Dynamics of Adjusted Net National Income Per Capita and Its Determinants: Application of ARDL and Vector Error Correction Models to Sub-Saharan Africa

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Abstract: *Over the past few decades, the Sub-Saharan Africa (SSA) region has experienced a myriad of economic challenges, including highly dynamic trade trends, fluctuating commodity prices, stagnating capital accumulation trends, varying levels of foreign investment, and rapid population growth. These, coupled with the region's unique socio-economic landscape, necessitate a comprehensive understanding of how different variables interact to shape income outcomes. This paper employs the Autoregressive Distributed Lag (ARDL) and Vector Correction Models (VECM) to analyse the dynamics of Adjusted Net National Income Per Capita (ANNIPC). The results show complex interdependencies of capital formation, trade, inflation, and demographics indicating that increased gross capital formation and manageable inflation positively affect ANNIPC. This underscores the need for policymakers in SSA to prioritise capital investment strategies, such as infrastructure development and enhanced financial access, to spur sustainable economic growth. Additionally, improving export capacities and trade balances for elevating income levels and paying attention to population dynamics is essential. Similarly, integrating human capital enhancement through education and skills training into economic policies remains one of the important focal areas. We also found a quick adjustment to long-run equilibrium among variables that underscores the need for proactive policymaking to mitigate short-term economic shocks. A comprehensive approach, considering these interconnected factors, will be critical for SSA's governments to create a stable economic environment, ultimately fostering resilience and prosperity in the region.*

Keywords: Adjusted Net Income Per Capita, Autoregressive Distributed Lag Model, Vector Error Correction Model, Cointegration, Gross Fixed Capital Formation

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1. Introduction

As nations in the Sub-Saharan Africa (SSA) region strive for sustainable development and economic resilience, understanding the factors that influence income levels becomes paramount. The region has experienced a myriad of economic challenges over the past few decades, including fluctuating commodity prices, varying levels of foreign investment, and rapid population growth. These factors, coupled with the region's unique socio-economic landscape, necessitate a thorough examination of how different variables interact to shape income outcomes. The ARDL model serves as an appropriate analytical framework for this investigation, given its ability to capture both short-term dynamics and long-term relationships among the variables under consideration. In particular, we choose five key predictors for estimating the ARDL and VECM models namely; the gross fixed capital formation, exports of goods and service, imports of goods and services, inflation, and total population. These factors are considered essential for understanding the underlying economic mechanisms involved (Tadaro & Smith, 2020).

The gross fixed capital formation is often regarded as a fundamental driver of economic growth, as it reflects investments in physical assets that can boost productivity and overall economic output which varies across countries (Ahumada & Villarrel, 2020). International trade is a key factor in a nation's economic integration (You *et al*., 2024) and its competitiveness in the global economy (Bacchetta *et al*., 2021). Its connection to GDP growth underscores its importance as a driver of economic development (Chen, 2018). Furthermore, inflation is also renowned as a key variable that affects purchasing power and consumer behaviour, influencing overall economic stability (Akinsola & Odhiambo, 2017). The total population also significantly impacts labour market dynamics and economic potential, affecting the demand for goods and services (Stibbard, 1999; Crenshaw *et al*., 1997).

Trade generates foreign exchange and stimulates domestic industries (Krugman *et al*., 2012). Imports, for example, can affect the trade balance and the overall health of the economy (IMF, 2009). Inflation influences purchasing power and can impact savings and investment decisions (Mishkin, 2022). Total population affects labour supply, consumption patterns, and the potential for economic growth (Friedman & Kuznets, 1954). The role of exports and imports in shaping an economy highlights the interconnectedness of global trade dynamics and local production capabilities. As countries strive to enhance their export capacity, they often invest in refining industries, which in turn creates job opportunities and stimulates domestic economic activities (World Bank, 2021). The fluctuations in the trade balance resulting from imports can often lead to adjustments in fiscal and monetary policies aimed at stabilizing economic conditions (IMF, 2020).

Understanding the interactions among these variables allows for a more nuanced analysis of economic conditions and potential policy implications. For instance, understanding the impact of inflation on purchasing power informs the framing of economic policies that cater not only to growth but also to equitable wealth distribution (Stiglitz & Walsh, 2006). Just as important, the understanding of how rising inflation can deter investment helps to careful monitor consumer price indices, which is vital for maintaining economic stability (SU & Soon, 2024). Lastly, changes in total population directly influence labour supply, which is a critical factor for sustaining economic momentum and adapting to shifts in market demands (Acemoglu & Robinson, 2013). By employing the ARDL and VECM models, we aim to provide empirical evidence that elucidates these relationships, thereby offering insights that can inform effective policy interventions. While we acknowledge that there is a growing body of literature on economic development in SSA, we argue that there remains a notable gap in comprehensive analyses that simultaneously consider the interplay of capital formation, trade, inflation, and demographic factors on ANNIPC. Previous studies have often focused on isolated variables or have been limited to cross-sectional analyses, thereby failing to capture the dynamic and interconnected nature of these factors over time at a regional scale. This study contributes to the existing literature by employing a robust time series approach, utilizing the ARDL and VECM models to analyze data from a diverse set of countries within the SSA region.

