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Challenges to Economic Development in Developing Countries: Case Study of Sudan's Economic Conundrum

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study explores the challenges to economic development in Sudan, a country endowed with substantial natural resources yet struggling to achieve sustainable growth. By utilizing time series data from 2002 to 2022, the research analyzes the relationship between Sudan's GDP growth rate and key economic indicators, including inflation rate, unemployment rate, FDI inflows, and net exports. Despite these factors' recognized significance, empirical analysis reveals a weak correlation between these variables and GDP growth, suggesting the presence of other underlying influences. The findings highlight that political instability, ineffective governance, and external economic pressures might be critical barriers to Sudan's development. Strategic recommendations are proposed to address these issues, focusing on improving policy frameworks, enhancing economic diversification, and fostering regional cooperation.

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JEL Codes: O4, O11, O55

1. INTRODUCTION

Economic development is the process that aim to enhance the growth of countries' economies by implementing many development plans that make them more advanced and developed, which has a positive impact on society by implementing a set of successful economic strategies and benefiting from the wealth available in their environments. It is regarded as important for a country to reduce its poverty by providing more employment, higher income, improve good and services, and the latest technologies of production [1].

The developing countries are characterized by common features such as high demographic growth, dependence on raw materials exports and poor level of education, which led to weak technological development. These countries also suffer from several problems that prevented them from achieving their development goals [2]. Poor production, large deficits in meeting the population's basic needs—such as food and health services—the spread of unemployment, and high external debt levels exacerbate these issues, creating barriers that hinder sustainable economic growth and social progress [3].

Sudan is considered one of the most developed African countries in term of natural resources, forests, rivers, and gold. Unfortunately, Sudan is still an undeveloped country due to many challenges that face economic development. However, Sudan needs programs implemented to raise the level of development.

A study about the general socioeconomic characteristics of Sudan and statistic problems for development in the country discusses the impact of oil and opportunities and challenges for enhancing economic development in Sudan, and found that Sudan needs to promote local skills and technologies to facilitate the implementation of five strategies of reducing poverty; achieving economic diversification; reducing unemployment and restructuring the labor market; building local technological capacity, and achieving long-term stabilization, sustainable and balanced economic growth and development [4].

Recently, global attention has increasingly focused on development issues, particularly in the context of developing countries. Many nations in the developing world, including Sudan, face significant barriers to economic development despite possessing enormous natural resources that could potentially drive growth. These barriers are multifaceted, encompassing economic, social, and political factors that create complex challenges for sustainable development.

This study is crucial as it not only outlines the specific challenges to economic development in developing countries generally but also delves deeply into the unique context of Sudan. By examining Sudan's economic conundrum, the study highlights the paradox of resource-rich countries struggling to achieve economic prosperity. Understanding these challenges is essential for formulating effective policies and strategies that can unlock the potential of these economies.

Moreover, the insights gained from this research are not only relevant to Sudan but also have broader implications for other developing countries facing similar obstacles. Identifying and addressing these challenges is vital for fostering global economic stability, reducing poverty, and achieving sustainable development goals. Therefore, this study serves as a foundational step toward developing appropriate, evidence-based solutions that can advance the economies of Sudan and other similarly situated nations.

1.1 Problem of the Study

The economies of developing countries, including Sudan, are often characterized by the abundant availability of natural resources in various forms. These resources hold the potential to significantly promote economic development, which could reduce these countries' reliance on external support and aid. However, despite the presence of these valuable resources, many developing nations, and Sudan in particular, have struggled to achieve the level of economic development that one might expect.

This paradox raises critical questions about the underlying factors that hinder economic

progress. The core problem this study seeks to address is: What are the specific obstacles that prevent Sudan, and other developing countries, from realizing their economic potential despite their resource wealth? Furthermore, what solutions can be identified to overcome these barriers and foster sustainable economic development? By exploring these questions, the study aims to uncover the complex interplay of economic, social, and political factors that contribute to this persistent challenge, and to propose actionable strategies for overcoming them.

1.2 Objective of the Study

To address the critical challenges identified in the context of Sudan's economic development, it is essential to explore the underlying factors that have hindered progress despite the country's resource wealth. Therefore, this study is guided by the following objectives:

1. To Assess the Relationship Between Key Macroeconomic Indicators and GDP Growth in Sudan.
2. To Identify the Limitations of Conventional Macroeconomic Indicators in Explaining Sudan's Economic Growth Dynamics.
3. To Propose Strategic Recommendations for Overcoming Economic Development Barriers in Sudan.

