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The Impact of Rapid Urbanization on Poverty Levels in the Context of Climate Change: Empirical Evidence from Somalia

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Abstract: This study investigates the relationship between rapid urbanization and poverty levels in Somalia, employing annual data spanning from 1990 to 2022. The analysis focused on critical variables, including urbanization rates, CO_2 emissions as a measure of climate change, and unemployment rates, with poverty quantified by real GDP per capita. A Johansen cointegration approach is utilized to ascertain long-term equilibrium relationships, while a Vector Error Correction Model (VECM) captures short-term dynamics. Results indicate that urbanization exerts a significant positive influence on poverty in the long term; specifically, a 1% increase in urbanization correlates with a 1.73% rise in poverty levels. Additionally, unemployment demonstrates a substantial and statistically significant positive effect, whereby a 1% increase in unemployment results in a 9.64% increase in poverty. In contrast, CO_2 emissions were found to be statistically insignificant. The long-run equilibrium adjustment rate is approximately 12.66% per period, suggesting a moderate pace of return to equilibrium. In the short run, the unemployment rate negatively influences poverty, with a coefficient of -2.369508. Furthermore, CO_2 emissions exhibit a delayed yet significant positive effect on poverty, indicated by a coefficient of 0.681835. Granger causality tests reveal strong causal relationships between past unemployment rates and future poverty levels, as well as between past urbanization trends and subsequent poverty levels. The findings underscore the necessity for integrated policies that address urbanization, enhance climate resilience, and promote employment, aiming to alleviate poverty in Somalia.

Keywords: Cointegration; Rapid urbanization; CO_2 emissions; GDP per capita; Employment; Climate resilience

1. Introduction

The world is urbanizing rapidly, particularly in developing countries, where, as projected by the United Nations, more than half the population will become urban by 2020 (United Nations, 2011), with global urbanization estimated to reach 68% by 2050 (United Nations, 2018). Rapid urbanization has become a critical phenomenon in many developing countries, including Somalia. Urban population growth, driven by both natural increase and rural-to-urban migration, has significant implications for socio-economic development and environmental sustainability (Cohen, 2006). In many developing countries, urban areas are expanding at unprecedented rates, often outpacing the development of necessary infrastructure and services (UN-Habitat, 2016). This rapid urbanization brings both opportunities and challenges. On the one hand, it can spur economic growth and innovation (Todaro & Smith, 2015). On the other hand, it can strain resources and exacerbate existing social inequalities, particularly in fragile states like Somalia (Buhaug & Urdal, 2013). In the context of climate change, urban areas in Somalia are facing increased vulnerabilities due to the compounded effects of rapid urbanization and environmental stressors (Mbow et al., 2019). Climate change, manifested through rising temperatures and increased CO_2 emissions, exacerbates these vulnerabilities, leading to adverse socio-economic outcomes, particularly poverty (Henderson et al., 2013). The impact of climate change on urban areas includes increased frequency and severity of extreme weather events, rising sea levels, and shifting agricultural patterns, all of which can undermine urban resilience and exacerbate poverty (Friel et al., 2011; IPCC, 2014). Furthermore, the rapid influx of people into urban areas often leads to the development of informal settlements, which are particularly vulnerable to environmental hazards (Satterthwaite, 2007). These areas typically lack adequate infrastructure, such as clean water, sanitation, and waste management systems, making them more vulnerable to the negative impacts of climate change (Douglas et al., 2008). For instance, increased rainfall and flooding can lead to waterborne diseases, while higher temperatures can exacerbate heat stress, particularly among the poor, who may lack access to cooling technologies (Owusu-Ansah & Braimah, 2013). In Somalia, the situation is further complicated by prolonged conflict and weak institutional capacity, which hinder effective urban planning and climate change adaptation efforts (Abdi, 2017). The intersection of rapid urbanization, climate change, and socio-economic vulnerabilities creates a complex landscape where poverty can become both a cause and a consequence of environmental and developmental challenges (Adger, 2006). The following Figure 1 illustrates the trends of these variables over time, providing a visual understanding of the shifts among them.