2. Theoretical Framework

In order to understand the dynamics of "adjusted net national income per capita" (ANNIPC) in SSA, we ground our analysis in relevant economic theories that elucidate the relationships between our dependent variable and the selected independent variables. The theoretical framework for the study is primarily anchored in the classical and contemporary theories of economic growth, which maintains that various macroeconomic factors significantly influence national income levels. In this regard, the concept of "adjusted net national income per capita" is considered as a crucial indicator of economic well-being, as it accounts for the depreciation of capital assets and the depletion of natural resources. This adjustment is vital for providing a more accurate representation of a nation's economic performance. The theoretical underpinnings of this concept can be traced to the Solow Growth Model, which emphasizes the role of capital accumulation, labour force growth, and technological progress in driving economic growth. In this context, "gross fixed capital formation" is expected to have a positive impact on "adjusted net national income per capita", as increased investment in physical capital enhances productive capacity and fosters economic development.

International trade, notably the exportation and importation of goods and services, constitutes one of the key variables influencing national incomes (Bezrukova *et al*., 2024). The theory of comparative advantage postulates that countries can benefit from specialization and trade (Kowalski, 2011). This increases efficiency and higher income levels (OECD, 2011). Accordingly, we consider exports and imports of goods and services driving net national income per capita (OECD, 2011). This reflects the interconnectedness of global markets and highlights the importance of trade in driving economic growth (You *et al*., 2024). We also assume that inflation is another factor that influences ANNIPC (Dorrance, 1963). The Phillips Curve suggests an inverse relationship between inflation and unemployment, indicating that moderate inflation may be linked to economic expansion. However, high levels of inflation can diminish purchasing power and destabilize economies, potentially leading to adverse effects on adjusted net national income per capita. Consequently, it is essential to understand the complex impact of inflation on income levels in our analysis.

Lastly, the population variable introduces demographic considerations into our framework. Theories of demographic transition highlight the relationship between population growth and economic development. A growing population can lead to an expanded labour force, which, if matched with adequate capital and resources, can drive economic growth. Conversely, rapid population growth without corresponding economic development may strain resources and hinder improvements in per capita income. Thus, the interaction between population dynamics and adjusted net national income per capita warrants examination.

3. Conceptual Framework

The conceptual framework for this paper (Figure 1) is grounded in the theoretical underpinnings of the Autoregressive Distributed Lag (ARDL) model, which allows for the examination of both short-term and long-term relationships between the dependent variable, "adjusted net national income per capita" and the selected independent variables. The ARDL approach is particularly suitable for our analysis as it accommodates variables of different integration orders, thereby enabling a robust investigation of the dynamic interactions among the variables over the specified period of 1991-2021.

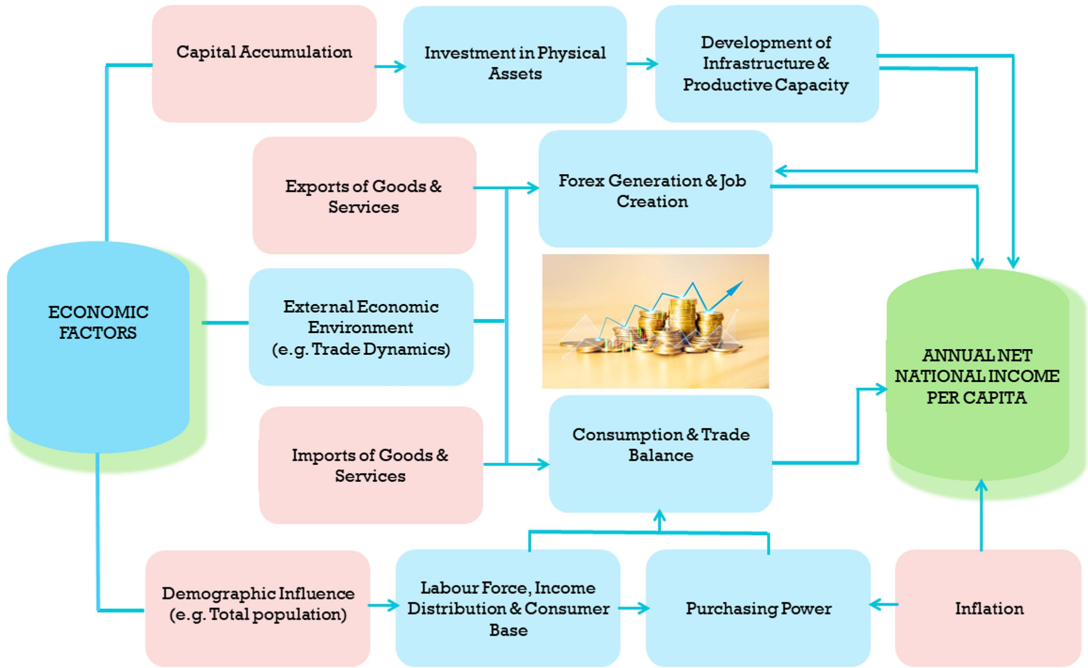

Figure 1: Conceptual framework for the study
Source: Authors' construction from literature review

