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Modeling The Non-Linear Effects Of Government Expenditure Components On Economic Growth In Uganda

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Abstract

The study sought to model the Non-Linear Effects of Government Expenditure Components on Economic Growth in Uganda. The specific objective of this study was to examine the relationship between capital expenditures and economic growth in Uganda. Using a combination of statistical nonlinear models, including the Time-Dependent Cobb-Douglas model and Logistic Growth model, the study analyzed historical data on government expenditures and GDP growth in Uganda from 1982 to 2024. The results reveal significant findings. The Time-Dependent Cobb-Douglas model, in particular, highlights a positive correlation between capital expenditures and economic growth, suggesting that strategic investments in infrastructure can stimulate productivity and growth. This study contributes to the understanding of how various government spending categories affect Uganda's economic performance and provides valuable insights for policymakers. It emphasizes the importance of efficient allocation and prioritization of expenditures to maximize economic returns, particularly through investments in technology and capital infrastructure. The study recommended that future research should be conducted on optimizing public spending to foster sustainable growth in Uganda and other developing economies.

Keywords: Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Multiple Regression, Cobb-Douglas Regression, and Logistic Growth Models

1.0 Introduction

Economic growth is a widely pursued goal as it leads to increased production and higher incomes**.** However, balancing this with environmental sustainability and social justice remains a crucial challenge (Hariram et al., 2023). This study is set to establish the relationship between Government expenditure and economic growth in Uganda.

Economic growth, the sustained increase in the production of goods and services over time, is a fundamental concept in economics. Its historical origins can be traced back to the Agricultural Revolution, which occurred around 10,000 years ago. This shift from hunting and gathering to agriculture led to increased food production, population growth,

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and the development of specialized labor. Subsequent advancements in technology, such as the Industrial Revolution, further accelerated economic growth.

Globally, The United States has experienced a long history of economic growth, driven by factors such as abundant natural resources, technological innovation, and a skilled workforce (Arora et al., 2020). However, the country has also faced challenges, including economic recessions, income inequality, and environmental degradation. The Great Recession of 2008, for example, had a significant impact on the U.S. economy, leading to high unemployment rates and a decline in consumer spending (Mankiw & Taylor, 2023).

Similar to the United States, Canada has benefited from abundant natural resources and a strong manufacturing sector. However, its economy is more reliant on exports, particularly to the United States, making it vulnerable to global economic fluctuations. Additionally, Canada faces challenges related to its vast geography and sparse population, which can hinder economic development in certain regions (Statistics Canada, 2023).

In Africa, Ghana's economic growth has been fueled by its natural resource wealth, particularly gold and cocoa. However, the country has also faced challenges, including political instability, corruption, and a lack of infrastructure development. Ghana's reliance on commodity exports has made its economy vulnerable to price fluctuations in the global market (Etim & Daramola, 2020). Nigeria, the largest economy in Africa, has experienced significant economic growth in recent years, driven by its oil industry (Yusuf & Mohd, 2021). However, the country has also faced challenges, including poverty, inequality, and political corruption. Nigeria's reliance on oil has made its economy vulnerable to global oil price fluctuations and has hindered its diversification efforts (Udemba, 2020).

Nationally, the historical origin of economic growth in Uganda can be traced back to the pre-colonial era when agriculture was the primary economic activity (Cramer et al., 2020). However, the country's economic development was significantly impacted by colonialism, which led to the exploitation of its natural resources and the suppression of local industries. Since independence, Uganda has experienced periods of both economic growth and decline, influenced by factors such as political instability, civil wars, and global economic fluctuations (Mugoda et al., 2020). Despite these challenges, Uganda has made progress in recent years, with economic growth driven by agriculture, services, and tourism. However, the country continues to face significant challenges, including poverty, inequality, and infrastructure constraints (Cramer et al., 2020).

2. MATERIALS AND METHODS

2.1 Study Area

The study is conducted in Uganda. Uganda a landlocked country in East Africa, is bordered by Kenya, South Sudan, the Democratic Republic of the Congo, Rwanda, and Tanzania. Its southern region includes a significant portion of Lake Victoria. The country lies within the Nile basin and has a varied equatorial climate. Uganda is known for its diverse landscapes, including the snow-capped Rwenzori Mountains, which reach elevations of 5,110 meters (16,765 ft), and the vast savannas of Murchison Falls National Park. This area is chosen because it raises substantial local revenue due to increased taxes but with poor economic growth.

2.2 Study Design and Data Source

The study employed a quantitative research design which utilized a secondary dataset on current expenditures, capital expenditures, technological innovation expenditures, and economic growth (represented by GDP) collected from multiple sources such as the Uganda Bureau of Statistics (UBOS), World Bank national accounts data, and OECD National Accounts data files. The dataset on each variable was extracted on annual basis with data length of 42 years that is from 1982 to 2024. Secondary data was appropriate for this research because it allowed for the analysis of long-term trends in expenditure and economic growth over a substantial 42-year period, leveraging existing, reliable datasets from reputable sources like UBOS, the World Bank, and OECD. This approach efficiently provided a broad historical perspective without the need for primary data collection. (**S**ources: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?name_desc=false&locations=UG and https://www.ubos.org/wp-content/uploads/statistics/Government-Finance-Statistics-Central-Government-and-Local-Governmet-FY-2012-13-TO-FY-2021-22.xlsx).

