talents. All of the industrialized countries in the globe, including the United States of America, are experiencing unbroken cycles of continuing economic growth and advancement in their national development as a result of their consistently rising rates of innovation (WBDI, 2022). This shows that underdeveloped nations can be linked to their countries' weak innovation growth, yet every country that wants to have huge economic growth can increase its innovative technology and development, which is crudely quantified by the innovation index.

Therefore, this research study will contribute to the existing body of knowledge with the sole objective of examining the dynamic relationship between the Innovation index and macroeconomic instruments in the US using suitable econometric models.

II. LITERATURE REVIEW

Literature review of this research work will be divided into two parts namely theoretical and empirical review.

2.1 Theoretical review

Following the Keynesian theory concept, innovation index of a country also contributes significantly to the gross domestic product (GDP growth) as well as the country inflation rate which in turn brings about economic growth and development. A simple equation that illustrated this expression can be written as:

$Y = INOV + INF$ …… (1)

Where Y represents the total output (GDP growth), INOV is the innovation growth index in the united states while INF is the inflation rate.

Nevertheless, apart from the gross domestic product growth (GDP growth) and gross domestic product (GDP), the inflation rate and the unemployment rate are also another key macroeconomic variable, and the sustenance of the economy is solely dependent on the macroeconomic instruments and the innovation growth (Raghupathi and Raghupathi, 2017).

In light of this, we can deduce the second equation with inclusion of the above variables as:

$Y = F (INOV, GDP, INF, UMP)$ ……... (2)

Where Y = GROSS DOMESTIC PRODUCT GROWTH (GDP GROWTH)
INOV = INOVATION INDEX
GDP =GROSS DOMESTIC PRODUCT
INF = INFLATION RATE
UMP = UNEMPLOYMENT RATE

2.2 Empirical review

The study conducted by Rana, Maradana, Saurav, Kunal, Manju, and Debaleena (2017) looks at the connection between innovation and per capita economic growth in 19 European countries from 1989 to 2014. The study looked at the long-term correlation between six different innovation indices and per capita economic growth. The sum of R&D expenditures, the number of researchers actively engaged in R&D, the export of high-tech goods, and the number of scientific and technical journal articles were some of these. The number of patents owned by residents and non-residents was also listed. The study finds that long-term innovation and per capita economic development are typically correlated. This evidence usually relates to the use of a certain innovation indicator. The investigation was carried out using cointegration as the methodology. The Granger causality test was used in the study, which concluded that there is a unidirectional and bidirectional causal relationship between innovation and per capita economic growth, though the direction of this relationship varies from country to country depending on the innovation indices that were examined. Importantly, the analysis shows a high correlation between each of these innovation criteria and the expansion of per capita GDP. Andreea, Olivera, and Florina (2015) looks at the relationship between an economy's capacity for innovation and the pace of long-term economic growth. The parameters for the Central and Eastern European countries of Poland, the Czech Republic, and Hungary were evaluated in the analysis using multiple regression models. The study used a range of variables, such as the number of patents, trademarks, and R&D expenditures, to assess innovation. The results support the substantial correlation between economic progress and innovation. This leads us to the conclusion that innovation is a crucial step in the process of gaining growth.

Additionally, Bailey (2010) researched altering the American economy through innovation, and the results show that innovation is also a crucial driver of job creation in industries like manufacturing where end-user demand is closely correlated with other economic performance metrics.

To evaluate the factors affecting R&D investment and patents as well as the relationship between innovation and economic growth, Westmore (2013) built a panel model employing a sample of 19 OECD

nations from 1980 to 2008. The study's conclusions indicate that encouraging innovation in the private sector can be accomplished through the use of financial incentives, government funding for R&D, and legal protection of intellectual property rights. There is no clear connection between these laws and product creation in general, according to the research. Standards that promote competitiveness are crucial for the transfer of data from any source, internal or external. Using an econometric model approach, Petrariu, Bumbac, and Cirbanu (2013) examines the relationship between innovation and economic growth. The paper claims that the allocation of resources to research and development is the main force behind innovation and a reliable indicator of progress at the economic level. However, this study will investigate the dynamiclink between innovation index and macroeconomic tools in the US, which is a new area of study and will make a significant contribution to the body of existing knowledge.