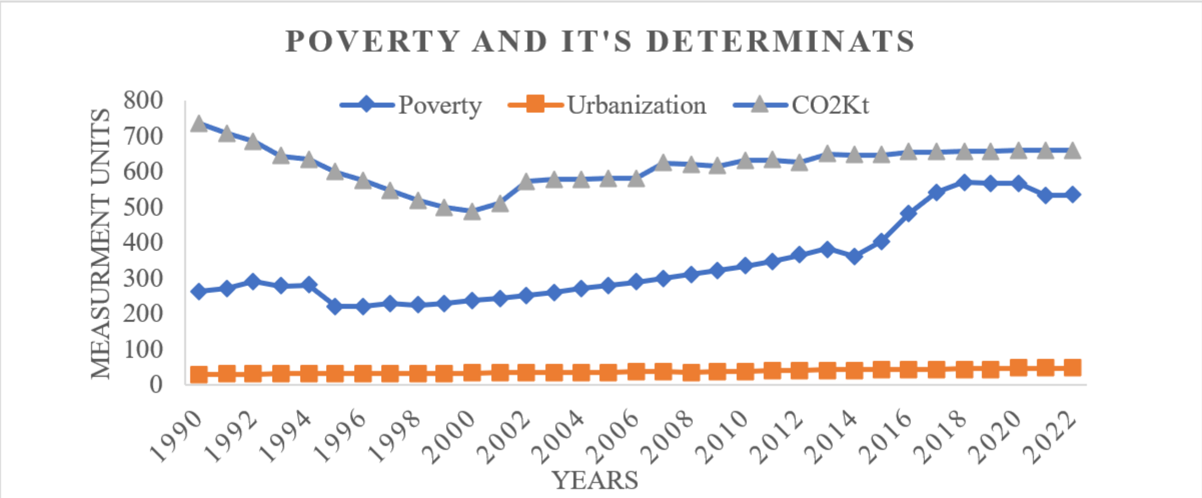

Figure 1. Poverty, urbanization, and CO_2 emissions (1990-2022)

As seen in Figure 1, it illustrates the trends of poverty, urbanization, and CO_2 emissions (in kilotons) from 1990 to 2022. Here is a detailed breakdown of each trend: Poverty shows a general downward trend from 1990 to around 2000. Between 2000 and 2010, poverty levels fluctuated but remained relatively low. After 2010, poverty levels started to rise again, reaching a peak around 2016 and then fluctuating slightly but remaining higher than in the 1990s. Urbanization appears to remain constant throughout the period from 1990 to 2022. Since the measurement is expressed as a percentage, the graph points are all below 100. CO_2 emissions: There was a steady increase from 1990 to 2005. Between 2005 and 2016, CO_2 emissions continued to rise, but slowly. After 2016, the trend appears to stabilize, with CO_2 emissions maintaining a relatively constant level. Considering these variables, this graph emphasizes the need for a comprehensive approach to addressing poverty.

Several studies have explored the relationships between urbanization, climate change, and poverty. For instance, Cohen (2006) highlighted the dual challenges of urbanization and environmental sustainability, emphasizing the need for integrated policies to address these issues. Similarly, Henderson et al. (2013) investigated the impact of urbanization on economic growth and found that while urbanization can drive economic development, it also poses significant environmental challenges. In the context of developing countries, studies such as those by Owusu-Ansah & Braimah (2013) and Friel et al. (2011) also demonstrated the detrimental effects of rapid urbanization on environmental quality and public health, which, in turn, exacerbate poverty levels. However, there is a dearth of empirical studies focusing specifically on Somalia, which presents a unique case due to its prolonged conflict, fragile institutions, and high vulnerability to climate change. Despite the growing body of literature on urbanization, climate change, and poverty, there is a significant gap in empirical evidence from Somalia. The country's unique socio-political context and environmental challenges necessitate a focused investigation into how rapid urbanization, climate change, and unemployment rates impact poverty. Understanding these intricate dynamics is crucial for developing targeted interventions that mitigate poverty and foster sustainable urban development in a region where traditional development models may not apply. Addressing these challenges promotes sustainable urban development in Somalia (UNDP, 2020). This study aims to fill the gap in the existing literature by providing actionable insights for policymakers. These insights aim to guide the development of effective strategies for poverty alleviation and the promotion of sustainable urban development (World Food Programme, 2021). All while navigating the ongoing environmental and socio-economic challenges that Somalia faces and empirically analyzing the impact of rapid urbanization, climate change (measured through CO_2 emissions), and unemployment rates on poverty levels in Somalia.