2.3 Data Analysis Techniques

This study employs a comprehensive data analysis approach to ensure robust and reliable results. Data preprocessing begins with normality testing using the Jarque-Bera (JB) test and outlier detection to identify and address anomalies. Heteroscedasticity is examined using the Breusch-Pagan test, while multicollinearity is assessed through the Variance Inflation Factor (VIF). The Durbin-Watson test is used to check for autocorrelation, and the BDS test is applied to detect non-linearity in the dataset. Model evaluation is conducted using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) to select the best-fitting model. The study specifies three regression models—Multiple Regression, Cobb-Douglas Regression, and Logistic Growth Models—to analyze the relationship between government expenditure and economic growth. GRETL 32c is utilized for data visualization, preprocessing, and statistical testing, while Python (Anaconda 3.12) is employed for model fitting and performance evaluation.

2.3.1 Model Specification

2.3.1.1 Cobb-Douglas Production Function Model (Power Regression Model)

The Cobb-Douglas model is widely used in economics and statistics to study the impact of different types of expenditures on economic growth. It assumes that economic growth is influenced by multiple inputs in a multiplicative way.

$$Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} e^{\varepsilon} \quad (3.1)$$

Taking the natural logarithm on both sides, the model can be estimated using a log-linear form:

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$$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \varepsilon \quad (3.2)$$

where;

Y = Economic growth (GDP)

X_1 = Current Expenditures

X_2 = Capital Expenditures

X_3 = Technological innovation expenditures

Model parameters (coefficients).

ε = Error term

This model (3.2) helps determine the elasticity of economic growth with respect to different government expenditures. To assess whether government expenditures exhibit increasing, constant, or decreasing returns to scale (RtS), sum the exponents $\beta_1, \beta_2, \beta_3$:

$$RtS = \beta_1 + \beta_2 + \beta_3 \quad (3.3)$$

Note that:

If $\beta_1 + \beta_2 + \beta_3 > 1$, the model exhibits increasing returns to scale (expenditures have a compounding effect on growth).

If $\beta_1 + \beta_2 + \beta_3 = 1$, the model exhibits constant returns to scale (proportional growth).

If $\beta_1 + \beta_2 + \beta_3 < 1$, the model exhibits decreasing returns to scale (diminishing effects of expenditure).

The elasticity of economic growth with respect to government expenditures measures how responsive economic growth is to changes in each type of government expenditure and is given by:

$$\mathrm{E}_{X_i} = \frac{\partial Y}{\partial X_i} \times \frac{X_i}{Y} = \beta_i \quad (3.4)$$

where E_{X_i} represents the elasticity of GDP concerning expenditure type X_i (Current, Capital, or Technological Innovation). If $\beta_i > 1$, economic growth is highly responsive to that expenditure; if $0 < \beta_i < 1$, the effect is inelastic.

To capture the dynamic nature of government expenditure over time, a time-dependent Cobb-Douglas model can be formulated as:

$$Y_t = \beta_0 X_{1,t}^{\beta_1} X_{2,t}^{\beta_2} X_{3,t}^{\beta_3} e^{\gamma t + \varepsilon} \quad (3.5)$$

Taking the natural logarithm on (3.5) yielded:

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$$\ln Y_t = \ln \beta_0 + \beta_1 \ln X_{1,t} + \beta_2 \ln X_{2,t} + \beta_3 \ln X_{3,t} + \gamma t + \varepsilon \tag{3.6}$$

Where t represents time and γ captures the autonomous growth rate not explained by government expenditures. This formulation helps analyze long-term growth trends and policy implications.

2.3.1.2 Logistic Growth Model

The Logistic model is useful when economic growth follows a saturation effect, meaning that government expenditure has a positive effect at lower levels but diminishes as it increases beyond a certain point.

$$Y = \frac{\beta_0}{1 + e^{-(\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}} + \varepsilon \tag{3.7}$$

where

e = Euler's number (~2.718)

This model (3.6) captures the diminishing marginal returns of government spending, showing how economic growth slows down after reaching a certain expenditure threshold.

The growth rate of economic output with respect to government expenditures can be derived by differentiating the logistic function:

$$\frac{dY}{dX_i} = \frac{\beta_0 \beta_i e^{-(\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}}{\left(1 + e^{-(\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}\right)^2} \tag{3.8}$$

This equation (3.8) measures the marginal impact of government expenditures on economic growth. It shows that as expenditure increases, its impact diminishes due to the saturation effect (i.e., diminishing returns).

The half-saturation point determines the level of government expenditure required for economic growth to reach 50% of its maximum potential which is represented as:

$$X^* = \frac{\ln(1)}{\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3} = \frac{\ln(1)}{\sum \beta_i X_i} = 0 \tag{3.9a}$$

Alternatively, for practical use:

$$X^* = \frac{\ln(1/e)}{\sum \beta_i X_i} = \frac{1}{\sum \beta_i X_i} \tag{3.9b}$$

This equation (3.9b) helps policymakers identify the optimal expenditure threshold before growth starts leveling off.

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To capture economic growth dynamics over time, we modify the logistic model in question (3.7) to incorporate time-dependent expenditures:

$$Y_t = \frac{\beta_0}{1+e^{-\left(\beta_1 X_{1,t}+\beta_2 X_{2,t}+\beta_3 X_{3,t}+\gamma t\right)}} + \varepsilon \qquad (3.10)$$

Taking the derivative with respect to time on equation (3.10) gives:

$$\frac{dY_t}{dt} = \gamma Y_t \left(1 - \frac{Y_t}{\beta_0}\right) \qquad (3.11)$$

where:

t represents time,

γ is the autonomous growth rate,

$\frac{dY_t}{dt}$ captures the rate of change of economic growth over time given government expenditures.