In this framework, we hypothesise that "adjusted net national income per capita" is influenced by a multitude of economic factors, which can be categorized into three primary dimensions: "capital accumulation", "trade dynamics", and "demographic" influences. Firstly, "gross fixed capital formation" serves as a critical driver of economic growth, reflecting the investments in physical assets that enhance productive capacity. Increased capital investment leads to higher income levels (Koopman, & Wacker, 2023; Grozdić *et al.*, 2020; Jones & Taylor, 2019) and can facilitate the development of infrastructure and productive capabilities within SSA economies (Calderon *et al.*, 2018). Secondly, trade variables, notably; "exports of goods and services" and "imports of goods and services", are integral to understanding the external economic environment's influence on national income (You *et al.*, 2024; Krugman *et al.*, 2012). Exports are anticipated to positively affect "adjusted net national income per capita" by generating foreign exchange and creating jobs, while imports can have a dual effect. They may enhance consumption and investment but could also lead to trade imbalances that negatively affect income levels. Thirdly, inflation, measured by the consumer price index, may play a pivotal role in shaping real income levels. High inflation, for example, can erode purchasing power and distort economic decisions, potentially leading to a decrease in adjusted net national income per capita. Thus, understanding the inflationary environment is essential for accurately estimating its impact on income. Finally, total population is included as a demographic variable that can influence income distribution and economic growth. A larger population may provide a broader labour force and consumer base, yet it may also strain resources and infrastructure if growth does not keep pace with population increases.

The interplay of these variables within the ARDL framework allows us to capture the complexities of economic dynamics in the context of SSA, offering insights into how these factors collectively contribute to the variations in "adjusted net national income per capita". By systematically analysing these relationships, our study aims to provide a comprehensive understanding of the determinants of income levels in the region, ultimately contributing to policy discussions aimed at fostering sustainable economic development.

4. Study Approach and Methodology

4.1 Study Area and Data Sources

This paper focuses on the SSA region of the African continent lying south of the Sahara. It encompasses the Central, East, Southern, and West Africa. It is important to note that the classification of SSA countries varies depending on the contexts or the way it is used in political, economic, or cultural discussions. Geopolitically, the term includes African countries and territories fully situated in the region, and polities that have only part of their territory found in the region (UN, 2010; Ekwe-Ekwe, 2020).

Table 1: Data series and source used in the study, 1971-2023

Variable	Description
ANNIPC	Adjusted net national income per capita (constant 2015 US$)
CAPITAL	Gross fixed capital formation (constant 2015 US$)
EXPORTS	Exports of goods and services (constant 2015 US$)
IMPORTS	Imports of goods and services (constant 2015 US$)
INFLAT	Inflation, consumer prices (annual %)
TPOPN	Total population (annual) for SSA

Data source: https://data.worldbank.org/country/

The SSA region is therefore considered a non-standardized geographical region with several countries included, varying from 46 to 48 depending on the organization describing the area (e.g., UN, WHO, World Bank, etc.) (World Bank Group, 2020). The African Union (AU) adopts a distinct regional classification, recognizing 55 member states on the continent (Assèdé *et al*., 2023) and grouping them into five distinct and standard regions. The United Nations Geoscheme for Africa excludes Sudan, while the African Union includes Sudan but excludes Mauritania (Assèdé *et al*., 2023). The Nations Development Program classifies 46 of the 54 countries as SSA countries, excluding Djibouti, Somalia, and Sudan (UN, 2010). In this paper, we use the classification of 48 countries adopted by Tapkigen *et al*. (2024) (Appendix 1) and the secondary data obtained from the World Bank's open data source of development indicators (Table 1). The dataset dimensions are selected to encompass as many countries as possible, spanning from 1971 to 2023, as the time series data for many SSA countries were available during that period.

4.2 Estimation of the ARDL Model

Before estimating the ARDL model, we tested the data series for stationarity using the Eviews version 12 software. Where non-stationarity or unit root was detected, it was corrected by differencing the respective series or variables. The unit root test and differencing; were done using the Augmented Dickey-Fuller (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin" (KPSS) approaches. The optimal lag lengths for the model were determined using the Akaike Information Criterion (AIC) in comparison against other information criteria, including the Schwarz Bayesian Criterion (SBC) (Figure 2).