III. DATA AND METHODOLOGY

3.1 Data

This research employed secondary data from World Bank data publications (data.worldbank.org) and theglobaleconomy.com for the period under consideration, 1991 to 2021, for macroeconomic instrumentsand innovation index respectively in the United States. The selection of the selected macroeconomic indicators was based first on the availability of data and then on a method of purposive sampling.

3.2 Methodology

For this research study, a quantitative research design will be adopted, and descriptive statistics (mean and standard deviation for the data summary) and econometric models such as multiple regression model, unit root test, Var model, Cointegration analysis and impulse response function will be used for data analysis. EViews software version 11.0 and Stata 17.0 were employed for the analysis of this study.

Table 1: Measurement of variables

Variables	Measurement
Gross domestic product growth (GDP growth)	Percentage annual growth (%)
Innovation index	Percentage (%)
Gross domestic product (GDP)	Trillion USD
Inflation rate	Percentage (%)
Unemployment rate	Percentage (%)

Source: Author

3.3 Multiple LinearRegression

Multiple linear regression is typically used to establish a linear relationship between a dependent variable and at least two independent variables. It is also a suitable model for predicting a dependent variable with a given independent or predictor variables. More so, regression model can also reveal the independent variable or variables that have significant impact on the dependent variables.

The multiple linear regression can be expressed below as:

$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \ldots\ldots\beta_kX_k + \varepsilon$

Where Y = GDP growth

X_1 = Innovation index

X_2 = GDP

X_3 = Inflation rate

X_4 = Unemployment

β_0 = Intercept and β1 to βk are the coefficient estimate or slope of the independent variables

ε = Error term

The dependent or outcome variable is GDP growth while the independent variables are innovation index and the other macroeconomic tools such as GDP, Inflation rate and Unemployment rate.

3.4 Unit root test

The presence of unit root indicated that the series is not stationary, which may yield erroneous findings if not eliminated. The test is carried out to eliminate the possibility of erroneous results. Theunit root test hypothesis is stated below as:

H_0: there is an existence of a unit root vs H_a: there is no unit root (the variable is stationary). The augmented dickey fuller(ADF) test can be presented mathematically as:

$$\Delta Y_t = \theta + \gamma Y_{t-1} + \sum_{i=1}^{p} \beta_i Y_{t-i} + \omega_t$$

Where, θ is a constant, γ is the coefficient of process root, β_i coefficient in time tendency, p is the lag order and ω_t is the disturbance (error) term.

3.5 Cointegration analysis

Johansen cointegration test is an approach for testing cointegration of integrated variables with zero level I (0), order 1, I (1)- after first difference or of order 2, I (2)-after second difference. This test permit more than one cointegrating relationship. There are two types of Johansen test which are the trace and max eigen value, and they form the basis of the inference or decision and their result might be little different from other. The Var model indicated by Var(p) is mathematically defined in a general term below as:

$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots\ldots + \beta_p y_{t-p} + e_t$

It is important to note that the variables should be stationary before proceeding to Johansen Cointegration test. When there is cointegration, it means there is a long run association between the variables.

3.6 Vector autoregressive (VAR) model estimation

VAR model is actually a quantitative econometric approach that examine the short run relationship between the variables. All the variables in vector autoregressive model are treated as endogenous variables. Meanwhile the generalized VAR model can be written as $y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots\ldots + \beta_p y_{t-p} + e_t$ and can be written with the corresponding lags as

$\Delta y_{1,t} = \theta_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{1,t}$ represent GDP Growth as endogenous and its corresponding lag values

$\Delta y_{2,t} = \theta_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{2,t}$ represent Innovation Index as endogenous and its corresponding lag values

$\Delta y_{3,t} = \theta_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{3,t}$ represent Gross domestic productas endogenous and its corresponding lag values

$\Delta y_{4,t} = \theta_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{4,t}$ represent Inflation rate and its corresponding lag values

$\Delta y_{5,t} = \theta_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{5,t}$ represent Unemployment rate and its corresponding lag values

3.7 Impulse response function

An impulse response function (IRF) in econometrics measures the effect of a shock on an endogenous variable on itself or another endogenous variable using a graphical approach. It is noteworthy that the vector auto regression (VAR) model will first be estimated before computing the impulse response function.