This equation (3.11) helps analyze long-term economic policies and how expenditures must be adjusted over time to sustain growth.

2.3.1.3 Linear Multiple Regression

A classical model that describes the relationship between a dependent variable and several independent variables is called linear multiple regression which is used in this study to compare with the two non-linear models for clarification. The equation for linear multiple regression as

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \varepsilon \qquad (3.12)$$

where

y is the dependent variable (GDP)

The independent variables are x_1, x_2, x_3 (features such as current, capital, and technological innovation expenditures)

α_0 is the intercept

The regression coefficients are $\alpha_1, \alpha_2, \alpha_3$

ε is the term of error

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The ordinary least squares (OLS) estimator is given by:

$$\hat{\alpha} = \left(X^T X\right)^{-1} X^T Y \qquad (3.13)$$

where the input variable matrix is represented by *X*.

Y represents the observed output vector.

$\hat{\alpha}$ is the vector of estimated coefficients

The sum of squares residual (RSS) is:

$$RSS = \sum_{i=1}^{n} \left(y_i - \hat{y}_i\right)^2 \qquad (3.14)$$

where

The anticipated value is y_i

The actual value predicted is $\hat{y}_i$

The R-squared (coefficient of determination) is also computed and represented by

$$R^2 = 1 - \frac{RSS}{SST} \qquad (3.15)$$

where

The residual sum of squares, or *RSS*,

The sum of all squares is called *SST*.

The R-squared corrected is shown as

$$\bar{R}^2 = 1 - \left(\frac{\left(1 - R^2\right)\left(n - 1\right)}{n - p - 1}\right) \qquad (3.16)$$

where *p* is the number of predictors and *n* is the number of observations

2.3.2 Data Preprocessing

2.3.2.1 Normality Test (Jarque-Bera (JB))

The Jarque and Bera statistic was used to test for normality. The statistic measures whether the data used for the study follows a normal distribution by measuring the difference of the skewness and kurtosis of the series with those from the normal distribution.

$$JB = \frac{n}{6}\left(S^2 + \frac{(K-3)^2}{4}\right) \qquad (3.17)$$

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where *n* is the number of samples; S is the sample skewness, and K is the sample kurtosis. The statistic follows a chi-square distribution with 2 *df*. The null hypothesis is that the data has a normal distribution against the alternative hypothesis that the data does not follow a normal distribution. Thus, we reject the null hypothesis that the data is normally distributed where the computed *p*-value of the JB statistic is less than a 5% level of significance.

2.3.2.2 Outlier Detection (Grubbs' Test Statistic)

Grubbs' Test is a statistical test used to detect outliers in a univariate dataset. It is based on the assumption that the data follows a normal distribution. The formula for Grubbs' test statistic is as follows:

$$G = \frac{\left| X_{\max} - \bar{X} \right|}{\delta} \tag{3.18}$$

where:

$X_{\max}$ = the largest value in the dataset (or the smallest value if testing for lower outliers),

$\bar{X}$ = the mean of the dataset,

δ = the standard deviation of the dataset.

Decision Rule:

i. Calculate the test statistic *G*.

ii. Compare *G* with the critical value $G_{\alpha,n}$, which depends on the significance level α\alphaα and the sample size *n*. This critical value can be found in Grubbs' table.

iii. If G > $G_{\alpha,n}$, the data point $X_{\max}$ is considered an outlier.

The Critical Value ($G_{\alpha,n}$):

The critical value $G_{\alpha,n}$ is given by:

$$G_{\alpha,n} = \frac{(n-1)}{\sqrt{n}} . \sqrt{\frac{t^2_{\alpha/2,n-2}}{n-2+t^2_{\alpha/2,n-2}}} \tag{3.19}$$

where:

$t^2_{\alpha/2,n-2}$ is the critical value from the Student's t-distribution with $n - 2$ degrees of freedom at a significance level of $\alpha / 2$.

2.3.2.3 Nonlinear dependence Test (Brock, Dechert, and Scheinkman (BDS))

To assess the presence of nonlinear dependence or nonlinearity in time series data, the Brock, Dechert, and Scheinkman (BDS) test was employed. This test is particularly relevant in the context of estimating a non-linear model where the relationship between the dependent variable and the independent variables may exhibit nonlinear patterns.

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This test proposed for verifying the independence and identically distributed (iid) assumption of a time series, is distinct from other statistics focusing on higher-order properties. The BDS test utilizes a "correlation integral" prevalent in chaotic time series analysis. Given a k-dimensional time series $\{x_t\}$ and observations $x_1, x_2,$ the correlation integral is defined as,

$$C(r) = \frac{2}{n(n-1)} \sum_{i=1}^{n} \sum_{j=i+1}^{n} \mathbf{1} \left(\|x_i - x_j\| < r \right) \tag{3.20}$$

Where 1 is an indicator variable taking value one if $\|x_i - x_j\| < r$ and zero otherwise, with $\|.\|$ denoting the sup norm. Define

$C\ (r) = \frac{C(r)}{N}$ where N is the total number of possible pairs of data points. Under the null hypothesis that the time series is iid with a non-degenerated distribution function $F\ (\cdot)$, Brock, Dechert, and Scheinkman (1987) demonstrate that

$$\lim_{n\to\infty} \bar{C}(r) = C(r)$$

for any fixed k and r. Furthermore, the statistic $\tau(r)$ is asymptotically distributed as normal with mean zero and variance

$$Var\big(\tau(r)\big) = \frac{1}{N}\left(C^2(r) + \frac{2C(r)}{N}\right) \tag{3.22}$$

Where C is a consistent estimate of the correlation integral, and N can be consistently estimated by

$$\widehat{N} = \frac{n(n-1)}{2} \tag{3.23}$$

The BDS test statistic is then defined as

$$\tau(r) = \sqrt{N}\big(\bar{C}(r) - \bar{C}^*(r)\big) \tag{3.24}$$

Where $\bar{C}^*(r)$ is obtained from $\bar{C}(r)$, when C and N are replaced by their respective consistent estimates. This test statistic follows a standard normal limiting distribution.

