The Impact of Inflation and Unemployment Rates on Macroeconomic Model: Statistical Evidence from Sudan

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Received: 10.07.2024 Revised: 14.08.2024 Accepted: 22.09.2024

ABSTRACT
This article aims at investigating the impact of inflation and unemployment rates on Gross Domestic Product (GDP) for an econometric model using the most frequently econometric techniques, to estimate and forecast an econometric model. Results were compared to Ordinary Least Squares(OLS) and(Two Stages Least Squares(or Instrumental Variable method) to see if satisfactory results can be obtained. The proposed technique was applied to annual time series economic data, particularly GDP data for Sudan. The method used seemed to have little usefulness in the model; this might be due to the nature and the number of the explanatory variables under study.

Keywords: Inflation Rate Instrumental Variable; Lagged variables; Least Squares Estimators; Unemployment Rates.

1.INTRODUCTION

If one (or more) of the assumptions is violated, then OLS may not be the best estimation technique. Fortunately, econometric tools allow one to modify the OLS technique or use a completely different estimation method if the CLRM assumptions don't hold. When experimental manipulations are impossible, instrumental variable (IV) estimations, such as two-stage least squares (2SLS) regressions, are one possible solution to the endogeneity problem.Each endogenous variable becomes the dependent variable in the first stage regression equation. Each is regressed on all exogenous and instrument (X) variables. The predicted values from these regressions replace the original values of the endogenous variables in the second stage regression model. The purpose of this paper is to provide an overview of the impact of inflation and unemployment rates on Gross Domestic Product (GDP) for an econometric model for Sudan. Econometric techniques were used to estimate an economic model, to explain how various factors affect some outcome of interest or to forecast future events. The ordinary least squares (OLS) technique is the most popular method of performing regression analysis and estimating econometric models, because it produces optimal (the best possible) results when the model satisfies a series of statistical assumptions. The economic development and growth literature contains extensive discussions on relationships between economic factors that affect economic growth. The rise in inflation and unemployment rates signals a worsening decline in economic activities and sectoral production. This results in reduced investment levels, slower economic growth, and negatively affects the balance of payments by making exports relatively more expensive. We contribute to this literature by providing a comprehensive survey of underlying applied issue and describe the changes in Sudan economy that have occurred, over the last two decades, in the methodologies used to empirically examine for relationships between economic variables and economic growth to provide information on the current findings. This study aims at using a proposed regression method for coping with econometric problems such as multicollinearity among independent variables and compare the OLS and 2SLS estimates to see if better estimates may be gained based on an econometric model data.
In the next section we present the literature review about the topic, we describe the proposed model and investigate how it can be specified in section 3. In Section 4, we report model estimating results, while in Section 4 we present the analysis of the proposed model and discuss the results in section 5 .Section 6 concludes.

2.LITERATURE REVIEW

Early applications and discussions of regression models for coping with econometric problems such as multicollinearity among independent variables were found in many studies (see for instance B. Desta; etal(2002),Rodrik, D. (2008), Frank Wood (2009), Tarım , B.Dergisi(2011),(Fekedulegn,).Michael Sarel