4. Result and Discussion

This section will present result of the analysis and the discussion of findings.

Table 2: Summary statistics

Variables	Mean	Standard deviation	Observations
GDP growth	2.432258	1.901762	31
Innovation	59.13871	1.322341	31
GDP	13.52581	4.920738	31
Inflation	2.386774	1.082249	31
Unemployment	5.919355	1.617492	31

Source: Author's Computation using EViews software

Table 2 shows the summary statistics of all the variables of interest in this research study. The GDP annual growth on average experiences an increase of about 2.43% with a variability of about 1.9%. The innovation growth on average is about 59.14% with little variability of about 1.32%, and the gross domestic product (GDP) in the US on average during the period under review is about 13.52 trillion dollars with a variability of about 4.92 trillion dollars. The inflation rate on average is about 2.39% with a variability of about 1.08% while the unemployment rate on average is about 5.92% with variability of about 1.62%.

Table 3: Multiple regression model

Dependent Variable: GDP_GROWTH

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.500061	20.85929	0.407495	0.6870
INNOVATION	-0.052357	0.343651	-0.152355	0.8801
GDP	-0.059583	0.077256	-0.771239	0.4475
INFLATION	0.434015	0.299951	1.446953	0.1599
UNEMPLOYMENT	-0.540846	0.246907	-2.190485	0.0377
F-statistic	3.628148	Durbin-Watson stat		1.759141
Prob(F-statistic)	0.017724			

Source: Author's Computation using EViews software

Table 3 shows the estimated multiple regression model which the overall P-value ($P = 0.018 < 0.05$) which indicate that the regression model is statistically significant at 0.05 significant level and this suggest that there is

a significant linear relationship between the US innovation index and the macroeconomic instruments (such as GDP growth, GDP, Inflation and Unemployment). Besides, the unemployment (β = -0.541, P<0.05) implies that US unemployment rate is statistically significant and have a negative significant impact on the gross domestic growth. The variance inflation factor for all the independent variables of the regression model is less than 5 (VIF<5) as we can see in the **appendix** which means that the fitted regression model those not suffer from the problem of multicollinearity which indicate that the model is robust and reliable.

Table 4: Unit root test

Differenced Variables	Test statistic	P-value	Order
GDP growth	-8.12	0.0000	I (1)
Innovation	-8.34	0.0000	I (1)
GDP	-5.68	0.0001	I (1)
Inflation	-5.86	0.0000	I (1)
Unemployment	-4.98	0.0004	I (1)

Source: Author's Computation using EViews software

Table 4 shows the result of the unit root test using augmented dickey fuller and we can see that the variables such as GDP growth, Innovation, GDP, Inflation and Unemployment are statistically significant after the first difference which indicates that they become stationary after the first difference which implies they are integrated of order one (that is, I(1)).

Table 5:Vector autoregression

Vector autoregression
Log likelihood = -58.41555 AIC = 7.821762
FPE = .002095 HQIC = 8.633903
Det (Sigma_ml) = .0000387 SBIC = 10.41491

Equation	Lags Parms	RMSE	R-sq	Chi2	P>Chi2
GDP growth	11	1.31715	.6901	64.59228	0.0000
Innovation	11	.999983	.6384	51.19117	0.0000
GDP	11	.278365	.9977	12777.89	0.0000
Inflation	11	.65913	.7483	86.23704	0.0000
Unemployment	11	.877602	.8152	127.9003	0.0000

Source: Author's Computation using Stata software

Table 5 shows the result of the estimated vector autoregression (VAR) model and we can see that the corresponding lags parameters of each of the endogenous variables are 11 which are all statistically significant at 1% level and the R-squared for all the parameters are above 0.6 which indicate that model is significant and adequate. This indicates that there is a short-run relationship between the innovation index and the macroeconomic instruments under review in the US.