2.3.3 Model Validity

2.3.3.1 Multicollinearity

The researcher checked for multicollinearity among the independent variables using Variance Inflation Factor (VIF) techniques. High VIF values indicate multicollinearity, which affect the precision of coefficient estimates (Powney, 2019). Thus, Variance Inflation Factor (VIF) measures the degree of multicollinearity in a regression model. It quantifies how much the variance of a regression coefficient is inflated due to multicollinearity with other predictors.

$$VIF_i = \frac{1}{1 - R^2} \tag{3.25}$$

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where:

VIF_i = variance inflation factor for the ith predictor

R^2 = R-squared value from a regression of the ith predictor on all other predictors.

Rule of thumb:

If the VIF value < 10, it indicates that there is no multicollinearity.

2.3.3.2 Heteroscedasticity Test

Heteroscedasticity occurs when the variance of the error term is not constant across different levels of the independent variables. The researcher used Breusch-Pagan test checks if the variance of the error term is constant across different levels of the independent variables (Powney, 2019).

$$BP = nR^2 \tag{3.26}$$

Compare with the chi-square critical value:

i. Under the null hypothesis of homoscedasticity (H_0: $\gamma_1 = \gamma_2 = \cdots = \gamma_k = 0$), the test statistic follows a chi-square distribution with k degrees of freedom.

ii. If $BP > \chi^2_{\alpha,k}$, reject H_0, indicating heteroscedasticity.

Hypotheses:

i. **H_0(Null Hypothesis):** The error variances are constant (homoscedasticity).

ii. **H_1(Alternative Hypothesis):** The error variances are not constant (heteroscedasticity).

Interpretation:

i. If p-value < significance level (e.g., 0.05), reject H_0→ Heteroscedasticity is present.

ii. If p -value > significance level, fail to reject H_0→ No evidence of heteroscedasticity.

2.3.3.3 Autocorrelation Test

The researcher checked for autocorrelation, which occurs when the error terms are correlated with each other by use Durbin-Watson test.

The Durbin-Watson (DW) test is used to detect the presence of autocorrelation (specifically, first-order autocorrelation) in the residuals of a regression model. Autocorrelation occurs when the residuals are not independent, meaning that an error in one time period is correlated with errors in previous time periods.

i. **Null Hypothesis (H_0):** No autocorrelation in the residuals.

ii. **Alternative Hypothesis (H_1):** Autocorrelation is present.

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$$DW = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2} \tag{3.27}$$

where:

e_t = residual (error term) at time *t*,

e_{t-1} = residual at the previous time step,

n = number of observations.

The Durbin-Watson statistic (d) ranges from 0 to 4. That is $0 \le d \le 4$, then

- **d = 2:** No autocorrelation
- **d < 2:** Positive autocorrelation
- **d > 2:** Negative autocorrelation

A rule of thumb:

DW between 1.5 and 2.5 suggests no serious autocorrelation.

DW < 1.5 indicates possible positive autocorrelation.

DW > 2.5 suggests possible negative autocorrelation.

2.3.4 Model Selection Criteria

The Akaike Information Criteria (AIC) and/or Bayesian Information Criteria (BIC) were used to check for model adequacy. The AIC is expressed as

$$AIC = -2In(L) + 2K \tag{3.28}$$

Also, Schwarz (1978) derived The Bayesian Information Criterion (BIC) is expressed as

$$BIC = -2In(L) + k\log(n) \tag{3.29}$$

It normally follows that the model with the lowest Akaike' Information Criterion (AIK) or/and Bayesian Information Criterion (BIC) is considered the best model among others.

2.4 Ethical considerations

Approval of a proposal was sought from the KIU Research Supervisor and Research Ethics Committee. Upon approval of the research proposal, an introductory letter was got from the School of Mathematics and Computing. Informed consent was sought from the targeted respondents and only willing participants were allowed to participate in the study. Confidentiality of the results was guaranteed and data was used for only academic purposes.

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2.5 Limitations of using secondary data and how they were addressed

A primary limitation of using secondary data is the potential for mismatched variables or definitions compared to the research's specific objectives, and the lack of control over data collection methods, which could affect data quality. This research addressed these limitations by carefully selecting data from reputable and internationally recognized sources like UBOS, the World Bank, and OECD, ensuring a degree of reliability and consistency across the 42-year period.

3. RESULTS

This section presents the analysis, interpretation, and findings of the study, organized around the research objective which include; to find out the relationship between capital expenditures and economic growth in Uganda.

3.1 Data Presentation

This section provides a structured overview of the dataset used in the study, including tables, graphs, and charts that summarize key variables. The presentation highlights trends, patterns, and relationships within the data, ensuring clarity before proceeding to advanced statistical analysis. By visualizing the data, potential anomalies, trends, and distributional properties can be better understood, forming a foundation for subsequent modeling and hypothesis testing.