(1995) explored the potential nonlinear effects of inflation on economic growth, identifying a significant structural break in the relationship between the two factors.Mashehdul Islam (2009) analyzed the relationships between exchange rates, inflation, and GDP in Bangladesh. Since moving from a currency board system to a floating exchange rate regime in 2003, Bangladesh's experience offers valuable insights into the efficiency of the floating rate system in least-developed countries. The study suggests that a successful free exchange rate regime can be achieved if the government maintains confidence in the currency, ensures its strength and convertibility, and holds sufficient foreign exchange reserves, supported by strong political and economic will.Martin et al. (2011) discovered a positive correlation between real exchange rate undervaluation and economic growth. Various explanations for this relationship suggest that the underlying mechanisms are likely stronger in developing countries.Evans and Antwi (2013) aimed to examine the impact of changes in inflation and interest rates on GDP in Ghana over the period from 1980 to 2010. Using multiple linear regression, the study found a fairly strong positive correlation between GDP, interest rates, and inflation. However, inflation and interest rates together could only account for 44% of GDP fluctuations.Zaroog(2013) examined the behavioral macroeconomic functions and the interactions between various macroeconomic variables and their impact on economic growth and policy stability from 1970 to 2005. The study employed a three-stage least squares estimation technique, showing that all equations were statistically significant. The results also highlighted periods of economic instability in Sudan, particularly between 1979-1981 and 1995-1996.Mukoka (2018) investigated the impact of inflation on economic growth in Zimbabwe, utilizing yearly time series data for inflation and GDP from 1990 to 2017. The study applied Ordinary Least Squares (OLS) to assess the effect of inflation on economic growth, revealing evidence of cointegration between the two variables. However, the findings indicated no significant relationship between inflation and GDP in Zimbabwe.

Extensive literature on the impact of inflation and unemployment rates on Gross Domestic Product (GDP) within econometric models and related issues has been explored by Elena-Adriana Andrei (2011), Khalafalla and Suliman (2013), Badreldin et al. (2016), Escanciano et al. (2016), Nizalova (2016), Jim Frost (2020), Mansfield (2020), and Sulaiman Abdalla (2022). Bollmann (2019) discussed the limitations of Instrumental Variable (IV) estimation, emphasizing the importance of weighing its estimates against the temporality criterion for causal inference and exploring its potential for analyzing change. He argued that estimates from traditional Ordinary Least Squares (OLS) regressions are often biased due to endogeneity, highlighting the need for alternative methods when reliable estimates are difficult to obtain.

3.The Model Description

Consider the following linear regression model:

$Y_i = \beta_{0+}\beta_1 x_1+\beta_2 x_2+\beta_3 x_3 + \mu_i$ ... [1]

where:

- Y_i is the dependent variable (outcome) for observation i
- x_i, are the independent variables (predictors) for observationi.
- $\beta_0, \beta_1, \ldots, \beta_k$ are the parameters (coefficients) to be estimated.
- μ_i is the error term or residual for observation i
- $i = 1,2, \ldots, ni = 1,2, \ldots, n$ refers to the i-th observation.

In matrix form, this can be written as:

$$Y = X\beta + u \ldots [2]$$

where:

- Y is an $n \times 1$ vector of the dependent variable.
- X is an $n \times (k + 1)$ matrix of the independent variables (including a column of ones for the intercept).
- β is a $(k + 1) \times 1$ vector of parameters (including the intercept term β_0.
- u is an $n \times 1$ vector of the residuals.

The objective of OLS is to minimize the sum of squared residuals:

Minimize:

$$S(\beta) = \sum_{I=1}^{n} u_i^2 = \sum_{I=1}^{n} (Y_i - \hat{Y}_i)^2 = \sum_{I=1}^{n} (Y_i - \sum_{j=0}^{k} \beta_j X_{JI})^2 \ldots [3]$$

In matrix notation, this becomes:

$$S(\beta) = (Y - X\beta)^T (Y - X\beta) \ldots [4]$$

To minimize the sum of squared residuals, we take the derivative of S(β) with respect to β and set it equal to zero:

$$\frac{\partial S(\beta)}{\partial \beta} = -2X^T(Y - X\beta) = 0 \ldots [5]$$

After simplifying this gives the solution to the normal equations and obtained by solving for β:

$$=X^T X\beta - X^T Y \ldots [6]$$

$$\hat{\beta} = (X^T X)^{-1} XY \ldots [7]$$

This equation provides the OLS estimator $\hat{\beta}$, which is the vector of estimated regression coefficients.$\hat{\beta}$ is the vector of estimated coefficients that minimizes the sum of squared differences between the observed values Y and the predicted values $\hat{Y} = X\hat{\beta}\{Y\} = \hat{X}\{\hat{\beta}\}\hat{Y} = X\hat{\beta}$ to reach to the formula for calculating the best-fitting line (or hyperplane) in the context of OLS regression.