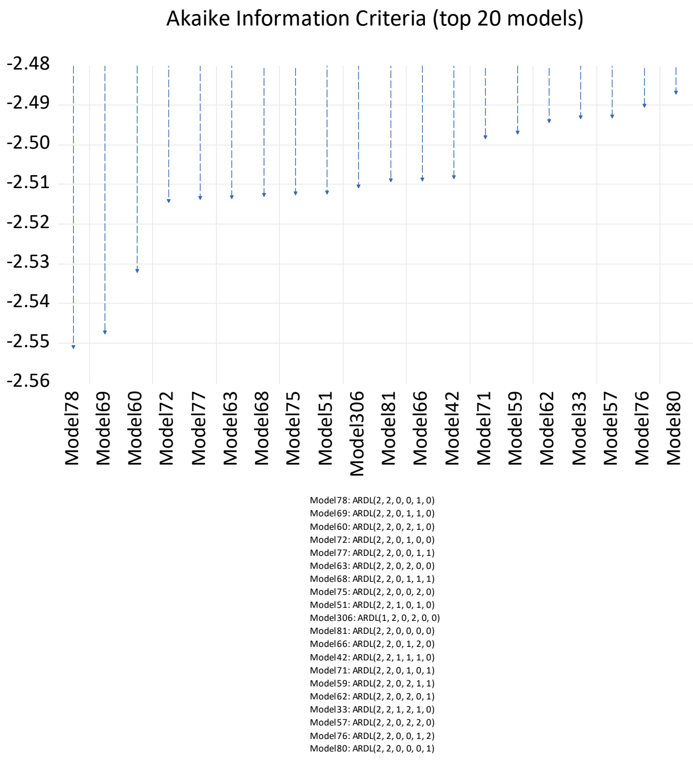

Figure 2: The top 20 ARDL models selected using the maximum lag length of 2

After confirming stationarity among variables, we applied the Johansen test of cointegration as a statistical method to determine the presence and number of cointegration relationships among the time series data or variables. After confirming the presence of cointegration we proceeded with the estimation of ARDL, ECM, and VEC models using the formulations by Pesaran *et al*. (2001); Pesaran & Shin (1999); Pesaran & Shin (1997); and Pesaran *et al*. (1996). The long-run coefficients were estimated and assessed to confirm the existence or absence of a long-term relationship among the variables. The F-statistics were compared against the critical values to determine the presence of cointegration. In addition to the long-run analysis, we derived the ECM to capture the short-term dynamics of the variables. The ECM included the lagged error correction term, which reflects the speed of adjustment towards the long-run equilibrium. To ensure the robustness of the model, we conducted diagnostic tests to check for autocorrelation, heteroscedasticity, and normality of residuals. We analyzed the long-run relationship based on the following Equation 1.

$$LOGANNIPC_t = \beta_0 + \beta_1 LOGCAPITAL_{t-1} + \beta_2 LOGCAPITAL_{t-2} + \beta_3 LOGEXPORTS_t + \beta_4 LOGIMPORTS_t + \beta_5 LOGINFLAT_t + \beta_6 LOGTPOPN_{t-1} + \epsilon_t \quad (1)$$

where: β_0 is the constant term; $\beta_1, \ldots, \beta_6$ are the coefficients associated with a linear trend; and ϵ_t represents the usual innovations or the error term or the shock that affects the model, and the lagged values (e.g. $LOGCAPITAL_{t-1}$) show how past levels of gross capital formation impact current net national income per capita.

For the Bounds test, we examined whether the null hypothesis of no long-run relationships could be rejected. This required us to estimate the above equation and derive the F-statistic from our cointegration equation. We then compared the F-statistic with the critical values provided by Pesaran *et al*. (2001) to determine whether our variables were cointegrated. This step was crucial as it established whether we could proceed to the Error Correction Model (ECM) analysis. Following the Bounds test, we confirmed the existence of cointegration. We then developed our ECM model, encompassing both long-run and short-run dynamics, as typically represented in Equation 2.

$$\Delta LOGANNIPC_t = \alpha + \gamma(LOGANNIP_{t-1} - \vartheta) - \delta \Delta LOGCAPITAL_{t-1} + \omega \Delta LOGCAPITAL_{t-2} + \tau \Delta LOGTPOPN_{t-1} + \mu_t \quad (2)$$

where; $LOGANNIP_{t-1} - \mu$ represents the error correction term where ϑ is the long-run relationship's equilibrium value. The γ coefficient indicates the speed of adjustment towards equilibrium.

We then complemented our analysis by applying a Vector Error Correction Model (VECM), the structure of which is similar to the ECM model. The idea was to account for multiple equations for the variables. This means that the VECM can comprise a system of equations considering the interaction between, for example, LOGANNIPC, LOGCAPITAL, and other relevant variables, allowing the exploration of how shocks to one variable can affect others in the short and long terms. Thus, by employing VECM, we could extend our analysis to a multivariate framework because; VECM allows the analysis of dynamic relationships between multiple time series while preserving long-run equilibrium properties. The model can be specified as in Equation 3.

$$\Delta Y_t = \alpha + \pi Y_{t-1} + \sum_{i=1}^{p-1} \tau_i \, \Delta Y_{t-1} + \mu_t \quad (3)$$

where;

- Y_t is a vector of our endogenous variables (including LOGANNIPC, LOGCAPITAL, LOGEXPORTS, etc.),
- π captures the long-run relationships,
- τ_i represents the short-run coefficients, and
- μ_t is the vector of error terms.