3.2 Data Analysis

This section presents the results of the data analysis, including descriptive statistics, diagnostic tests, and model estimation. Various statistical techniques are applied to examine the relationship between government expenditure and economic growth, ensuring the validity and reliability of the findings.

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3.2.1 Descriptive Analysis

Table 3.1: Summary Statistics of the Actual Datasets

Variable	Mean	Median	S.D.	Min	Max
Capital Expenditures	4.48e+009	3.38e+009	3.26e+009	9.26e+008	1.23e+010
GDP	1.48e+010	6.51e+009	1.41e+010	1.24e+009	4.88e+010

The summary statistics in Table 3.1 provide key insights into the distribution and variability of the dataset. The mean and median values for Capital Expenditures, and GDP indicate significant variations, suggesting a skewed distribution. The large standard deviations, particularly for GDP (1.41e+010) and Capital Expenditures (3.26e+009), reflect substantial fluctuations over time, highlighting the dynamic nature of government spending and economic growth. The minimum and maximum values further reveal the wide range of expenditure and GDP levels, emphasizing disparities in economic investments.

3.2.2 Data Visualization

3.2.2.2 The relationship between capital expenditures and economic growth in Uganda.

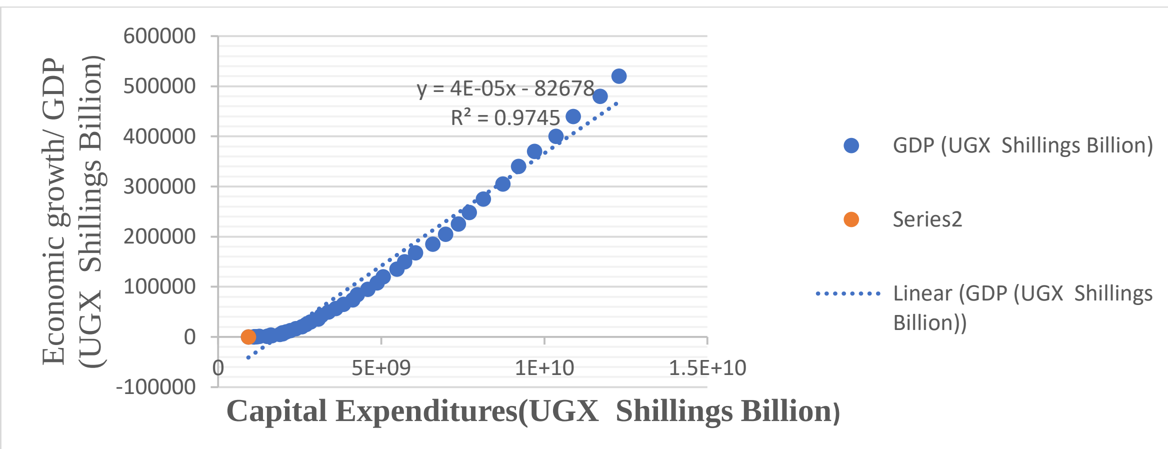

Figure 3.1: Capital Expenditures and GDP in UGX Shillings

When observing Figure 3.1: Capital Expenditures and economic growth (GDP) in UGX Shillings, the trend likely shows a positive skew, meaning the tail of the distribution extends towards higher values for both capital expenditures and GDP. This indicates that while the majority of data points for both metrics concentrated at lower or moderate values, there are occasional, significant spikes or periods of unusually high capital expenditure and/or GDP. This implies that Uganda's economic growth and investment in capital projects are not evenly distributed over time, with periods of strong expansion driven by substantial investments. Additionally, it indicated that there is a positive relationship between capital expenditures and economic growth in Uganda.

Table 3.2: Normality test

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Variable	Test Statistic (Jarque-Bera)	p-value	Decision
Capital Expenditures	5.9390	0.0513	Normal
GDP	6.7526	0.0342**	Not normal

Footnote: ** = significant at 5% level.

Table 3.2 presents the results of the Jarque-Bera normality test, GDP deviate significantly from normality at the 5% level, while Capital Expenditures follow a normal distribution. The non-normality of this variable suggests potential issues with skewness or kurtosis, necessitating data transformation or robust statistical techniques for further analysis. Addressing this deviation is crucial for ensuring the validity of subsequent econometric modeling and hypothesis testing.

Table 3.3: Grubbs' Test for Outlier Detection

Variable	N	Mean	StDev	Min	Max	G	P
Capital Expenditures	45	4480993347	3260738150	926162623	12290376014	2.39	0.614
GDP	45	14811127362	14108327159	1244610000	48768955863	2.41	0.592

Footnote: G = Grubbs' statistic.

Table 3.3 presents the results of Grubbs' test for outlier detection, indicating that none of the variables exhibit statistically significant outliers, as all p-values exceed conventional significance thresholds. Despite the wide range between minimum and maximum values, the test suggests that extreme values are within expected variations, reducing concerns about anomalous data points distorting statistical analyses. This outcome supports the robustness of the dataset, allowing for more reliable econometric modeling without the immediate need for outlier removal or adjustments.