2. LITERATURE REVIEW

To effectively address the objectives of this study, it is crucial to first understand the existing body of knowledge surrounding the challenges of economic development in resource-rich developing countries. Our literature review explores significant theories, past research, and key insights so as to explain the factors behind economic stagnation.

A study in Kenya found that there are myriad of challenges in achieving economic development, among them, Government debt, poverty and inequality, population, over-reliance on Agriculture, BOP and foreign exchange Gap, insecurity and political instability, poor education and Human capital constraint, Healthcare, poor taxation, corruption and poor Governance [5].

A research study the barriers within economic development which differentiate the issues and problem in economic growth procedure in Pakistan found that the most common barriers are financial issue, negative human resource policies, micro inflation and corruption in public and private projects [6].

All developing nations of the world face barriers to economic development of which some are internal and some external which they have no or very little control such as; lack of capital formation, resources are under-utilized, mis-utilized or unutilized, lack of marketable surplus of agriculture, Poor currency strength, poor economic system, Inadequate financial markets, Lack of infrastructure, lack of skilled human resources, lack of technical know-how and general education, Corruption, Weak legal system, Ineffective tax structures, Political instability [7].

A research done by Abdulrahman investigates the influence of exports on Sudan's economic development between 1990 and 2016. In this analysis, GDP is utilized as the dependent variable to signify economic development, while exports and gross fixed capital formation (local investment) serve as the independent variables. The findings from the econometric model indicate that exports have a negative impact on economic development. Conversely, there is a significant positive relationship between local investment and economic development throughout the study period [8].

Since the start of 2018, Sudan has been grappling with significant economic difficulties. The removal of subsidies on wheat and flour in February 2018, along with repeated devaluations of the Sudanese Pound, led to shortages of vital goods and foreign currency. This economic crisis has disrupted public services, hindered agricultural activities, and caused substantial price hikes for basic food items (Food and Agriculture Organization, 10 December 2018; Famine Early Warning Systems Network, December 2018) [9].

A study examining the impact of Sudanese agricultural exports on the gross domestic product (GDP) for the period 2005-2018 found a statistically significant correlation between GDP and agricultural exports in Sudan. The study recommended the development of a dedicated program to advance manufacturing industries that process agricultural raw materials, which are currently exported in their unprocessed form Jamea [10].

A study by Yassin Eltahir, the Sudanese economy's fundamental makeup precludes the use of the market mechanism to address imbalance. As a result, the implementation of any market-based policy offers a means of restructuring economic variables through the reconstruction of the financial (credit and monetary) and real (product)sectors in a manner that permits the beneficial effects of the market mechanism. To stimulate productive and consumer activity through fiscal and monetary policy, the Sudanese economy must first restructure itself so that supply and demand return to their proper framework. Only then can the economy be appropriately applied based on this mechanism [11].

According to a study by İbrahim Keskin, Sudan's sustainable development is hampered by several challenges, including administrative inefficiencies and a lack of infrastructure. Corruption is highlighted as a significant barrier to achieving sustainable progress in the country. The study notes that Sudan's vast geographic area complicates the planning process. Since independence, political instability has led to the marginalization of some communities, which has, in turn, sparked the emergence of armed movements with specific demands. Keskin also points out a decline in essential services such as education, healthcare, and environmental protection. The secession of South Sudan and the subsequent loss of 70% of Sudan's oil revenue have further hindered development efforts. Additionally, the displacement of populations from key agricultural regions, including South Kordofan, Darfur, and Blue Nile, has contributed to the deterioration of rain-fed agriculture. The study concludes that the Sudanese government should focus more on revitalizing and investing in these productive areas [12].

A study examines the nature of the connection between political instability and economic growth in a few nations that have experienced political unrest, such as Egypt and Sudan, between 1994 and 2019. Both statistically and economically, the study conclude that political instability and economic growth are significantly negatively. The significance of transmission routes that uphold the strong inverse relationship between political instability and economic progress in emphasized in recommendations [13].

The relationship between economic development and the levels of rule of law, political instability, and violence in the Greater Horn of Africa from 2015 to 2019 was found to have a positive association, where, on average. Lower economic development was associated with a weak rule of law, violence and political instability. On the contrary, improved economic development was associated with improved rule of law, political stability, and the absence of violence [14].