By using the selected lags and conducting further estimation we could assess not only the individual influences of the explanatory variables on net national income but also the interdependencies across the entire system of equations. Through the execution of the ARDL(2, 2, 0, 0, 0, 1) model configuration, we provided a comprehensive assessment of the short-run dynamics and long-run relationships that shape net national income per capita in the context of capital formation, trade, inflation, and population growth in SSA.

Assuming Y_t denotes the vector of our dependent and independent variables we can represent our ARDL(2, 2, 0, 0, 0, 1) model in the context of a Vector Error Correction Model (VECM), expressing the long-run relationships and short-run dynamics among the variables in a vector form (Equation 4). The VECM includes error correction terms that capture the deviations from long-run equilibrium, alongside the lagged variables specified by the ARDL model.

$$Y_t = \begin{bmatrix} LOGANNIPC_t \\ LOGCAPITAL_t \\ LOGEXPORTS_t \\ LOGIMPORTS_t \\ LOGINFLAT_t \\ LOGTPOPN_t \end{bmatrix} \tag{4}$$

We can express the VECM as in Equation 5:

$$\Delta Y_t = \pi Y_{t-1} + \tau_1 \Delta Y_{t-1} + \tau_2 \Delta Y_{t-2} + \epsilon_t \tag{5}$$

where;

- ΔY_t is the first difference of the variables to capture short-run dynamics,
- π is the matrix of long-run coefficients derived from the equilibrium relationships among the variables,
- τ_1 and τ_2 are matrices of short-run coefficients capturing the influences of lagged differences,
- ϵ_t is the vector of error terms.

Given our ARDL(2, 2, 0, 0, 0, 1) model specification, we further identify the structure of π and τ matrices as in Equations 6.

$$\pi = \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} \\ 0 & \beta_{22} & \beta_{23} & 0 & 0 \\ 0 & 0 & \beta_{33} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \beta_{55} \end{bmatrix} \quad \tau_1 = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{14} & \gamma_{15} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{24} & \gamma_{25} \\ 0 & 0 & \gamma_{33} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ \gamma_{51} & \gamma_{52} & \gamma_{53} & \gamma_{54} & \gamma_{55} \end{bmatrix}$$

$$\tau_2 = \begin{bmatrix} \gamma_{11}^2 & \gamma_{12}^2 & \gamma_{13}^2 & \gamma_{14}^2 & \gamma_{15}^2 \\ \gamma_{21}^2 & \gamma_{22}^2 & \gamma_{23}^2 & \gamma_{24}^2 & \gamma_{25}^2 \\ 0 & 0 & \gamma_{33}^2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ \gamma_{51}^2 & \gamma_{52}^2 & \gamma_{53}^2 & \gamma_{54}^2 & \gamma_{55}^2 \end{bmatrix} \quad (6)$$

The first row of the π matrix includes coefficients that reflect the long-run relationship between LOGANNIPC and all other variables. The rows corresponding to LOGCAPITAL and LOGEXPORTS include respective coefficients from the second lags because of the ARDL(2, 2, 0, 0, 0, 1) order. According to the ARDL specification, there will be no terms for LOGIMPORTS and LOGINFLAT, indicating no long-run relationship in this model context. LOGTPOPN will have a first lag appearing only in the error correction term, linking it to the long-run relationship. This structural representation facilitated the analysis of both short-run and long-run dynamics among variables while retaining the integrity of the original ARDL model specifications.

5. Results

5.1 Results of Johansen Cointegration Test

The results of the Johansen cointegration test presented in Table 2 indicate the presence of a long-run equilibrium relationship (cointegration) among the variables. For the hypothesis of "none," the findings show a statistically significant trace statistic of 122.1639, which exceeds the critical value of 95.75366 at the 0.05 significance level. This strong evidence leads us to reject the null hypothesis that there are no cointegrating relations, suggesting the existence of at least one cointegrating vector among the variables. For the hypothesis of "at most 1," the trace statistic of 68.14516 is slightly below the critical value of 69.81889. Thus, we fail to reject the null hypothesis meaning that while there is at least one significant cointegrating relationship, the evidence for a second co-integrating vector is weaker, as indicated by the *p*-value of 0.0675 that hovers around the conventional cut-off of 0.05. For the hypothesis of "at most 2," the trace statistic of 43.70917 is again below the critical value of 47.85613, reinforcing our previous conclusion that we do not have sufficient evidence to identify more than one cointegrating relationship among the variables. The corresponding *p*-value of 0.1162 indicates a lack of significant evidence for additional long-run relationships. Overall, the trace results suggest that our log series share a long-term equilibrium while indicating that one single cointegrating relationship, rather than multiple relationships, adequately describes the behaviour of the variables.