The predicted values of Y denoted by$\hat{Y}$ can be obtained by:

$$\hat{Y} = X\hat{\beta} \ldots [8]$$

The residuals u, which are the differences between the observed and predicted values, are calculated as:

$$\hat{u} = Y - \hat{Y}$$

$$=Y - X\hat{\beta} \ldots [9]$$

In summary, the OLS method estimates the coefficients by solving the normal equations to minimize the sum of squared residuals. The OLS solutiongives the best linear unbiased estimates under the assumption that the error terms are homoscedastic, uncorrelated, and have zero mean.

A two-stage regression model, also known as a Two-Stage Least Squares (2SLS) model, is typically used when dealing with endogeneity in a regression model. Endogeneity can occur due to omitted variables, measurement errors, or simultaneity, where one or more independent variables are correlated with the error term. The 2SLS method solves this by using instrumental variables that are correlated with the endogenous explanatory variables but not with the error term. Here are the steps and the equations for a two-stage regression model:

In the first stage, you regress the endogenous variable(s) on the instrumental variable(s) and other exogenous variables to estimate the predicted (fitted) values of the endogenous variables. These predicted values will be uncorrelated with the error term and can then be used in the second stage.

Let the original model be:

$$Y = \beta_{0+} + \beta_1 X_{1+} + \beta_2 X_2 + u \ldots [10]$$

where:

- Y is the dependent variable.
- X_1 is an endogenous explanatory variable.
- $X_2$is an exogenous explanatory variable.
- u is the error term.
- $\beta_0, \beta_1, \beta_2$ are parameters to be estimated.

In the first stage, we replace the endogenous variable X_1 with an instrumental variable $Z_{1,}$, which is correlated with X_1 but uncorrelated with the error term. We run the following regression:

$$X_1 = \pi_0 + \pi_1 Z_1 + \pi_2 X_2 + vX_1 \ldots [11]$$

$$= \pi_0 + \pi_1 Z_{1,} + \pi_2 X_2 + vX_1 \ldots [12]$$

$$= \pi_0 + \pi_1 Z_{1,} + \pi_2 X_2 + vX_1 + v \ldots [13]$$

where:

- $Z_{1,}$is the instrumental variable for X_1
- v is the error term.
- π_0 , π_1 , π_2 are parameters to be estimated.

From this regression, we obtain the predicted value of X_1, denoted as $\widehat{X_1}$

In the second stage, we substitute the endogenous variable X_1 with its predicted value $\widehat{X_1}$ from the first stage. The second-stage regression equation is:

$$Y = \beta_{0+} + \beta_1 \widehat{X_1} + \beta_2 X_2 + \varepsilon Y \ldots [14]$$

where:

- $\widehat{X_1}$ is the predicted value from the firststage.
- ε is the new error term (which should no longer be correlated with $\widehat{X_1}$.
- **Summary of the Two Stages:**

1. Stage 1 (Instrumental Variable Regression):

$$X_1 = \pi_0 + \pi_1 Z_1 + \pi_2 X_2 + vX_1 \ldots [11]$$

$$X_1 = \pi_0 + \pi_1 Z_1 + \pi_2 X_2 + v \ldots [13]$$

Obtain predicted values $\widehat{X_1}$.

2. Stage 2 (Main Regression with Predicted Values):

$$Y = \beta_{0+} + \beta_1 \widehat{X_1} + \beta_2 X_2 + \varepsilon Y \ldots [14]$$

$$= \beta_{0+} + \beta_1 \widehat{X_1} + \beta_2 X_2 + \varepsilon \ldots [15]$$

In this way, the 2SLS method addresses the endogeneity problem by using instrumental variables to create exogenous fitted values for the endogenous variable, allowing for unbiased and consistent estimates of the regression coefficients.Two-Stage least squares (2SLS) regression analysis is a statistical technique that is used in the analysis of structural equations. This technique is the extension of the OLS method. It is used when the dependent variable's error terms are correlated with the independent variables. Additionally, it is useful when there are feedback loops in the model. structural equations modelling, we use the maximum likelihood method to estimate the path coefficient. This phenomenon commonly occurs when many independent variables are incorporated in a regression model. Multicollinearity is not the only violation of the OLS assumptions. However, an accurate multicollinearity violates the assumption that the matrix **X** is given the highest rank, which makes the OLS impossible. When a model does not reach the peak, which is the inverse of **X** that cannot be defined, an infinite number of least squares solutions is obtained.