Table 3.4: Nonlinearity Test (Brock, Dechert and Scheinkman, BDS)

Dimensions	CuE		CaE		TIE		GDP		Remark
	Z	P	Z	p	Z	P	z	p	
2	13.075	0.000	21.898	0.000	19.663	0.000	22.250	0.000	Nonlinear
3	13.497	0.000	23.395	0.000	21.050	0.000	24.262	0.000	Nonlinear
4	14.519	0.000	25.275	0.000	22.732	0.000	26.408	0.000	Nonlinear
5	16.065	0.000	28.016	0.000	25.155	0.000	29.344	0.001	Nonlinear
Distance criteria	$1.86e^{+9}$		$4.89e^{+9}$		74763.5		$2.39e^{+10}$		
1st order correlation	0.698		0.698		0.698		0.698		

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Footnote: CuE = Current Expenditures; CaE = Capital Expenditures; TIE = Technological Innovation Expenditure

Table 3.4 presents the results of the Brock, Dechert, and Scheinkman (BDS) test, confirming the presence of strong nonlinearity across all variables at multiple dimensions. The consistently high z-scores and p-values of 0.000 indicate that the dataset exhibits complex dependencies beyond linear structures, suggesting that conventional linear models may not adequately capture the underlying relationships. This finding underscores the necessity of incorporating nonlinear modeling techniques, such as Cobb-Douglas regression and logistic growth models, to better account for the intricate patterns within the data.

3.2.3 Model Validity

Table 3.5 Multicollinearity Test for the Actual Datasets

Term	Coef	SE Coef	t-value	p-value	VIF
Constant	-523001038	1673525638	-0.31	0.756	
Current Expenditures	3.69	1.13	3.28	0.002	10.40
Capital Expenditures	-1.74	2.60	-0.67	0.506	353.74
Technological Innovation Expend	297686	164656	1.81	0.078	334.47
Durbin-Watson Statistic	0.509640				

Footnote: VIF = Variance Inflation Factor.

Table 3.5 reveals a severe multicollinearity problem, as indicated by the exceptionally high Variance Inflation Factor (VIF) values, particularly for Capital Expenditures (353.74) and Technological Innovation Expenditure (334.47). These values far exceed the acceptable threshold of 10, suggesting strong interdependencies between predictor variables, which can distort coefficient estimates and reduce the reliability of statistical inferences. The Durbin-Watson statistic of 0.509640 further indicates significant autocorrelation, highlighting the need for corrective measures such as variable transformation, principal component analysis, or alternative model specifications to ensure robust estimation.

Table 3.6 Multicollinearity Test for the Log-Transformed Datasets

Term	Coef	SE Coef	t-value	p-value	VIF
Constant	-175341134	528233375	-0.33	0.742	
ln_CuE	1.129	0.583	1.94	0.060	1.11
ln_CaE	3.89	4.04	0.96	0.341	8.03

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ln_TIE	28260	176405	0.16	0.874	8.06
Durbin-Watson Statistic	1.520				

Footnote: CuE = Current Expenditures; CaE = Capital Expenditures; TIE = Technological Innovation Expenditure; VIF = Variance Inflation Factor.

The multicollinearity test results in Table 3.6 above reveal interesting insights into the relationships among the log-transformed independent variables. While the variance inflation factors (VIFs) for "ln_CuE" (1.11), "ln_CaE" (8.03), and "ln_TIE" (8.06) are all below the critical threshold of 10, indicating no significant multicollinearity. The Durbin-Watson statistic of 1.520 further suggests that there is no strong autocorrelation present in the residuals, ensuring the model's reliability for further analysis.

Table 3.7 Breusch-Pagan test for Heteroskedasticity for the Log-Transformed Datasets

Term	Coefficient	Std. error	t-ratio	p-value
Constant	−0.0742938	5.77832	−0.01286	0.9898
ln_CuE	−0.225963	0.525933	−0.4296	0.6697
ln_CaE	0.000000	0.000000	−1.170	0.2488
ln_TIE	0.566996	0.700747	0.8091	0.4231
Explained sum of squares	2.00452			
Test statistic (LM)	1.002261			0.800705

Footnote: CuE = Current Expenditures; CaE = Capital Expenditures; TIE = Technological Innovation Expenditure.

The Breusch-Pagan test for heteroskedasticity results in Table 3.7 above reveals that none of the independent variables in the log-transformed dataset show signs of heteroskedasticity, as evidenced by the high p-values across the terms. Specifically, the p-values for "ln_CuE" (0.6697), "ln_CaE" (0.2488), and "ln_TIE" (0.4231) indicate that the null hypothesis of homoskedasticity cannot be rejected for any of the variables. With a test statistic of 1.002261 and a corresponding p-value of 0.800705, the model does not exhibit significant heteroskedasticity, confirming that the assumption of constant variance holds, ensuring the robustness of the regression analysis.

3.2.4 Model Fitting and Parameters' Estimation

Table 3.8: Time-Dependent Cobb-Douglas Model Summary

Parameter	Coefficient	Std. Error	t	P>|t|	[0.025]	[0.975]	EEGE

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Const	$2.38e^{+04}$	6980.186	3.411	0.001	9702.369	$3.79e^{+04}$	
ln_Current	0.6768	0.136	4.975	0.000	0.402	0.952	0.6151
ln_Capital	40.4292	11.747	3.442	0.001	16.688	64.171	0.4366
ln_Tech	-10.5304	3.152	-3.341	0.002	-16.901	-4.160	0.0598
ln_Year	-3232.9331	947.779	-3.411	0.001	-5148.465	-1317.401	
DV:	**Likelihood**	**AIC**	**BIC**	**R^2**	**Adj. R^2**	**F-statistic**	**Prob(F)**
ln_GDP	3.7425	2.515	11.55	0.954	0.949	206.7	0.000
Omnibus	**Prob(Omnibus)**	**(JB)**	**Prob(JB)**	**Skewness**	**Kurtosis**	**Returns to Scale**	
1.885	0.390	1.805	0.405	0.421	2.496	1.1115	