A study measured the impact of some microeconomic factors that influence the economic growth of a developing country, Kosovo, using the gross domestic product GDP as a dependent variable, and the independent variables are; private consumption, remittance, export, and employment. The study concludes that the independent variables have a positive impact on economic growth measured by GDP. The study recommended that increasing employment, and increasing the export to gain economic growth and sustainability [15].

There are many obstacles facing countries, some of which are natural, some are economic, represented by the different conditions, most of which rely on the export of natural raw materials in their various forms, and this is what makes them unstable and vulnerable to fluctuation in global market, and governs from the major industrial countries, including some that are social; its forms are evident in the spread of illiteracy, poverty, ignorance, disease, the spread of corruption, and others [16].

3. METHODOLOGY

This study employs a quantitative research design, utilizing time series data from 2002 to 2022 to analyze the factors influencing Sudan's economic development. The data collected (Table 1) includes GDP growth rate, inflation rate, unemployment rate, FDI inflows as a percentage of GDP, net exports and population growth rate (Table 1).

We initiated the analysis by summarizing the dataset with descriptive statistics to visualize key trends and patterns in the economic indicators. Next, we conducted stationarity tests, including the Augmented Dickey-Fuller (ADF) test, to assess the stability of the time series data. We then performed correlation analysis to identify preliminary relationships between the GDP growth rate and other variables. Following this, we applied multiple linear regression to examine the impact of inflation, unemployment, FDI inflows, and net exports on GDP growth, using

population growth, poverty rate, and literacy rate as control variables. To validate our model, we conducted diagnostic tests to check for multicollinearity, autocorrelation, and heteroskedasticity. By concluding our empirical analysis at this stage, we focused on deriving meaningful insights from the regression results, which provided a solid foundation for formulating strategic recommendations to address Sudan's economic challenges.

3.1 Variable Classification

The study classified variables into three categories: the dependent variable (GDP growth rate), independent variables (inflation rate, unemployment rate, FDI inflows, and net exports), and control variables (population growth rate). This classification ensures a structured analysis of their relationships and impacts on economic growth

Table 1. Operational definitions of model variables

Variable	Label
Dependent Variable	
GDP Growth Rate	Y
Independent Variable	
Inflation Rate	X_1
Unemployment Rate	X_2
FDI Inflows as % of GDP	X_3
Net Exports as % of GDP	X_4
Control Variable	
Population Growth Rate	C_1

Source: Researcher's construction

3.2 Model Equation

GDP Growth Ratet=β0+β1Inflation Ratet+β2 Unemployment Ratet+β3FDI Inflowst+β4 Net Exportst+β5Population Growth Ratet+ϵt

Or

$$\mathrm{Yt} = \beta 0 + \beta 1X1t + X2t + X3t + \beta 4X4t + \beta 5C1t + \epsilon t$$

Where:

β0 is the intercept of the regression line
β1,β2,…,β7 are the coefficients representing the effect of each independent variable on the GDP growth rate.

ϵt is the error term at time t, representing the unexplained variation in GDP growth.
t represents time period.

3.3 Empirical Results

3.3.1 Descriptive statistics

In this study, we applied the natural log transformation to variables that were strictly positive, such as inflation rate, unemployment rate, FDI inflows and population growth rate. For variables like GDP growth rate (Y) and net exports (X4), which contain negative values, we adjusted the data by adding a constant to shift all values into the positive range before applying the log transformation (Table 2).

The descriptive statistics for the natural log-transformed variables reveal insightful trends (Table 2). The skewness and kurtosis metrics indicate the distributions of variables are notably asymmetric and leptokurtic, particularly for GDP growth, highlighting the presence of extreme values. The Jarque-Bera test confirms that the transformed variables significantly deviate from normality ($p < 0.001$), reinforcing the appropriateness of further analysis on these transformed datasets.

3.3.2 Test of stationarity

The unit root test was conducted to assess the stationarity of the variables used in the analysis (Table 3). The null hypothesis (H0) states that the data is non-stationary and has a unit root. The rejection of the null hypothesis for all variables signifies that the data does not contain a unit root, confirming stationarity at the specified levels or differences. This ensures that the time series data is suitable for further analysis without the risk of spurious regression results.

3.3.3 Correlation analysis

The correlation matrix indicates that the independent and control variables do not show a significant relationship with the GDP growth rate, as evidenced by their relatively low correlation coefficients (Table 4). This lack of significant correlation means that the independent and control variables in your study might not have a direct linear relationship with the GDP growth rate.