4.Data Analysis

Sudan has experienced lengthy social conflict, civil war, and, in July 2011, the loss of three-quarters of its oil production due to the secession of South Sudan. The oil sector had driven much of Sudan's GDP growth since 1999. Since the economic shock of South Sudan's secession, Sudan has struggled to stabilize its economy and make up for the loss of foreign exchange earnings. The interruption of oil production in South Sudan in 2012 for over a year and the consequent loss of oil transit fees further exacerbated the fragile state of Sudan's economy. A Sudanese econometric model was estimated with annual observations covering the underlying period. The best method to choose depends mainly on the information available. However, if more than one method can be applied, forecasters typically use all the methods that are possible and rely on the one with the greatest forecast accuracy.For a given time series variable, cases with missing values are not used in the analysis. Also, cases with negative or zero values are not used if the log transform is requested. Maximum Number of Lags in Autocorrelation or Partial Autocorrelation Plots equals 16.Maximum Number of Lags Per Cross-Correlation Plots = 7.Confidence Interval Percentage Value=95.Tolerance for Entering Variables in Regression Equations = .0001.

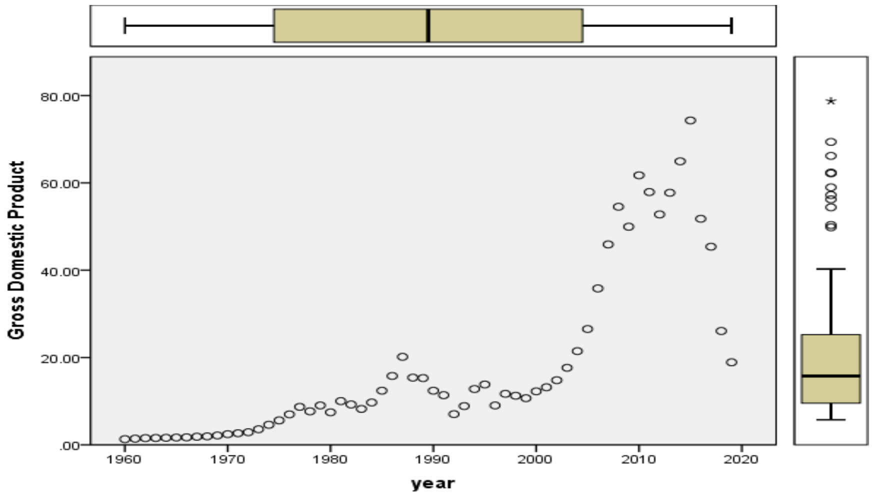

Figure 1:GDP Stats regression plot variables: GDP,Year.

Figure (1) shows a line graph of GDP levels in the period under consideration. Overall, the line graph shows a clear dominance of a long-term upward trend, suggesting a non-stationary time series in levels. Regression plots for exports and imports are presented in figure (2) and figure(3) respectively, while inflation rates plots are shown in figure(4).The descriptive graph (figure (1),(figure (2)and (figure (3) suggested upward trend for the series although there is deterioration (downward) after the year 2010 due to the loss of petroleum exports after the secession of South Sudan.