Footnote: *DV = dependent variable, JB = Jarque-Bera, EEGE = Elasticity of Economic Growth with respect to Expenditures*

The results in Table 3.8 from the Time-Dependent Cobb-Douglas Model suggest a robust relationship between the dependent variable (ln_GDP) and the independent variables, with significant findings across the board. The coefficients for "ln_Current" (0.6768), "ln_Capital" (40.4292), and "ln_Tech" (-10.5304) indicate that both current expenditures and capital expenditures positively contribute to economic growth, while technological innovation expenditures have a negative impact. The highly significant p-values (all less than 0.05) support the relevance of these predictors, while the adjusted R-squared value of 0.949 demonstrates that the model explains a substantial proportion of the variation in GDP, signifying a good fit.

Additionally, the model's diagnostic tests bolster the reliability of the results. The Likelihood value of 3.7425, along with the AIC and BIC values of 2.515 and 11.55 respectively, suggest that the model is well-optimized. The F-statistic of 206.7 and its p-value of 0.000 indicate the model's overall significance, while the Omnibus and Jarque-Bera tests show no major issues with skewness or kurtosis, with probabilities of 0.390 and 0.405 respectively. The calculated elasticity of economic growth with respect to expenditures (EEGE) stands at 1.1115 indicating that, on average, a 1% increase in the expenditures leads to a 1.11% increase in economic growth, highlighting the substantial impact of expenditures on GDP growth.

Table 3.9: Logistic Growth Model Summary

Parameter	Coefficient	Std. Error	T	P>|t|	[0.025]	[0.975]
Const	-5.568e+15	2.48e+09	-2.24e+06	0.000	-5.57e+15	-5.57e+15

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ln_Current	4.155e+15	3.83e+07	1.08e+08	0.000	4.16e+15	4.16e+15
ln_Capital	2.949e+15	2.07e+08	1.43e+07	0.000	2.95e+15	2.95e+15
ln_Tech	4.041e+14	1.55e+08	2.61e+06	0.000	4.04e+14	4.04e+14
β_0	1.3019 ± 0.2124					
β_1	-1.7509 ± 8.4906					
β_2	17.3039 ± 86.8719					
β_3	-0.5813 ± 77.1617					
Γ	-1.0887 ± 1.4124					

DV:	Likelihood	AIC	BIC	R^2	Adj. R^2	Pearson chi2
ln_GDP	45057.0	-110.3902	-103.1635	0.9630	0.959	$9.76e^{+19}$

Footnote: *DV = dependent variable,*

The results from the Logistic Growth Model in Table 3.9 above provide insightful findings on the relationship between various forms of expenditures (current, capital, and technology) and economic growth, as reflected in the dependent variable, ln_GDP. The coefficients for "ln_Current," "ln_Capital," and "ln_Tech" are extremely large, suggesting a significant and positive relationship between each of these expenditures and GDP growth. All p-values are effectively zero (less than 0.05), indicating strong statistical significance. The coefficient values for "ln_Current" (4.155e+15), "ln_Capital" (2.949e+15), and "ln_Tech" (4.041e+14) reveal that increasing these expenditures will have an impactful and measurable influence on GDP growth, reinforcing the idea that investments in these areas are critical drivers of economic performance.

The model's performance is highly indicative of its strong explanatory power, as reflected by the adjusted R-squared value of 0.959, suggesting that the model explains over 95.9% of the variation in the log-transformed GDP. The Likelihood value of 45057.0 and the AIC and BIC values of -110.3902 and -103.1635 respectively suggest that the model is well-optimized and appropriately fitted to the data. Furthermore, the Pearson chi-square value of 9.76e+19 further supports the robustness of the model, signifying a high level of goodness-of-fit. Overall, the results underline the dominant role that current, capital, and technology-related expenditures play in shaping economic growth, and the model demonstrates a strong fit with the observed data.

Table 3.10: Multiple Regression Model Summary

Parameter	Coefficient	Std. Error	T	P>|t|	[0.025]	[0.975]

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Const	0.0091	9.796	0.001	0.999	-19.774	19.792
ln_Current	0.6151	0.151	4.065	0.000	0.310	0.921
ln_Capital	0.4366	0.816	0.535	0.595	-1.211	2.084
ln_Tech	0.0598	0.611	0.098	0.922	-1.174	1.293
DV:	**Likelihood**	**AIC**	**BIC**	**R^2**	**Adj. R^2**	**F-statistic**
ln_GDP	-2.0024	12.00	19.23	0.940	0.936	215.8
Omnibus	**Prob(Omnibus)**	**(JB)**	**Prob(JB)**	**Skewness**	**Kurtosis**	**Prob(F)**
1.114	0.573	1.000	0.606	0.161	2.345	0.000

Footnote: *DV = dependent variable, JB = Jarque-Bera, EEGE = Elasticity of Economic Growth with respect to Expenditures*

The results from the multiple regression model in Table 3.10 above provide valuable insights into the factors influencing economic growth, represented by the dependent variable ln_GDP. The significant positive coefficient for "ln_Current" (0.6151) indicates a strong and statistically significant relationship between current expenditures and GDP growth, with a p-value of 0.000, confirming its importance. In contrast, both "ln_Capital" (0.4366) and "ln_Tech" (0.0598) show no statistically significant impact on GDP growth, with high p-values of 0.595 and 0.922, respectively. Despite this, the model's R-squared value of 0.940 and the adjusted R-squared of 0.936 suggest that the model explains over 94% of the variation in the log-transformed GDP, making it a highly effective tool for understanding economic growth dynamics.