3.3.4 OLS Regression analysis

The multiple regression results provide further evidence that the independent and control

variables do not significantly explain the variability in the GDP growth rate (Table 5). The p-values for each independent variable are all above the common significance levels (0.05 or 0.1), indicating that none of these variables have a statistically significant impact on the dependent variable (GDP growth rate). The R-squared value of 0.328 and adjusted R-squared value of 0.088 suggest that the model explains only about 32.8% and 8.8% of the variability in the GDP growth rate, respectively. The F-statistic's p-value of 0.294 is also above the common significance levels, implying that the overall regression model is not statistically significant.

Table 2. Descriptive Statistics

	lnshiftedY	lnX1	lnX2	lnX3	lnshiftedX4	lnC1
Mean	-1.772	-1.342	-1.812	-3.673	-2.873	-3.618
Median	-1.611	-1.709	-1.768	-3.665	-2.727	-3.597
Maximum	-1.405	1.278	-1.650	-2.761	-1.965	-3.408
Minimum	-4.605	-2.735	-2.040	-4.804	-4.605	-3.907
Std. Dev.	0.675	1.069	0.107	0.537	0.666	0.132
Skewness	-3.731	0.885	0.281	-0.412	-0.840	-0.381
Kurtosis	16.279	3.102	2.025	2.641	3.303	2.644
Jarque-Bera	202.991	2.749	1.109	0.708	2.548	0.619
Probability	0.000	0.253	0.574	0.702	0.280	0.734
Sum	-37.209	-28.172	-38.061	-77.141	-60.338	-75.992
Sum Sq. Dev	9.125	22.853	0.231	5.774	8.868	0.348

Source: EViews results

Table 3. Unit root test null hypothesis (H0): there is no stationarity in the data and it has a unit root

Variables after unit root test	Result of stationarity	Result of Null Hypothesis
Y (0)	Y is stationary at level without trend and intercept	H0 is rejected as critical value is 0.0072
X1(1)	X1 is stationary at 1st difference with intercept	H0 is rejected as critical value is 0.0140
X2(1)	X2 is stationary at 1st difference with intercept	H0 is rejected as critical value is 0.0174
X3(1)	X3 is stationary at 1st difference with intercept	H0 is rejected as critical value is 0.0133
X4(0)	X4 is stationary at level with intercept	H0 is rejected as critical value is 0.0428
C1(0)	C1 is stationary at level with intercept	H0 is rejected as critical value is 0.0439

Source: Author's compilation from EViews results

Table 4. Correlation analysis

	lnshiftedY(0)	lnX1(1)	lnX2(1)	lnX3(1)	lnshiftedX4(0)	lnC1(0)
lnshiftedY(0)	1					
lnX1(1)	-0.301	1				
lnX2(1)	-0.092	0.452	1			
lnX3(1)	-0.325	0.003	0.009	1		
lnshiftedX4(0)	0.348	0.048	0.125	-0.110	1	
lnC1(0)	0.002	0.043	-0.139	-0.167	-0.485	1

Source: EViews results

Table 5. OLS regression analysis dependent variable ln Y(0)

Independent Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	3.007	5.448	0.552	0.590
lnX1(1)	-0.391	0.280	-1.396	0.185
lnX2(1)	0.427	2.687	0.159	0.876
lnX3(1)	-0.358	0.330	-1.085	0.296
lnshiftedX4(0)	0.428	0.261	1.639	0.123
lnC1(0)	0.984	1.390	0.708	0.491
R-squared	0.328	Mean dependent var		-1.789
Adj. R- squared	0.088	S.D dependent var		0.688
S E of regression	0.657	Akaike info criterion		2.242
Sum squared resid	6.046	Schwarz criterion		2.540
Log likelihood	-16.416	Hannan-Quinn criterion		2.300
F-statistic	1.368	Durbin-Watson stat		1.666
Prob (F-Statistic)	0.294			

Source: EViews results

4. RESULTS AND FINDINGS

The low R-squared, insignificant p-values, and F-statistic indicate that the current model does not fit the data well and that the independent variables selected are not strong predictors of GDP growth. The model we developed to predict GDP growth in Sudan may not be a good fit due to the influence of other non-economic factors that are not captured in our dataset. Political instability, social unrest, weak governance, external shocks, environmental challenges, and data limitations can all contribute to unpredictable economic behavior in Sudan. When a country's economy is driven by factors beyond conventional economic indicators, it often leads to low explanatory power in regression models.