2. Literature Review

This section provides an extensive review of the existing literature on the impact of rapid urbanization on poverty levels in the context of climate change. The review focuses on the key concepts of urbanization, poverty, and climate change. We used empirical studies that examined these relationships in different regions, focusing on developing countries. It highlights the specific context of Somalia, summarizing previous research findings. Climate Change and Poverty: An Analytical Framework, examine how climate change and climate policies impact poverty through price changes, assets, productivity, and opportunities (Hallegatte et al., 2014). The study argues that climate change poses a major barrier to poverty eradication, calling for well-designed policies and strong social protection systems. The need for immediate action is underscored to mitigate the growing risks that climate change presents to vulnerable populations. Nguyen et al. (2021) examine the impact of urbanization on poverty reduction in Vietnam, finding a U-shaped relationship where initial urbanization decreases poverty. However, excessive levels beyond certain thresholds (40.19% and 43.68%) lead to an increase in poverty. The study also highlights that regional GDP, human capital, and agricultural value reduce poverty, while government spending and export value increase it. The analysis is based on panel data from 2006 to 2016, using Driscoll and Kraay's and D-GMM methods. Rapid urbanization, characterized by a swift increase in urban population, has profound implications for poverty. In developing countries like Somalia, urbanization often leads to the proliferation of informal settlements, insufficient infrastructure, and limited access to basic services, exacerbating urban poverty (Satterthwaite, 2007). Urbanization, while driving economic growth, can also create spatial inequalities, with poverty becoming concentrated in urban areas (Tacoli et al., 2015). Global Non-linear Effect of Temperature on Economic Production analyzes the nexus between temperature variations and economic performance, revealing how climate change disproportionately impacts economic productivity in poorer countries. The study demonstrates that higher temperatures can significantly reduce GDP in low-income regions, intensifying poverty. It calls for international cooperation and investment in climate adaptation to protect vulnerable economies from the adverse effects of global warming (Olsson et al., 2014). Livelihoods and Poverty in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) investigates the intersection of climate change and poverty, focusing on livelihood impacts. The report identifies climate change as a multiplier of existing vulnerabilities, stressing the necessity for sustainable development pathways prioritizing poverty reduction and climate resilience (Skoufias et al., 2011). The Poverty Impacts of Climate Change: A Review of the Evidence explores the channels through which climate change affects poverty, including health, agricultural productivity, and income stability. The authors highlight the disproportionate impact on the poorest populations and the need for adaptive strategies to reduce vulnerability. The paper underscores the importance of integrating climate risk management into poverty reduction strategies to build resilience among the poor (Jordaan, 2016). Stabilization and humanitarian aid in Somalia evaluate the impact of stabilization and humanitarian aid in Somalia, finding that while these interventions can temporarily alleviate conditions, they often fail to address underlying issues of poverty and unemployment. The effectiveness of aid is inconsistent, with varying success across different regions (Makamu et al., 2018). Poverty and its dynamics in East Africa explore poverty dynamics in East Africa, revealing that poverty is deeply entrenched and cyclical. The study shows that despite various poverty reduction efforts, economic instability and unequal growth continue to contribute to high poverty and unemployment rates. Barrett et al. (2017), on rural Africa's structural transformation, find that Africa's structural transformation is unique, characterized by slower agricultural productivity growth and a significant reliance on informal employment. They highlight the need for policies that support agricultural productivity and facilitate labor migration to urban areas, which are crucial for driving economic growth and poverty reduction (Mohammed & Asfaw, 2019). Urbanization and its impact on poverty in developing countries: A case study of Ethiopia reveals that urbanization in Ethiopia has a dual impact on poverty: it stimulates economic growth and provides opportunities for poverty reduction, but it also exacerbates income inequality and leads to the expansion of informal settlements. The study underscores that the benefits of urbanization are unevenly distributed, with rural migrants and the urban poor often marginalized. It highlights the critical role of inclusive urban planning and social protection programs in mitigating the negative effects of rapid urban growth.

3. Data and Methodology

3.1 Data Description

This study utilized annual data spanning from 1990 to 2022. The data were sourced from the World Bank, the poverty and equity database, and the Statistical, Economic, and Social Research and Training Centre website for Islamic Countries (SESRIC). The selected period reflects the availability of crucial data on key variables of interest, such as urbanization, climate change, and the unemployment rate in Somalia. The dependent variable is poverty, measured by gross domestic product per capita. The independent variables are urbanization, measured by the percentage of the population living in urban areas; climate change, proxies by carbon dioxide emissions; and unemployment rate, measured as the percentage of the unemployed labor force.

3.2 Model Specification

The model aims to assess the impact of rapid urbanization on poverty levels within the context of climate change. The dependent variable, used as a poverty indicator, is the natural logarithm of real GDP per capita (LGDPP). The independent variables include the natural logarithm of urbanization (LUNRP), the natural logarithm of carbon emissions (LCO_2) as a proxy for climate change, and the natural logarithm of the unemployment rate (LUNR). Utilizing the natural logarithm helps stabilize variance, makes growth rate interpretation easier, improves the model's performance, and enhances data analysis.

$$\left(\mathrm{LGDP}_t\right) = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\mathbf{ln}\left(\mathrm{UNRP}_t\right) + \boldsymbol{\beta_2}\ln\left(\mathrm{LCO}_{2t}\right) + \boldsymbol{\beta}_3\ln\left(\mathrm{UNR}_t\right) + \boldsymbol{\varepsilon}_t \tag{1}$$

where,

LGDP: Gross Domestic Product Per Capita.
UNRP: Urbanization (Urban Population Growth Annual).
LCO_2: Carbon Dioxide Emissions Kt tons (Climate Change Measure).
UNR: Unemployment Rate Annual Percentage.
ε: Random error term assumed to be normally, identically and independently distributed.
β_0 is a constant whare, β_1, β_2, β_3 are coefficient elasticity of the variables.
t is time variant.