Table 6: Johansen Cointegration

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.852382	115.2866	69.81889	0.0000
At most 1 *	0.681268	59.80592	47.85613	0.0026
At most 2	0.406599	26.64715	29.79707	0.1106
At most 3	0.257992	11.51249	15.49471	0.1818
At most 4	0.093883	2.859022	3.841466	0.0909

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level

Table 6 shows the result of the Johansen cointegration test and two of the cointegrating equations (None* and At most 1*) are statistically significant at 0.05 significant level and this implies that there is existence of cointegration among the endogenous variables which suggest that there is a long-run connection between the innovation index and the macroeconomic instruments.

Figure 1: Impulse response

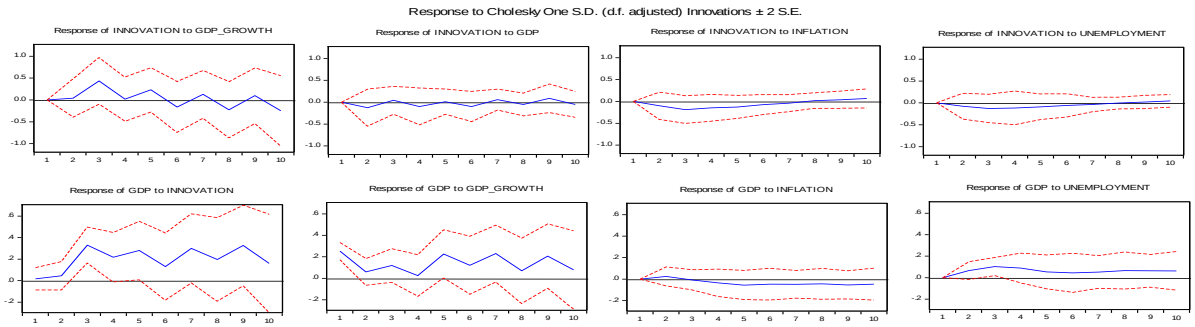

Figure 1 shows the impulse response function for all the endogenous variables in the blue line which falls within the two 95% confidence intervals which are the red lines. In addition, the impulse response of GDP to innovation fell between the two 95% confidence intervals and indicates a positive response. It is noteworthy that the line below zero shows a negative response while the one above zero line shows a positive response. The impulse response of Innovation to GDP growth shocks falls between the two 95% confidence intervals which approximately falls above the zero line and indicates a positive response. The impulse response of innovation to GDP shocks falls between the two 95% confidence intervals which are constant along the zero line and a little above the zero line which also indicates a positive response. Response of innovation index inflation and unemployment fall between the two 95% confidence interval but fall below the zero line which indicates a negative response while the impulse response of GDP to GDP growth also falls between the two 95% confidence interval but fall above the zero line which indicates a positive response.

Figure 2: US Gross Domestic Product Growth

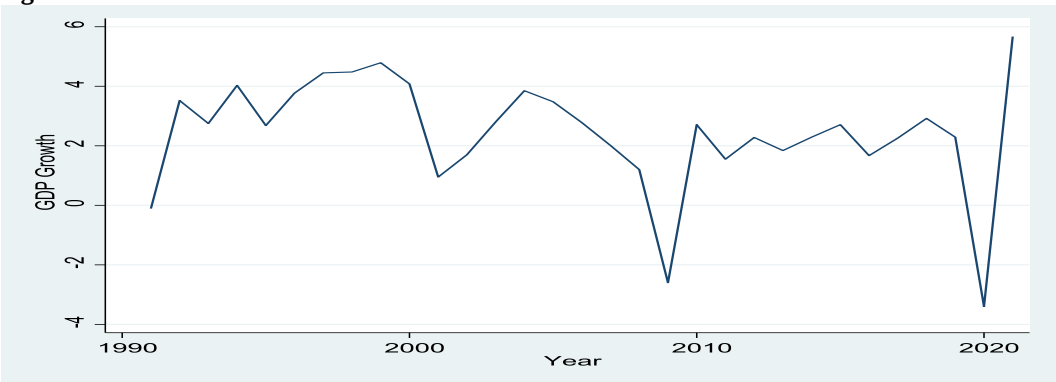

Figure 2 shows the US gross domestic product growth during the period under review and we can see the United States of America experience negative fall in her GDP growth in 2020 due to the adverse effect of covid-19 pandemic and also rise to about 5.67% in 2021 after adopting effective approach to contain the spread of the covid-19 pandemic virus.