5. DISCUSSION

Based on the empirical analysis and statistical results of our study on Sudan's economic growth dynamics, we observe that the traditional macroeconomic indicators used in the model have not shown a significant impact on the GDP growth rate. This lack of statistical significance and the low explanatory power of our model suggests that the key macroeconomic variables traditionally assumed to influence GDP growth may not be capturing the full picture of Sudan's economic reality. There could be various political, geographical, social, and economic factors in Sudan that might be influencing the effectiveness of these indicators for predicting GDP growth rate. Here are some possible reasons to consider.

5.1 Structural and Political Instability in Sudan

The ineffective role of these indicators could be attributed to Sudan's political instability and conflict situations over the past decades. The country has faced significant civil unrest, internal displacement, and a lack of strong governance structures, which have hindered economic planning and the efficient use of resources. Political instability often results in inconsistent policy implementation, which in turn impacts economic performance regardless of traditional macroeconomic indicators.

5.2 Impact of Economic Sanctions and Trade Restrictions

Sudan has experienced various economic sanctions and international trade restrictions that have severely limited its ability to engage in global trade and attract foreign direct investments. The limitations on trade and external relations may have led to a situation where net exports and foreign direct investments do not behave in a predictable manner compared to other economies. This could be one reason why net exports and FDI have not shown a significant influence on GDP growth in the empirical analysis.

5.3 Geopolitical and Geographical Factors

Sudan's geographic location and its dependence on agricultural and extractive industries play a crucial role in shaping its economic outlook.

Factors such as climate change, drought, and desertification have a direct impact on agricultural productivity, which is a significant part of Sudan's economy. These issues might not be directly reflected in the traditional macroeconomic variables used in our model but have a profound effect on GDP growth.

5.4 Natural Resource Management and Wealth Distribution

Despite Sudan's wealth in natural resources, including oil and minerals, the impact of this wealth on economic development has been minimal due to poor management and unequal distribution of these resources. The resource-rich regions of the country have often seen conflict and exploitation, leading to inefficiencies and corruption, which inhibit sustainable growth.

5.5 Socioeconomic Challenges

High poverty rates, low literacy levels, inadequate healthcare, and limited infrastructure in Sudan continue to be major challenges that affect productivity and economic growth. These socioeconomic issues can create a gap in human capital development, resulting in a labor force that is less equipped to contribute to economic advancements, regardless of other economic indicators.

6. CONCLUSION AND RECOMMENDA-TIONS

The study aimed to analyze the relationship between key macroeconomic indicators and GDP growth in Sudan, highlighting the limitations of conventional economic factors in explaining the country's economic dynamics. The empirical results revealed that traditional macroeconomic variables, such as net exports, inflation rate, and foreign direct investment, did not significantly impact GDP growth in Sudan. This suggests that other structural factors, such as political instability, economic sanctions, inadequate resource management, and socioeconomic challenges, are likely playing a more critical role in influencing the country's economic performance. The study concludes that focusing solely on these economic indicators may not be sufficient to understand the complexities of Sudan's economic development.

To address the economic development barriers in Sudan, following strategic recommendations aim to create a sustainable economic environment that fosters growth, stability, and inclusivity.

- ✓ Enhance political stability and governance to build trust among citizens and stakeholders.
- ✓ Reduce dependency on oil and natural resources by promoting diversification into agriculture, manufacturing, and services through investment in infrastructure, technology, and training.
- ✓ Invest in essential infrastructure, including transportation, energy, and telecommunications, to facilitate trade and economic activity.
- ✓ Focus on education and vocational training to improve the skills of the workforce, equipping citizens for a modern economy.
- ✓ Create an enabling environment for small and medium-sized enterprises (SMEs) by providing access to finance and reducing bureaucratic hurdles.
- ✓ Engage in regional trade agreements and partnerships with neighboring countries to enhance market access and economic collaboration.
- ✓ Implement sustainable management practices for natural resources to ensure long-term economic viability and prevent environmental degradation.
- ✓ Develop targeted programs to address poverty, inequality, and social disparities to ensure all segments of society benefit from economic growth.
- ✓ Create a favorable investment climate by streamlining regulations, providing incentives for foreign investors, and ensuring the protection of property rights.
- ✓ Formulate comprehensive economic recovery strategies in response to crises or shocks, allowing for resilience-building and rapid recovery.