Table 2: Results of unrestricted cointegration rank test (trace)

Hypothesised No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.653264	122.1639	95.75366	0.0002
At most 1	0.380682	68.14516	69.81889	0.0675
At most 2	0.351341	43.70917	47.85613	0.1162
At most 3	0.221270	21.63390	29.79707	0.3193
At most 4	0.156791	8.879274	15.49471	0.3767
At most 5	0.003557	0.181742	3.841465	0.6699

Trace test indicates 1 cointegration equation at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) *p*-value

Likewise, the Maximum Eigenvalue results in Table 3 indicate one statistically significant cointegrating relationship, reinforcing the idea that a long-term equilibrium relationship exists among the variables. For the hypothesis of "none" cointegrating relationships, the Maximum Eigen statistic of 54.01873 exceeds the critical value of 40.07757 at the 0.05 significance level, with a *p*-value of 0.0007. This strong statistical evidence allows us to reject the null hypothesis of no cointegration, indicating the presence of at least one cointegrating relationship among the series. This finding implies that changes in any of the independent variables (LOGCAPITAL, LOGEXPORTS, LOGIMPORTS, LOGINFLAT, and LOGTPOPN) are expected to have a long-run impact on LOGANNIPC, reinforcing the validity of our model for further analysis in this context.

Table 3: Results of unrestricted cointegration rank test (Maximum Eigenvalue)

Hypothesised No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None*	0.653264	54.01873	40.07757	0.0007
At most 1	0.380682	24.43599	33.87687	0.4242
At most 2	0.351341	22.07527	27.58434	0.2165
At most 3	0.221270	12.75463	21.13162	0.4751
At most 4	0.156791	8.697532	14.26460	0.3122
At most 5	0.003557	0.181742	3.841465	0.6699

Max-eigenvalue test indicates 1 cointegration equation at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) *p*-value

5.2 ARDL Long Run Form and Bounds Tests

5.2.1 Results of Conditional Error Correction (CEC) Regression

The results of the ARDL Long Run – Conditional Error Correction (CEC) model are presented in Table 4. The coefficient of LOGANNIPC(-1)* of -0.766310 indicates a significant negative long-run relationship between the lagged dependent variable and the model. The *t*-statistic of -5.084807 and the *p*-value of 0.0000 reinforce the notion that past values of net national income per capita (ANNIPC) exert a strong negative influence on its current level.

This implies that higher previous levels of LOGANNIPC are associated with lower current levels, which could suggest a mean reversion phenomenon.

Table 4: Results of ARDL(2, 2, 0, 0, 1, 0) - CEC regression

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	-1.649759	1.121275	-1.471324	0.1490
LOGANNIPC(-1)*	-0.766310	0.150706	-5.084807	0.0000
LOGCAPITAL(-1)	0.250673	0.062575	4.005987	0.0003
LOGEXPORTS**	0.047165	0.061964	0.761167	0.4510
LOGIMPORTS**	-0.016652	0.037385	-0.445414	0.6584
LOGINFLAT(-1)	0.035533	0.016242	2.187744	0.0346
LOGTPOPN**	0.050370	0.046382	1.085981	0.2840
D(LOGANNIPC(-1))	0.470308	0.151078	3.113017	0.0034
D(LOGCAPITAL)	0.102463	0.117411	0.872680	0.3880
D(LOGCAPITAL(-1))	-0.373822	0.135091	-2.767189	0.0085
D(LOGINFLAT)	0.003342	0.017610	0.189803	0.8504

**p*-value incompatible with *t*-Bounds distribution
**Variable interpreted as Z = Z(-1) + D(Z)

The coefficient of LOGCAPITAL(-1) at 0.250673 reveals a positive long-run impact of lagged gross capital formation on net national income per capita. The *t*-statistic of 4.005987 and a *p*-value of 0.0003 indicate that the relationship is statistically significant. This suggests that increases in capital formation, as measured in logarithmic terms, contribute positively to the growth of national income per capita in the long run, underscoring the importance of investment in economic development. The coefficient of LOGINFLAT(-1) of 0.035533 signals a positive relationship between lagged inflation and LOGANNIPC. With a *t*-statistic of 2.187744 and a *p*-value of 0.0346, this outcome implies that inflation can have a long-term effect on income per capita, albeit modestly.

The coefficient of LOGANNIPC(-1) at 0.470308 further suggests that past levels of net national income per capita positively contribute to its current levels. The *t*-statistic of 3.113017 and a *p*-value of 0.0034 highlight the robustness of this relationship, confirming that historical performance in terms of income can have significant implications for its present value, potentially highlighting the persistence of economic conditions. The coefficient of LOGCAPITAL(-1) being -0.373822 introduces an interesting complexity to the analysis. With a *t*-statistic of -2.767189 and a *p*-value of 0.0085, this negative relationship indicates that while gross capital formation is generally expected to lead to growth, there may be some contexts or periods where an increase in lagged capital formation has a detrimental effect on LOGANNIPC. This could suggest issues like overinvestment, inefficiencies in capital use, or periods of economic adjustment and contraction following capital increases, signaling the necessity for careful economic policy monitoring and intervention.