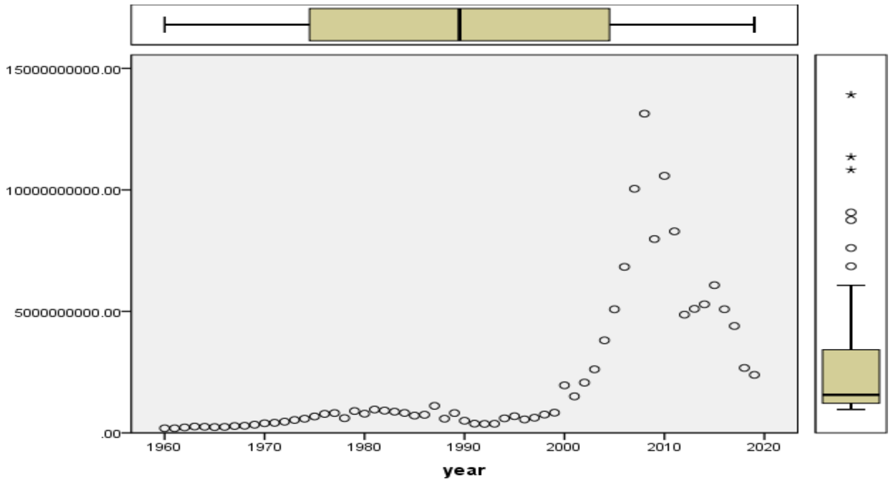

Figure 2: Stats regression plot variables : Exports Year

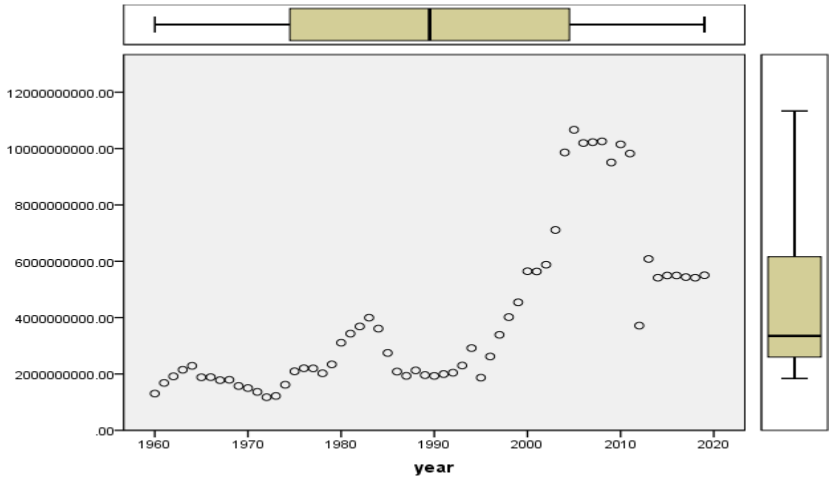

Figure 3: Stats regression plot variables :Imports ,Year**.**

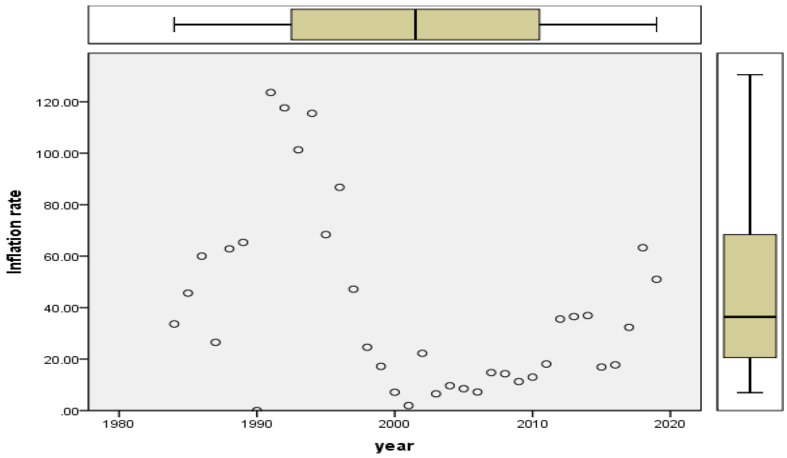

Figure 4: Inflation rates.