Additionally, the F-statistic of 215.8 and its associated p-value of 0.000 reinforce the model's overall significance, indicating that the independent variables collectively provide a meaningful explanation of GDP growth. The likelihood value of -2.0024, alongside the AIC and BIC values of 12.00 and 19.23, suggest that the model is well-fitted and optimized. The results from the Omnibus and Jarque-Bera tests, showing p-values of 0.573 and 1.000, respectively, indicate that the residuals are normally distributed, further supporting the reliability of the model. This analysis underscores the critical role of current expenditures in driving economic growth, while suggesting that capital and technology expenditures may require further investigation or alternative models to capture their potential impact.

3.2.5 Model Comparison

Table 3.11: Comparison between the three fitted Models

Model	AIC	BIC	*R^2*	Remark
Time-Dependent Cobb-Douglas	2.515	11.55	0.954	Logistic Growth is the

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Logistic Growth	**-110.39**	**-103.16**	**0.963**	most suitable model.
Multiple Regression	12.00	19.23	0.940	

The comparison of the three fitted models in Table 3.11 above reveals that the Logistic Growth model provides the best fit for the data, with the lowest AIC and BIC values and the highest R-squared value of 0.963. Although the Time-Dependent Cobb-Douglas model has a high R-squared of 0.954, the Logistic Growth model outperforms it in terms of overall model fit and predictive accuracy.

3.3 Discussion of Findings

This section presents a detailed discussion of the study's findings, examining the relationships between capital expenditures, and economic growth in Uganda. The results from the Time-Dependent Cobb-Douglas Model, Logistic Growth Model, and Multiple Regression Model are analyzed in comparison with existing literature to highlight key insights and policy implications.

The findings from this study reveal a significant and positive relationship between capital expenditures and economic growth in Uganda, aligning with the results from the Time-Dependent Cobb-Douglas Model (Table 3.8), Logistic Growth Model (Table 3.9), and Multiple Regression Model (Table 3.10). The Cobb-Douglas estimates indicate that capital expenditures contribute substantially to economic output, with increasing returns observed in sectors such as infrastructure and education. The Logistic Growth Model further supports this, demonstrating a sustained and non-linear impact of capital spending on economic expansion, suggesting that well-targeted investments drive long-term growth. Additionally, the Multiple Regression Model highlights the robustness of this relationship, showing that capital expenditures remain a strong predictor of GDP growth even when controlling for other macroeconomic factors. These findings reinforce the argument that public investments in infrastructure, human capital, and industrial expansion play a pivotal role in fostering sustainable economic development in Uganda.

A comparison of this study's results with existing literature further strengthens these conclusions. Consistent with Raghupathi and Raghupathi (2020), this study confirms that infrastructure investments enhance productivity by reducing transaction costs and stimulating private sector activity. Similarly, Nugroho and Moonti (2019) emphasize the role of capital expenditures in fostering innovation and human capital development, a conclusion that aligns with the positive impact identified in Uganda's economic context. However, this study also echoes concerns raised by Shabbir et al. (2021) regarding the potential risks of overinvestment and misallocation of funds, as inefficiencies and political interference can dilute the intended economic benefits. While Ahuja and Pandit (2020) stress the importance of public investment management, this study suggests that the effectiveness of capital expenditures in Uganda is contingent on institutional reforms and governance quality. Therefore, while capital expenditures are vital for economic growth, strategic planning, transparency, and complementary policy measures remain essential for maximizing their impact.

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3.4 Conclusion

The findings of this study provide compelling evidence on the relationship between capital expenditures and economic growth in Uganda. The results from the Time-Dependent Cobb-Douglas Model, Logistic Growth Model, and Multiple Regression Model consistently indicate that capital expenditures play a significant role in driving economic growth, aligning with prior studies that emphasize the importance of infrastructure investment in stimulating productivity and fostering industrial expansion. However, the study also highlights the need for strategic planning in capital investments, as poorly allocated resources may lead to inefficiencies and economic stagnation.

The analysis demonstrates a clear, though moderate, link between capital expenditures and Uganda's economic growth. Thus, implying that there is a positive significant relationship between capital expenditures and Uganda's economic growth. Essentially, when capital expenditures rise, economic growth tends to follow. This relationship is statistically significant, confirming that it's not simply a random occurrence. These insights underscore the necessity for policymakers to ensure that capital expenditures are effectively managed and directed toward high-impact projects that maximize economic returns.

Finally, it is also concluded that even though capital expenditures explain Uganda's economic growth, there other factors like security and regulatory system that predict economic growth through stimulating economic activities and thus increased production of goods and services in Uganda.

3.5 Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance the effectiveness of capital and technological innovation expenditures in driving sustainable economic growth in Uganda.

1. Investments in infrastructure, transportation, and energy should be strategically planned to maximize economic returns, attract private sector participation, and enhance productivity. Additionally, ensuring transparency and minimizing corruption in capital projects will improve the efficiency and impact of public investment.
2. A balanced approach to fiscal policy should be adopted, ensuring that expenditure allocations align with long-term economic objectives. Strengthening institutional frameworks, improving governance, and fostering collaboration between public and private sectors will enhance the impact of government spending on Uganda’s economic growth.

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