Figure 3: US Innovation Index

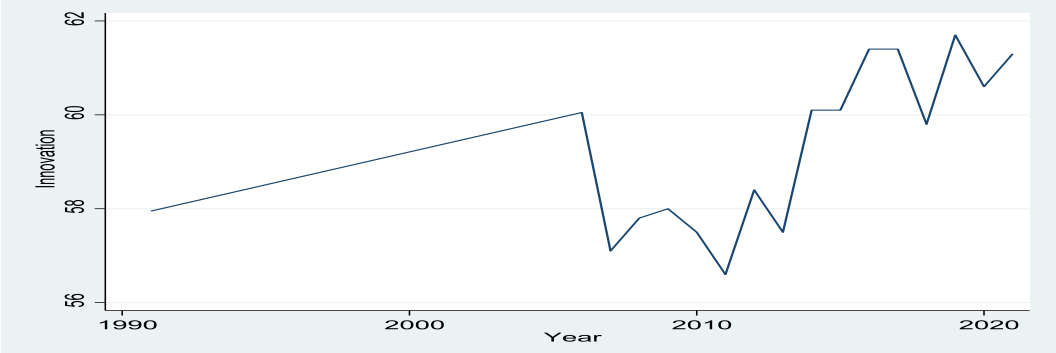

Figure 3 shows the US innovation index during the period under review and we can see that united states experience minimum innovation index of 56.6% in 2011 and maximum innovation index of 61.7% in 2019.

Figure 4: US Gross Domestic Product

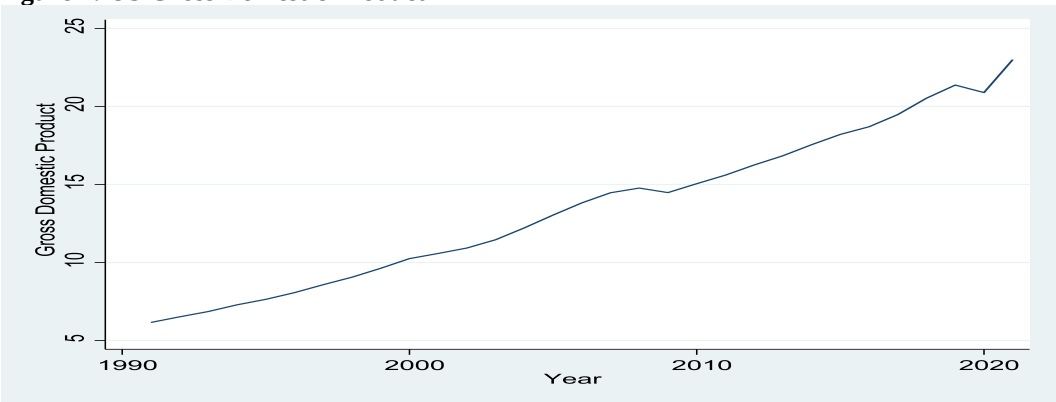

Figure 4 shows that the US gross domestic product have a positive upward growth during the period under review except the slight decline in 2020 which is attributed the effect of the global covid-19 pandemic.

Figure 5: US Inflation

Figure 5 shows that the US inflation rate during the period under review and we can see a sharp rise in inflation rate from 1.23% in 2020 to 4.7% in 2021 due to the covid-19 pandemic effect and the US government expenses to contain the effect, research for virus that can prevent it and also rendering support to other developing countries.

Figure 6: US Unemployment

Figure 6 shows the graph of the US unemployment rate during the period under review and we can see that the unemployment rate is at the peak level of 8.1% in 2020 due to the covid-19 pandemic effect and later drop to 5.5% in 2021.

4.1 Model Diagnostic check

From the **appendix**, we can see that the normality check using Jarque-Bera (P>0.05) which indicate the data is normally distributed. The autocorrelation test using Breusch-Godfrey Serial Correlation LM Test in the **appendix** shows that P>0.05 which indicate that there is no presence of autocorrelation which implies that the fitted econometric models does not suffer from the problem of autocorrelation. The heteroscedasticity test using Breusch-Pagan-Godfrey in the **appendix** (P>0.05) shows that there is homoscedasticity which implies that the fitted models does not suffer from the problem of heteroscedasticity.