From table(1) the correlation coefficient R for each of the four models exceeds 0.80wherethe R square is about 0.64 with almost 11.8 standard error of estimate except for the fourth model where the R value is 0.93 and the R square is about 0.87with very low standard error of estimate(0.417).

Table 1: ANOVA Gross Domestic Product Models summary.

Model type	R	R square	Adjusted R Square	Std. Error of the Estimate
Linear	.801	.642	.636	11.798
Logarithmic	.800	.640	.634	11.825
Quadratic	.802	.643	.637	11.770
Logistic	.934	.873	.870	.417

Source: Author's processing

In this analysis of GDP data, a summary of the model descriptive statistics for GDP) is given in table(2),where one way ANOVA Summary for the same model is shown in table (2)for the classical regression model .

Table 2: ANOVA for Gross Domestic Product model.

Model	Sum of Squares	df	Mean Square	F	Sig
Regression 1	Regression : 14458.993 Residuals : 8072.756 Total : 22531.749	1 58 59	14458.993 139.185	103.883	.000
Regression 2	Regression : 14421.122 Residuals : 8110.627 Total : 22531.749	1 58 59	14421.122 139.838	103.127	.000
Regression 3	Regression : 14496.461 Residuals : 8035.288 Total : 22531.749	1 58 59	14496.461 138.539	104.638	.000
Regression 4	Regression :69.015 Residuals : 10.083 Total : 79.097	1 58 59	69.015 .174	397.002	.000

Source: Author's processing

Table (3) show Model insignificant results for small using t test due to lower size of observations.

Table 3: Model significance using t test.

		Unstandardized Coefficients		Beta	t	Sig.
		B	Std. Error			
Equation 1	(Constant)	-221.522-	571.074		-.388-	.710
	Exports	5.949E-9	.000	1.483	.348	.738
	Inflation_1	-.321-	1.873	-.413-	-.171-	.869
	Unemployment_1	14.847	24.993	1.805	.594	.571

Source: Author's processing

Table 4: Correlations Coefficient

			Exports	Inflation_1	Unemployment_1
Equation 1	Correlations	Exports	1.000	.961	.978
		Inflation_1	.961	1.000	.909
		Unemployment_1	.978	.909	1.000

Source: Author's processing

Regression analysis was run using Unemployment rate , Exports of goods and services, Inflation rate as predictors and Gross Domestic Product as dependent Variable . The coefficients for the two-stage model are presented in table(4) ,while descriptive Statistics for model variables with 60 series observations are summarized in table (5).

Table 5: Descriptive Statistics for model variables.

	Mean	Std. Deviation	N
Gross Domestic Product	18.4523	19.54211	60
Exports of goods and services	89.3660	549.20802	60
SMEAN(Inflation)	40.5974	26.08823	60
SMEAN(Unemployment)	15.9990	.70322	60

Source: Author's processing

Two-Stage Least Squares was applied using New variable 2SLS GDP With Exports ,Inflation-1, Unemployment-1.Instrument: Population ,GNI and Infant mortality. GDP Dependent, exports and inflation predictors, unemployment ,predictor, population instrument ,GNI instrumental.The multiple R for the model is 0.939 and the R square is 0.881 with 6.91702 standard error of estimate(table(6)) .

Table 6: Gross Domestic Product.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.939[a]	.881	.875	6.91702	.881	138.310	3

Source: Author's processing

The F value(138.310)for the two-stage regression is highly significant (table 7).Note :Predictors: (Constant), SMEAN(Unemployment), Exports of goods and services, SMEAN(Inflation).

Table 7: ANOVA: Dependent Variable: Gross Domestic Product.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19852.418	3	6617.473	138.310	.000[b]
	Residual	2679.331	56	47.845		
	Total	22531.749	59			
Source: Author's processing						
Note :Predictors: (Constant), SMEAN(Unemployment), Exports of goods and services, SMEAN(Inflation)						

Residuals statistics for Gross Domestic Product are presented in table(8),the Coefficients in table(9) and Correlations Coefficient are presented in table(10).