5.2.2 Results of ARDL long run – levels equation

The results of the ARDL long run levels equation in Table 5 indicate a coefficient of LOGCAPITAL, which is 0.327117, implying a positive long-term relationship between gross capital formation and adjusted net national income per capita. Specifically, a one percent increase in gross capital formation is associated with an approximate 0.327 percent increase in adjusted net national income per capita. The *t*-statistic of 5.651483, coupled with the *p*-value of 0.0000, suggests that this coefficient is statistically significant at conventional levels, reaffirming the critical role of gross capital formation in influencing national income.

Table 5: Results of ARDL(2, 2, 0, 0, 1, 0) - Level equation (restricted constant and no trend)

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
LOGCAPITAL	0.327117	0.057882	5.651483	0.0000
LOGEXPORTS	0.061548	0.079014	0.778951	0.4406
LOGIMPORTS	-0.021730	0.049358	-0.440245	0.6621
LOGINFLAT	0.046370	0.017688	2.621563	0.0123
LOGTPOPN	0.065731	0.059916	1.097055	0.2792
C	-2.152863	1.354523	-1.589388	0.1198

EC = LOGANNIPC - (0.3271*LOGCAPITAL + 0.0615*LOGEXPORTS - 0.0217*LOGIMPORTS + 0.0464*LOGINFLAT + 0.0657*LOGTPOPN

Similarly, the coefficient of LOGINFLAT is 0.046370, pointing to a positive relationship between inflation and adjusted net national income per capita. This implies that a one percent increase in the log of inflation is linked to a roughly 0.046 percent increase in the log of adjusted net national income per capita. The *t*-statistic of 2.621563 and the *p*-value of 0.0123 further indicate that this relationship is statistically significant, suggesting that inflation, in this context, plays a noteworthy role in the long-term determination of national income levels. Overall, LOGCAPITAL and LOGINFLAT exhibited statistically significant positive effects on LOGANNIPC, indicating that enhancements in capital formation and a moderate level of inflation may be beneficial for increasing adjusted net national income per capita in the long run.

5.2.3 Results of Bounds test

The results of the Bounds test are shown in Table 6. To interpret these results in the context of the provided critical values across different significance levels, we compare the calculated *F*-statistic to the critical values for I(0) and I(1). The results show an *F*-statistic of 4.675495 which is greater than the critical values at the significance levels of 10%, 5%, and 2.5% indicating the presence of a long-run relationship among the variables in the ARDL model.

At the 10% significance level, the critical values are 2.26 for I(0) and 3.35 for I(1). Since our *F*-statistic (4.675495) is greater than both critical values, we can reject the null hypothesis of no long-run relationship among the variables. Moving to the 5% significance level, the critical values are 2.62 for I(0) and 3.35 for I(1). Again, our *F*-statistic exceeds these thresholds, reinforcing our earlier conclusion that there is a significant long-run relationship present at this level as well. At the 2.5% significance level, the critical values shift to 2.96 for I(0) and 4.18 for I(1). Our *F*-statistic continues to surpass these values, providing further support for the existence of a long-run association between the variables under examination. At the 1% significance level, the critical values are 3.41 for I(0) and 4.68 for I(1). Here, our *F*-statistic is marginally above the critical value for I(1) but not above the critical value for I(0). This suggests that while the long-run relationship is still apparent, it becomes weaker under the most stringent level of significance.

Table 6: Results of ARDL(2, 2, 0, 0, 1, 0) - Bounds test

***F*-Bounds Test**	**Null Hypothesis: No levels relationship**			
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
		Asymptotic: n=1000		
F-statistic	4.675495	10%	2.26	3.35
K	5	5%	2.62	3.79
		2.5%	2.96	4.18
		1%	3.41	4.68
Actual Sample Size	51	Finite Sample: n=55		
		10%	2.393	3.583
		5%	2.848	4.16
		1%	3.928	5.408
		Finite Sample: n=50		
		10%	2.435	3.6
		5%	2.9	4.218
		1%	3.955	5.583
***t*-Bounds Test**	**Null Hypothesis: No levels relationship**			
	Value	**Signif.**	**I(0)**	**I(1)**
t-statistic	-5.08481	10%	-2.57	-3.86
		5%	-2.86	-4.19
		2.5%	-3.13	-4.46
		1%	-3.43	-4.79

Overall, the results of the Bounds test indicate robust evidence of a long-run relationship among LOGANNIPC, LOGCAPITAL, LOGEXPORTS, LOGIMPORTS, LOGINFLAT, and LOGTPOPN at the 10%, 5%, and 2.5% significance levels, with slightly weaker evidence at the 1% level. This suggests that the independent variables collectively explain the variations in the dependent variable over the long term (Narayan, 2004; Pesaran & Shin, 1997).