4.2 Discussion of Findings

As a result of the analysis of this research study, the following were the notable findings deduced.

Figure 2 shows the US gross domestic product growth during the period under review and we can see the United States of America experience a negative fall in its GDP growth in 2020 due to the adverse effect of covid-19 pandemic and also rise to about 5.67% in 2021 after adopting an effective approach to contain the spread of the covid-19 pandemic virus.

Figure 3 shows the US innovation index during the period under review and we can see that the united states experience a minimum innovation index of 56.6% in 2011 and a maximum innovation index of 61.7% in 2019.

The summary statistics show that GDP annual growth on average experiences an increase of about 2.43%. The innovation growth on average is about 59.14%, and the gross domestic product (GDP) in the US on average during the period under review is about 13.52 trillion dollars. The inflation rate on average is about 2.39% while the unemployment rate on average is about 5.92% (see table 2).

Multiple regression model is applied and the result shows that the regression model is statistically significant at 0.05 significant level and this suggests that there is a significant linear relationship between the US innovation index and the macroeconomic instruments (such as GDP growth, GDP, Inflation and Unemployment) which is consistent with the work of Westmore (2013).

Besides, the unit root test was adopted using augmented dickey fuller and it shows that all the variables (such as the Innovation index, GDP growth, GDP, Inflation and Unemployment) are integrated of order one and this suggests that further econometrics model can be applied. The vector autoregression model and Johansen cointegration test was also adopted and the result indicates that there is a short- and long-term association between the US innovation index and the macroeconomic instruments which is very consistent with the research conducted by Rana, Maradana, Saurav, Kunal, Manju, and Debaleena (2017).

Meanwhile, the impulse response function was estimated which shows that the impulse response of innovation to GDP growth shocks falls between the two 95% confidence intervals which approximately falls above the zero line and indicates a positive response. In the same vein, the impulse response of innovation to GDP shocks falls between the two 95% confidence intervals which are a little above the zero line which also indicates a positive response. This suggests that there is a positive connection between innovation and macroeconomic instruments such as GDP and GDP growth which support the work of Raghupathi and Raghupathi (2017).

IV. CONCLUSION AND POLICY IMPLICATION

Innovation is a crucial driver of the economic growth and development of every nation. The US economy has adopted innovative technology enormously and this has contributed to the united states gross domestic product growth which is a proxy for economic growth which is very consistent with the affirmation of the claim by Fraser (2021).

This research study's primary objective is to examine the dynamic relationship between the Innovation index and macroeconomic instruments in the US. The dynamic relationship is explored using different econometric models such as the regression model which indicate that there is a significant linear relationship between innovation and macroeconomic instruments, vector autoregression shows that there is a short-run relationship between innovation and macroeconomic instruments while Johansen cointegration shows that there is a long-run relationship between them and impulse response function reveals that there is a positive response of innovation index to GDP and GDP growth shocks which indicate that there is a positive relationship between the US innovation index and macroeconomic tools. This suggests that innovation growth in the united states contributed immensely to the country's growth and development.

Hence, there is a need for the US government to continually instill sustainable policy that is capable of accommodating global economic crisis (like the covid-19 pandemic, Russia-Ukraine war etc) into the system that will promote innovation growth for sustainable economic growth and development.

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Appendix

Variance inflation factor (VIF)

Variable	Coefficient Variance	Centered VIF
C	435.1101	NA
INNOVATION	0.118096	2.313122
GDP	0.005969	1.618856
INFLATION	0.089970	1.180407
UNEMPLOYMENT	0.060963	1.786608

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.002600	Prob. F(2,24)	0.9974
Obs*R-squared	0.006715	Prob. Chi-Square(2)	0.9966

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	2.194223	Prob. F(4,26)	0.0976
Obs*R-squared	7.823690	Prob. Chi-Square(4)	0.0983
Scaled explained SS	5.937536	Prob. Chi-Square(4)	0.2039

Normality test