Table 8: Residuals Statistics for Gross Domestic Product.

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	4.4948	73.9664	18.4523	18.34344	60
Residual	-19.43939-	25.28138	.00000	6.73887	60
Std. Predicted Value	-.761-	3.026	.000	1.000	60
Std. Residual	-2.810-	3.655	.000	.974	60

Source: Author's processing

The standard error of regression here became smaller than in the precedent one and so is the sum squared residuals.

Table 9: Coefficients of two stage model.

		Unstandardized Coefficients				
		B	Std. Error	Beta	t	Sig.
Equation 1	(Constant)	-226.106-	54.467		-4.151-	.000
	Exports	7.588E-9	.000	1.150	.	.
	Inflation_1	.206	1.071	.274	.192	.849
	Unemployment_1	13.717	2.444	.494	5.613	.000

Source: Author's processing

Table 10: Correlations Coefficient.

			Exports	Inflation_1	Unemployment_1
Equation 1	Correlations	Exports	1.000	.991	-.287-
		Inflation_1	.991	1.000	-.295-
		Unemployment_1	-.287-	-.295-	1.000
	Covariances	Exports	1.213E-17	3.698E-9	-2.443E-9
		Inflation_1	3.698E-9	1.147	-.772-
		Unemployment_1	-2.443E-9	-.772-	5.971

Source: Author's processing

5.DISCUSSION

Sudan GDP Annual Growth Rate Forecasts are projected using two stage regression model. We model the past behavior of Sudan GDP Annual Growth Rate using historical data and adjustments of the coefficients of the econometric model by considering analysis assessments and future expectations. It can be seen that time series are very complex because each observation is somewhat dependent upon the previous observation, and often is influenced by more than one previous observation. Random error is also influential from one observation to another. It should be noted that, in econometric model, the classical OLS method is not recommended when the number of explanatory variables been included in a function is very large relative to size of the sample, or when there is a need to check for problem of multicollinearity. We evaluate the impact of inflation and unemployment rates on economic growth(Gross Domestic Product) for an econometric model of the GDP series using four different equations which are , linear, logarithmic, quadratic, and logistic equations(the latter seems not preferable but used for comparison). Based on the parameter values, we found that the the best model for the data. We provide method for prediction and forecasting based on data, which may be applicable and useful to government and business institutions. Thus, if we rely on this information, we may conclude that we have a good fit for the impact of inflation rates and unemployment rates on economic growth .From table (4)and table(9),we could put the model using inflation rates and unemployment rates as the following form:

$$y = \beta_0 + \beta_1 x_i \text{ , or}$$

GDP= $0.206 + .274x_{1,}$with standard error(1.071)for β_1 .

GDP= $-2.443E - 9 + -.772 - x_1$, with standard error(2.444)for β_1 .

6.CONCLUSION

This paper has discussed the impact of inflation and unemployment rates on Gross Domestic Product (GDP) for an econometric model of the Sudan . It is assumed that the values of the estimated parameters are constant throughout the series. An important policy consideration rises from the study is that there is increasing trend for the model of the data. More advanced future work can be done based on these investigations, particularly in residual analysis of the model.

Our current study focused solely on the effects of inflation and unemployment rates on economic growth from 1960 to 2020, utilizing a macroeconomic modelbased onclassical regression model. Future research can build on this topic using Box-Jenkins methodology to gain more accurate results and forecasting by exploring the following areas:

1. Examine the influence of ongoing conflict and political instability on inflation in Sudan and its impact on economic growth.
2. Analyze the effect of tax collection and enforcement on inflation rates and budget deficits in Sudan.
3. Investigate the potential advantages of promoting foreign investment in Sudan and its role in fostering economic growth.
4. Study the benefits of collaboration with international organizations and neighboring countries for Sudan's economic development.
5. Investigate the effects and problems of corruption, poverty, unemployment, and investing in key sectors for economic diversification and growth in Sudan.

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