3.3 Econometric Modeling

The Johansen correlation testing approach is utilized to estimate the relationship among these variables. This method is advantageous because it uses a system approach, simultaneously estimating all the relationships in a system of equations. This provides a more comprehensive analysis compared to single-equation methods if the variables are integrated into different orders I (1). As long as the existence of the cointegration is tested and we can estimate the VECM, including both short-term dynamics and long-term equilibrium relationships, the short-term dynamics are specified as follows:

$$\Delta\mathrm{POV}_t = \alpha_1 + \lambda_{pov}e_{t-1} + \sum_{i=1}^{n}\alpha_{11}(i)\Delta\,\mathrm{POV}_{t-i} + \sum_{i=1}^{n}\alpha_{12}(i)\Delta URB_{t-i} + \sum_{i=1}^{n}\alpha_{13}(i)\Delta\mathrm{LCO}_{2t-i} + \sum_{i=1}^{n}\alpha_{14}(i)\Delta\mathrm{LUNR}_{t-i} + u_{1t} \tag{2}$$

$$\Delta UNB_t = \alpha_1 + \lambda_{\mathrm{unbe}_{t-1}} + \sum_{i=1}^{n}\alpha_{21}(i)\Delta\mathrm{URB}_{t-i} + \sum_{i=1}^{n}\alpha_{22}(i)\Delta\mathrm{POV}_{t-i} + \sum_{i=1}^{n}\alpha_{23}(i)\Delta\mathrm{LCO}_{2t-i} + \sum_{i=1}^{n}\alpha_{24}(i)\Delta\mathrm{UNR}_{t-i} + u_{2t} \tag{3}$$

$$\Delta\mathrm{LCO}_{2t} = \alpha_1 + \lambda_{lco2}e_{t-1}\sum_{i=1}^{n}\alpha_{32}(i)\Delta\mathrm{LCO}_{2t-i} + \sum_{i=1}^{n}\alpha_{32}(i)\Delta\,\mathrm{Pov}_{t-i} + \sum_{i=1}^{n}\alpha_{33}(i)\Delta LURB_{t-i} + \sum_{i=1}^{n}\alpha_{34}(i)\Delta LUNR_{t-i} + u_{3t} \tag{4}$$

$$\Delta\mathrm{LUNR}_t = \alpha_1 + \lambda_{Lunr}e_{t-1}\sum_{i=1}^{n}\alpha_{41}(i)\Delta\mathrm{LUNR}_{t-i} + \sum_{i=1}^{n}\alpha_{42}(i)\Delta\,\mathrm{Pov}_{t-i} + \sum_{i=1}^{n}\alpha_{43}(i)\Delta\mathrm{LCO}_{2t-i}\sum_{i=1}^{n}\alpha_{44}(i)\Delta\mathrm{LURB}_{t-i} + u_{4t} \tag{5}$$

where, Δ represents the first difference operator, and n refers to the number of lags; u_1, u_2, u_3, and u_4 are the random error terms. The expression $\boldsymbol{e_{t-1}}(\mathrm{POV}_{t-1} - \beta 0 - \beta 1\mathrm{URB}_{t-1} - \beta 3\mathrm{LCO}_{2t-1} - \beta\mathrm{UNR}_{t-1})$ denotes the one-period lag of the error correction term (ECT), which stems from the long-run cointegration equation. The α

coefficients capture the short-run dynamics, while λLPOV, λLURB, λLCO_2, and λUNR are the speed of adjustment parameters, indicating how quickly the dependent variable return to the long-run equilibrium. Before analyzing the model, the study follows the steps that are essential for developing the Johansen Cointegration Model. First, the stationarity of the variables was examined using unit root tests, specifically the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test at the first difference, I (1). Subsequently, appropriate lag intervals were selected. Using the Lag Length Selection Criterion Determining the appropriate number of lags for each variable using information criteria (AIC, BIC). Before VECM, the Johansen Cointegration Test is conducted. Since this test is crucial before estimating a VECM because it determines whether a long-run equilibrium relationship exists among the non-stationary variables, this test helps determine whether a group of non-stationary series is cointegrated, meaning they have a stable long-run relationship despite being non-stationary individually. After confirming at least one cointegration equation, the study estimates the short-run dynamics and long-run coefficients since the Error Correction Model (ECM) formulates the ECM to capture the speed of adjustment towards the long-run equilibrium.

Table 1. Variable description and measurements

Variable	Code	Measurement
Poverty	RGDPP	Real GDP Per capita
Urbanization	URB	Population, Urban % Total Pop
Carbon Dioxide Emissions	CO_2	Kt tons
Unemployment	UNR	Unemployment Rate

The above Table 1 provides a summary of key variables used in the analysis, along with their respective codes and measurement units.

4. Result and Discussions

This section provides the findings of the empirical analysis, structured into multiple subsections: descriptive statistics, unit root test, cointegration test, VECM estimation, Granger causality test, and diagnostic test.

4.1 Descriptive Statistics

Descriptive statistics offer an initial overview of the data, summarizing key characteristics such as the variables' mean, standard deviation, maximum, and minimum values. These statistics are presented in Table 2 and provide essential insights into the basic features and variability of the dataset.