By focusing on key areas such as political stability, diversification, infrastructure investment, education, and regional collaboration, these strategies can help overcome the challenges facing Sudan's economy. Implementing these recommendations will not only enhance economic performance but also ensure that the benefits of growth are shared among all segments of society.

Future research should build on the findings of this study by exploring the broader socio-economic and political factors influencing Sudan's economic development. Investigating the impact of governance structures, regional stability, and global market trends can provide deeper insights into the complexities of Sudan's economic landscape. Additionally, examining the effectiveness of the strategic recommendations proposed in this study will be crucial for understanding their long-term viability. By focusing on these areas, future research can contribute to a more comprehensive understanding of the challenges and opportunities for economic growth in Sudan, ultimately guiding policymakers in implementing effective solutions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We declare that generative AI technologies were not used in the writing or editing of this manuscript. All analyses, interpretations, and conclusions presented in this manuscript are the result of our own intellectual efforts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendices: Data Set

Appendix 1. Original values of dependent, independent and control variables

	Y	X1	X2	X3	X4	C1
Year	GDP Growth Rate	Inflation Rate (%)	Unemployment Rate (%)	FDI Inflows, US $ as % of GDP	Net Exports as % of GDP	Population Growth Rate
2002	6.01%	22.22%	14.75%	3.93%	-2.81%	2.28%
2003	6.29%	6.49%	14.74%	6.32%	-1.94%	2.46%
2004	5.14%	9.66%	14.78%	5.67%	-1.83%	2.68%
2005	5.64%	8.51%	14.79%	4.44%	-6.95%	2.83%
2006	6.53%	7.20%	14.77%	4.07%	-6.02%	2.80%
2007	5.74%	14.75%	14.75%	2.53%	-0.60%	2.75%
2008	3.85%	14.30%	14.80%	2.55%	3.79%	2.40%
2009	-2.77%	11.26%	13.00%	2.96%	-3.68%	2.01%
2010	3.86%	12.98%	15.12%	2.78%	2.23%	2.15%
2011	-3.21%	18.10%	17.44%	2.21%	-2.55%	2.36%
2012	-17.00%	35.56%	17.97%	3.66%	-8.14%	2.81%
2013	1.96%	36.52%	18.04%	2.56%	-7.84%	3.16%
2014	4.66%	36.91%	17.75%	1.63%	-5.63%	3.16%
2015	1.91%	16.91%	17.06%	2.03%	-5.54%	3.31%
2016	3.47%	17.75%	17.00%	1.03%	-5.28%	3.24%
2017	0.71%	32.35%	17.14%	0.82%	-5.61%	2.94%
2018	-2.68%	63.29%	17.31%	3.51%	-6.57%	2.80%
2019	-2.18%	50.99%	17.51%	2.55%	-9.22%	2.74%
2020	-3.63%	163.26%	19.21%	2.65%	0.30%	2.67%
2021	-1.87%	359.09%	19.19%	1.53%	0.37%	2.63%
2022	-0.95%	138.81%	17.59%	1.11%	0.44%	2.60%

Source: GDP Growth Rate: https://data.worldbank.org (World Bank Open Data, n.d.) [17]; Inflation Rate: https://www.worlddata.info (Inflation Rates in Sudan, n.d.) [18]; Unemployment Rate: https://tradingeconomics.com (Sudan Unemployment Rate, n.d.) [19]; FDI Inflows: https://www.macrotrends.net (Sudan Foreign Direct Investment 1970-2024, n.d.) [20]; Population Growth Rate: https://www.macrotrends.net (Sudan Population 1950-2024, n.d.) [21]; Net Exports: https://www.macrotrends.net (Sudan Exports 1960-2024, n.d.) (Sudan Imports 1960-2024, n.d.) [22,23]

Appendix 2. Natural log transformation of dependent, independent and control variables