Table 2. Descriptive statistics

Statistics	RGDPP	URBN	CO_2Kt	UNR
Mean	340.7121	36.84909	615.4677	18.88588
Std Error	20.22047	0.975441	10.16672	0.083337
Median	289.94	35.53	631.2	18.694
St. Deviation	116.1578	5.603482	58.40333	0.478737
S. Variance	13492.63	31.39901	3410.949	0.229189
Kurtosis	-0.40691	-1.29558	0.055006	0.116188
Skewness	0.991407	0.386139	-0.51311	1.025109
Range	350.37	17.42	248.52	1.817
Minimum	219.28	29.31	486.6	18.293
Maximum	569.65	46.73	735.12	20.11

As shown in Table 2, it shows descriptive statistics. Over the past 32 years, the average per capita income has been 340.7121 USD, offering a snapshot of general economic well-being. Standard Deviation: 116.16 USD. The high standard deviation indicates significant income disparities among the population. Maximum: 569.65 USD the highest recorded per capita income in 2022 and the lowest recorded per capita income was 219.28 in 1995, highlighting economic hardship. Population, Urban, % of Total: averages 36.85%. This is the average proportion of the population living in urban areas, providing a general sense of urbanization. Standard Deviation: 5.60%. This value reflects variability in urbanization rates, indicating differing levels of urban development. The maximum number is 46.73% in 2022. This represents the highest level of urbanization, pointing to regions with highly concentrated year-round urban populations. Minimum: 29.31% in 1990. This indicates the lowest urbanization level; this indicates how, year after year, the rural population is migrating to the urban. Climate Change (CO_2 emissions) means 615.47 kilotons. The average CO_2 emissions reflect the overall environmental impact across the dataset. Standard Deviation: 58.40 kilograms. It indicates considerable variability in emissions, pointing to differences in industrial activity and environmental policies. Maximum: 735.12 kilograms. The highest emissions level, highlighting the most industrialized or high-emission regions. Minimum: 486.6 kilograms. The lowest emissions level. The unemployment rate is the unemployment total (% of the total labor force) modeled by ILO's estimated average of 18.89%. This represents the average unemployment rate, reflecting the general employment situation—standard Deviation: 0.48%. The low standard deviation indicates relatively stable unemployment rates across the dataset. Maximum: 20.11%. The highest unemployment rate points to areas with significant labor market challenges. Minimum: 18.29%. The lowest unemployment rate suggests regions with somewhat better employment conditions.

Table 3. Stationarity test

Variable	ADF (Constant)	ADF (Constant with Trend)	PP (Constant)	PP (Constant with Trend)
At Level				
LPOV	-0.08003	-2.322871	0.13896	-1.898562
LURB	0.087007	-2.493002**	0.087007	-2.493002**
LCO_2	-1.91387	-4.249652***	-2.0463	-2.644738
LUNR	-1.825634*	-1.812365*	-1.94429	-1.755035
At First Difference				
D(LPOV)	-3.022831**	-4.388802***	-4.2204***	-4.34693***
D(LURB)	-5.67052***	-5.615246	-5.6705***	-5.61526***
D(LCO_2)	-3.325651**	-3.532821	-3.2574**	-3.506895*
D(LUNR)	-5.06382***	-3.477849**	-5.4291***	-5.419522**

Table 3 shows the unit root test of the variables. We found all variables (D(LPOV), D(LURB), D(LCO_2), and D(LUNR)) become stationary after differencing, as indicated by the results of the ADF and PP tests. The results of the stationarity test confirm that these variables are stationary at I (1) and thus suitable for VECM modeling. The next step is to test for cointegration to establish the long-term relationships among these variables. Once cointegration is confirmed, a VECM will effectively capture both the short-term dynamics and the long-term equilibrium relationships, providing a comprehensive analysis of the relationship among the variables.

Table 4. Cointegration test

No. of CE(s)	Trace Statistic	Prob.	Max-Eigenvalue	Prob.
$r \leq 0$	60.31	0.0022**	34.81489	0.0050***
$r \leq 1$	25.4951	0.1445	13.89805	0.3735
$r \leq 2$	11.5971	0.1733	11.05036	0.1517
$r \leq 3$	0.54671	0.4597	0.546713	0.4597

** denotes rejection of the hypothesis at the 0.05 level.

Table 4 shows the Johansen cointegration test. The Johansen test starts with null hypotheses about the number of cointegrating vectors. So, the null hypothesis is that there are no cointegrating vectors (r=0) in the trace statistics test, while the Max-Eigenvalue statistics' null hypothesis assesses the cumulative effect of having r or fewer cointegrating vectors and focuses on whether there are (r+1) cointegrating vectors. The result shows we can reject the null hypothesis of no cointegration (r = 0). Since both Trace Statistics and Max-Eigenvalue's values are greater than critical with the significance level of 5%, so we conclude that there is at least one cointegrating vector and there is no significant evidence for more than one cointegrating vector, as the hypotheses for r≤1, r≤2, and r≤3 are not rejected. As the pre-required condition is conducted and confirmed that there is at least one cointegration factor, we can estimate the VECM, and here are the coefficients of the model:

Table 5. Long-run coefficient elasticities

	LPOV	LURBN	LCO_2	LUNR
Cointegration Coefficients	1	1.72902***	-0.5352	9.63783***
Standard Error		0.19775	0.31243	1.70029
t-statistic		8.74332	-1.71319	5.6686

As shown in Table 5, poverty is the dependent variable in the VECM, and its coefficient is normalized to 1. It serves as the basis for interpreting the coefficients of the other variables. This normalization is common practice to simplify interpretation and is necessary for estimating other coefficients. The coefficient of 1.729026 for urbanization (LURBN) indicates that, in the long run, a 1% increase in urbanization is associated with an increase of approximately 1.73% in poverty, with 1% statistically significant (denoted by ***), a high t-statistic of 8.74332, suggesting a strong and reliable effect of urbanization on poverty. The coefficients of climate change are not statistically significant at 5%. Since the t-statistic of 1.71319 is relatively lower than the critical value for the chosen significance level. This implies that there is evidence of the effect of CO_2 emissions on poverty. The coefficient of 9.637883 for unemployment (LUNR) indicates that a 1% increase in unemployment is associated with an increase of approximately 9.64% in poverty with a 5% significant level. In summary, urbanization has a statistically significant and negative effect on poverty, with a 1% increase in urbanization leading to a 1.73% increase in poverty. CO_2 emissions are not statistically significant. Unemployment has a substantial and statistically significant positive effect on poverty, with a 1% increase in unemployment leading to a 9.64% increase in poverty.

Table 6. Analysis of the short-run dynamics

Variable	Coefficient	Std. Error	t-Statistic
$\Delta LRGDPP_{t-1}$	-0.122097	0.30238	-0.40379
$\Delta LRGDPP_{t-2}$	-0.289083	0.23227	-1.24461
$\Delta LUNBP_{t-1}$	0.778982	0.52398	1.48666
$\Delta LUNBP_{t-2}$	0.158167	0.50523	0.31306
ΔLCO_2KT_{t-1}	-0.083767	0.32793	-0.25544
ΔLCO_2KT_{t-2}	0.681835	0.34037	2.00324
$\Delta LUNR_{t-1}$	2.369508	0.6375	3.71689
$\Delta LUNR_{t-2}$	-0.542151	0.86725	-0.62514
Ect_{t-1}	-0.126646	0.06038	-2.09765

Table 6 shows the short-run dynamics of poverty in relation to rapid urbanization, climate change, and unemployment rates. The model captures how deviations from the long-run equilibrium are corrected in the long run. The ECT has a statistically significant negative coefficient, indicating that deviations from the long-run equilibrium are corrected at a rate of approximately 12.66% each period, suggesting a moderate speed of adjustment back to equilibrium. The result reveals that only $\Delta LUNR_{t-1}$ and ΔLCO_2KT_{t-2} are statistically significant. Increased CO_2 emissions have a delayed but significant positive impact on poverty in the short run, highlighting the adverse effects of environmental degradation, and immediate past increases in unemployment have a significant negative effect on poverty, possibly due to temporary mitigating measures or delayed effects of unemployment reduction policies. while all other lagged $\Delta LRGDPP_{t-1}$, $\Delta LRGDPP_{t-2}$, $\Delta LUNBP_{t-1}$, $\Delta LUNBP_{t-2}$, ΔLCO_2KT_{t-1}, $\Delta LUNR_{t-2}$ didn't show significance relationship in the short run. In conclusion, CO_2 emissions and unemployment rates show short-term impacts on poverty; other variables, like recent changes in poverty and urbanization, have no relationship in the short run.

Table 7. Pairwise granger causality test

Null Hypothesis	F-Statistic	Prob.
LUNBP → LRGDP	0.0701	0.9326
LCO_2KT → LRGDP	3.8454	0.0344
LRGDPP → LCO_2KT	2.3323	0.1171
LUNR → LRGDPP	18.349	0.0001
LRGDPP → LUNR	1.592	0.2227
LCO_2KT → LUNBP	0.866	0.4324
LUNBP → LCO_2KT	2.5047	0.1012
LUNR → LUNBP	0.1622	0.8511
LUNBP → LUNR	0.0615	0.9405
LUNR → LCO_2KT	1.7892	0.1871
LCO_2KT → LUNR	2.8774	0.0743

The Granger causality test was performed to determine if the historical values of one variable can predict the future values of another variable. The Granger Causality Result in Table 7 shows that Significant Granger causality from Rapid Urbanization and Unemployment Rate to Poverty Rapid Urbanization (LUNBP) and Poverty Levels (LRGDPP): F -Statistic: 3.8454 with Prob. Value: 0.0344 indicates a statistically significant causal relationship between rapid urbanization and poverty levels. This suggests that past trends in urbanization can help predict future poverty levels. Poverty Levels (LRGDPP) and Rapid Urbanization (LUNBP): Unemployment Rate (LUNR) and Poverty Levels (LRGDPP): F-Statistic: 18.349 with Prob. Value: 0.0001 reveals There is a highly significant causal relationship between the unemployment rate and poverty levels. This indicates that past unemployment rates are strong predictors of future poverty levels. In contrast, all other pairs of variables do not show significant Granger causality.