Year	Shifted Y*	ln Shifted Y	lnX1	lnX2	lnX3	Shifted X4*	ln shifted X4	lnC1
2002	24.01%	-142.67%	-150.42%	-191.39%	-323.65%	7.41%	-260.23%	-378.10%
2003	24.29%	-141.51%	-273.49%	-191.46%	-276.15%	8.28%	-249.13%	-370.50%
2004	23.14%	-146.36%	-233.72%	-191.19%	-287.00%	8.39%	-247.81%	-361.94%
2005	23.64%	-144.22%	-246.39%	-191.12%	-311.45%	3.27%	-342.04%	-356.49%
2006	24.53%	-140.53%	-263.11%	-191.26%	-320.15%	4.20%	-317.01%	-357.56%
2007	23.74%	-143.80%	-191.39%	-191.39%	-367.70%	9.62%	-234.13%	-359.36%
2008	21.85%	-152.10%	-194.49%	-191.05%	-366.91%	14.01%	-196.54%	-372.97%
2009	15.23%	-188.19%	-218.39%	-204.02%	-352.00%	6.54%	-272.72%	-390.70%
2010	21.86%	-152.05%	-204.18%	-188.92%	-358.27%	12.45%	-208.34%	-383.97%
2011	14.79%	-191.12%	-170.93%	-174.64%	-381.22%	7.67%	-256.79%	-374.65%
2012	1.00%	-460.52%	-103.39%	-171.65%	-330.77%	2.08%	-387.28%	-357.20%
2013	19.96%	-161.14%	-100.73%	-171.26%	-366.52%	2.38%	-373.81%	-345.46%
2014	22.66%	-148.46%	-99.67%	-172.88%	-411.66%	4.59%	-308.13%	-345.46%
2015	19.91%	-161.39%	-177.73%	-176.84%	-389.71%	4.68%	-306.19%	-340.82%
2016	21.47%	-153.85%	-172.88%	-177.20%	-457.56%	4.94%	-300.78%	-342.96%
2017	18.71%	-167.61%	-112.86%	-176.38%	-480.36%	4.61%	-307.69%	-352.68%
2018	15.32%	-187.60%	-45.74%	-175.39%	-334.96%	3.65%	-331.04%	-357.56%
2019	15.82%	-184.39%	-67.35%	-174.24%	-366.91%	1.00%	-460.52%	-359.72%
2020	14.37%	-194.00%	49.02%	-164.97%	-363.06%	10.52%	-225.19%	-362.31%
2021	16.13%	-182.45%	127.84%	-165.08%	-417.99%	10.59%	-224.53%	-363.82%
2022	17.05%	-176.90%	32.79%	-173.78%	-450.08%	10.66%	-223.87%	-364.97%

Y and X4 are having some negative values therefore we need to apply conversion of constant shift before transforming on natural log.
Constant Shift = /Minimum Value/+1; Shifted Y= 17.00+1=18.00; Shifted X4* = 9.22+1=10.22; Source: Authors' calculation*

Appendix 3. Values of dependent, independent and control variables after conversion on difference

Year	lnShifted Y(0)	lnX1(1)	lnX2(1)	lnX3(1)	lnShiftedX4(0)	lnC1(0)
2002	-1.427				-2.602	-3.781
2003	-1.415	-1.231	-0.001	0.475	-2.491	-3.705
2004	-1.464	0.398	0.003	-0.109	-2.478	-3.619
2005	-1.442	-0.1268	0.001	-0.245	-3.420	-3.565
2006	-1.405	-0.1672	-0.001	-0.087	-3.170	-3.576
2007	-1.438	0.717	-0.001	-0.475	-2.341	-3.594
2008	-1.521	-0.031	0.003	0.008	-1.965	-3.730
2009	-1.882	-0.239	-0.130	0.149	-2.727	-3.907
2010	-1.521	0.142	0.151	-0.063	-2.083	-3.840
2011	-1.911	0.333	0.143	-0.229	-2.568	-3.747
2012	-4.605	0.675	0.030	0.504	-3.873	-3.572
2013	-1.611	0.027	0.004	-0.357	-3.738	-3.455
2014	-1.485	0.011	-0.016	-0.451	-3.081	-3.455
2015	-1.614	-0.781	-0.040	0.219	-3.062	-3.408
2016	-1.539	0.048	-0.004	-0.678	-3.008	-3.430
2017	-1.676	0.600	0.008	-0.228	-3.077	-3.527
2018	-1.876	0.671	0.010	1.454	-3.310	-3.576
2019	-1.844	-0.216	0.011	-0.320	-4.605	-3.597
2020	-1.940	1.164	0.093	0.038	-2.252	-3.623
2021	-1.824	0.788	-0.001	-0.549	-2.245	-3.638
2022	-1.769	-0.950	-0.087`	-0.32	-2.239	-3.650

Source: Authors' calculation

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