Table 8. Diagnostic test

Diagnostic	Test Applied	Prob.
Serial Correlation Test	LM Test	0.2373
Normality Test	Jarque-Bera	0.3475
Heteroscedasticity	Breusch-Pagan Godfrey	0.1123

The result in Table 8 shows the diagnostic analysis of the model. Prob. Value: 0.2373 of the Serial Correlation Test (LM Test) is greater than the significance level of 0.05. This suggests no significant serial correlation evidence exists in the model's residuals—as the same Normality Test (Jarque-Bera Test) Prob. Value 0.3475 is also more significant than the significance level of 0.05. This indicates that there is no significant deviation from normality in the residuals. Heteroscedasticity Test (Breusch-Pagan Godfrey test) Prob. Value: 0.1123 also exceeds the 0.05 significance level. This suggests that there is no significant evidence of heteroscedasticity in the model. Also evaluate the model's stability, CUSUM and CUSUM of Squares tests were conducted. These tests check for potential structural breaks in the model's coefficients, ensuring the reliability of the results over the analyzed period. The following Figure 2 and Figure 3 display the results of these tests.

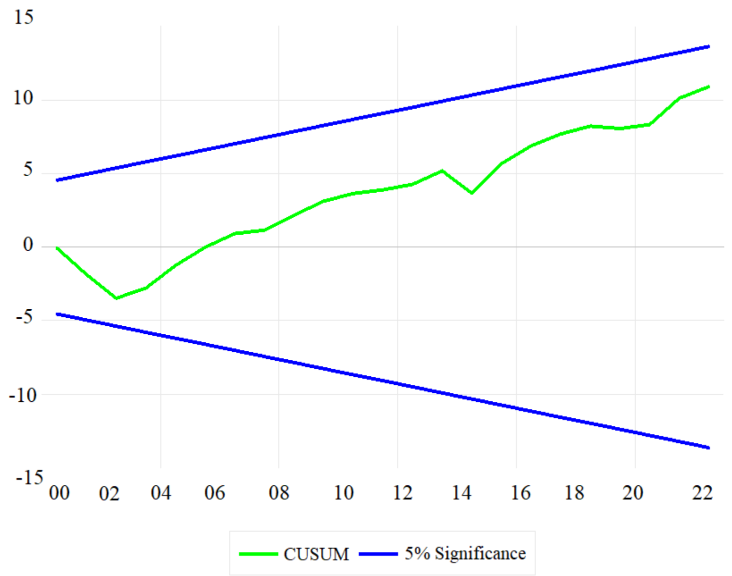

Figure 2. CUSUM test

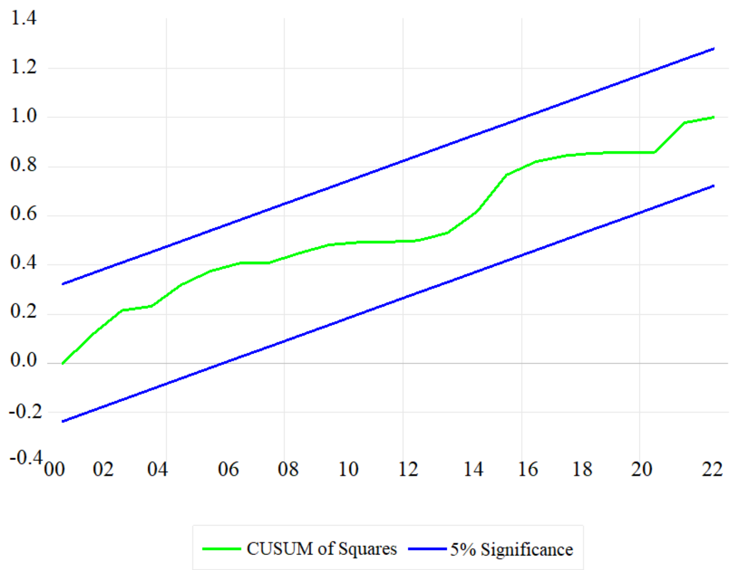

Figure 3. CUSUM of square test

Figure 2 and Figure 3 of CUSUM and CUSUM of Squares tests for stability analysis indicate that the model remains stable throughout the sample period. Specifically, the test statistics remain within the 5% significance boundaries, suggesting no significant deviations or shifts in the variance of the residuals over time. This stability implies that the residuals' variance is consistent across the period studied. Furthermore, the absence of significant structural breaks in both the regression coefficients and the variance of the residuals supports the conclusion that the model parameters are stable and reliable. This consistency reinforces the robustness of the model and suggests that it effectively captures the underlying relationships without experiencing substantial changes or instability.

Overall, the study reveals that rapid urbanization and unemployment significantly contribute to poverty in Somalia. A 1% increase in urbanization leads to a 1.73% rise in poverty, primarily due to inadequate infrastructure and informal settlements in urban areas. Unemployment has an even more substantial effect, with a 1% rise resulting in a 9.64% increase in poverty, highlighting the urgent need for job creation to reduce poverty. In contrast, CO_2 emissions did not show a significant long-term impact on poverty, suggesting that environmental factors may play a less direct role in Somalia's poverty dynamics. In the short term, unemployment remained a key driver, while urbanization and CO_2 emissions had no immediate effect. Granger causality tests confirmed that past unemployment and urbanization trends are strong predictors of future poverty, underscoring the need for policies focused on sustainable urbanization and reducing unemployment to alleviate poverty.

5. Conclusion and Policy Implications

This paper aimed to empirically analyze the impact of rapid urbanization, climate change (measured through CO_2 emissions), and unemployment rates on poverty levels in Somalia. This study addressed a gap in the existing literature by providing focused insights into these dynamics within Somalia's unique socio-political and environmental context. The study used annual data from 1990 to 2022 from the World Bank Poverty and SESRIC databases. The dependent variable is poverty, measured by real GDP per capita. In contrast, the independent variables are urbanization, measured by the percentage of the population living in urban areas, climate change (carbon dioxide emissions), and unemployment rate (the percentage of the labor force that is unemployed). The study employed a Johansen cointegration testing approach to estimate the long-run relationships among these variables. The model included a VECM to capture both short-term dynamics and long-term equilibrium relationships. Steps in the analysis included the stationarity test. Using ADF and PP tests to ensure variables were stationary at the first difference (I (1)). We also determine the appropriate number of lags using AIC and BIC criteria. Johansen Cointegration Approach Confirmed the presence of long-term relationships among variables. VECM Estimated short-term dynamics and long-term coefficients after confirming cointegration. Descriptive statistics first Provided insights into the basic features and variability of the dataset, such as variability of poverty levels, urbanization rates, CO_2 emissions, and relatively stable unemployment rates over the past 32 years. The Stationarity Test result indicated that all variables became stationary after differencing, confirming their suitability for VECM modeling. The Johansen cointegration test confirmed the existence of at least one cointegration equation, indicating long-term equilibrium relationships among the variables. Short-term Dynamics: Captured the immediate effects of changes in urbanization, CO_2 emissions, and unemployment rates on poverty levels. Long-run equilibrium is adjusted at approximately 12.66% per period, indicating a moderate pace of returning to equilibrium over the long term. Higher urbanization rates were associated with increased poverty in the long run due to the development of informal settlements and inadequate infrastructure—a 1% rise in urbanization results in a 1.73% increase in poverty. Climate, however, is not statistically significant. Unemployment exhibits a substantial and statistically significant positive effect on poverty, with a 1% increase in unemployment leading to a 9.64% rise. Urbanization, while driving economic growth, also leads to challenges such as the proliferation of informal settlements and inadequate infrastructure, exacerbating urban poverty. Short-run results reveal that the unemployment rate (ΔLUNR t-1) significantly impacts poverty, with a coefficient of 2.369508, indicating that an increase in unemployment increases poverty. While changes in real GDP per capita, urbanization, and CO_2 emissions (lagged changes) did not show significant short-run relationships with poverty. Granger Causality Results reveal a strong causal relationship, with past unemployment rates significant predictors of future poverty levels. While rapid urbanization to poverty levels Significant causal relationship, indicating that past urbanization trends can predict future poverty levels. Other variables did not show significant causal relationships observed among other pairs. All diagnostic analyses confirmed that the model is free from any issues and demonstrates strong stability.

The study suggests the following recommendations:

Urban Planning: Implement better urban planning to manage rapid urbanization, improve infrastructure, and reduce poverty by addressing informal settlements and resource shortages.

Employment Programs: Focus on job creation and labor market reforms, as unemployment significantly drives poverty. A 1% rise in unemployment leads to a 9.64% increase in poverty.

Climate Adaptation: Strengthen climate resilience and environmental policies to mitigate the delayed but significant impact of CO_2 emissions on poverty.

Regional Strategies: Develop region-specific policies to address varying levels of urbanization, unemployment, and climate vulnerability across Somalia.

Although this study offers valuable insights, it also recognizes critical limitations. One significant limitation is the model's treatment of Somalia as a homogenous entity despite substantial regional variations in urbanization, unemployment rates, and the impacts of climate change. This generalized approach may obscure critical local differences, potentially reducing the precision and relevance of the findings for specific regions. Future research should incorporate these regional variations to improve accuracy, ensuring the results more accurately reflect the diverse realities across Somalia's different areas.

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Data Availability

The data used to support the research findings are available from https://databank.worldbank.org/source/world-development-indicators; https://www.sesric.org/query.php.

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Conflicts of Interest

The authors declare no conflict of interest.

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