5.3 Results of ARDL Error Correction Model (ECM)

The results of ECM are presented in Table 7. The results provide insights into the dynamics of the adjusted net national income per capita (ANNIPC) concerning the independent variables considered. For example, the coefficient for D(LOGANNIP(-1)) is 0.470308 indicating a positive and significant relationship between the lagged value of the dependent variable and its current value. This suggests that approximately 47% of the changes in ANNIPC can be attributed to the previous year's value, reinforcing the idea of persistence in income levels over time. The *t*-statistic of 3.376906 and the *p*-value of 0.0016 confirm that this result is statistically significant, allowing us to reject the null hypothesis. In contrast, the coefficient for D(LOGCAPITAL(-1)) of -0.373822 presents a negative relationship, signifying that a lagged increase in gross capital formation has a detrimental impact on ANNIPC. The *t*-statistic of -3.578304 and *p*-value of 0.0009 further substantiate this effect, indicating strong evidence that past capital formation decreases per capita income, perhaps due to issues like inefficient capital allocation or diminishing returns.

Table 7: Results of ARDL(2, 2, 0, 0, 1, 0) - Error Correction Model (ECM)

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	-1.649759	0.294934	-5.593659	0.0000
D(LOGANNIPC(-1))	0.470308	0.139272	3.376906	0.0016
D(LOGCAPITAL)	0.102463	0.090981	1.126197	0.2668
D(LOGCAPITAL(-1))	-0.373822	0.104469	-3.578304	0.0009
D(LOGINFLAT)	0.003342	0.014143	0.236329	0.8144
CointEq(-1)*	-0.766310	0.136408	-5.617793	0.0000
R-squared	0.450475	Mean dependent variable		0.007432
Adjusted R-squared	0.389416	S.D. dependent variable		0.074210
S.E of regression	0.057987	Akaike information criterion		-2.747048
Sum squared residual	0.151315	Schwarz criterion		-2.519774
Log likelihood	76.04972	Hannan-Quinn criterion		-2.660200
F-statistic	7.377767	Durbin-Watson statistic		2.296376
Prob(*F*-statistic)	0.000040			

**p*-value incompatible with *t*-Bounds distribution

The coefficient of CoIntEq(-1)* (-0.766310) suggests a strong negative long-run relationship between the cointegrating equation and ANNIPC. A *t*-statistic of -5.617793, with a *p*-value of 0.0000, indicates that this result is very statistically significant, implying that deviations from the long-run equilibrium will lead to adjustments that negatively impact ANNIPC, stressing the importance of returning to equilibrium for sustainable income growth. The R-squared value of 0.450475 indicates that approximately 45% of the variance in ANNIPC is explained by the independent variables in the model, while the adjusted R-squared of 0.389416 accounts for the number of predictors, suggesting a moderate fit. The *F*-statistic of 7.377767, with a corresponding *p*-value of 0.00004, shows that the overall regression model is statistically significant, meaning at least one of the independent variables is a significant predictor of ANNIPC. Lastly, a Durbin-Watson statistic of 2.296376 suggests the absence of autocorrelation in the residuals, indicating that our model's assumptions regarding the independence of errors are valid.

In a nutshell, the ECM results suggest a complex interplay between past income levels, capital formation, and the long-run equilibrium status of net national income. The dynamics highlighted in the coefficients and their statistical significance substantiate the need for careful policy consideration regarding capital investments and their expected outcomes on income growth. The presence of cointegration as established by not only the Johansen and Bounds tests but also the ECM results suggests that policies aimed at improving gross capital formation or enhancing export proportions, could yield a sustainable increase in national income per capita in SSA. The significant speed of adjustment implies that policymakers in the region should anticipate the short-run impacts of their decisions, recognizing that economic shocks may be corrected swiftly toward the long-term growth trajectory.

5.4 Results of Vector Error Correction Model (VECM) Estimation

Table 8 presents the estimates of VECM. The coefficient for LOGANNIPC(-1) of 1 implies that the adjusted net national income per capita is directly related to its own lagged value, suggesting a stable long-run relationship where increases in ANNICP are expected to persist in future periods. The negative coefficient for LOGCAPITAL(-1) of -0.511698 indicates that a 1% increase in gross capital formation is associated with approximately a 0.51% decrease in adjusted net national income (ANNIPC), holding all other variables constant. The high absolute value of the *t*-statistic (-12.3107) confirms that this relationship is statistically significant, implying a strong negative influence of capital formation on adjusted net national income per capita.

Table 8: Results of Vector Error Correction Model (VECM)

Cointegrating Eq:	Coefficient	Std. Error	*t*-Statistic
LOGANNIPC(-1)	1		
LOGCAPITAL(-1)	-0.511698	0.04157	-12.3107
LOGEXPORTS(-1)	0.108144	0.06929	1.56083
LOGIMPORTS(-1)	0.243788	0.03929	6.20523
LOGINFLAT(-1)	-0.026044	0.01608	-0.62007
LOGTPOPN(-1)	-0.068047	0.04431	-1.53585
C	-3.055392		

The coefficient for LOGEXPORTS(-1) of 0.108144 suggests that a 1% increase in exports of goods and services is associated with an approximate 0.11% increase in adjusted net national income per capita. However, the *t*-statistic of 1.56083 indicates that this relationship is not statistically significant at conventional levels, suggesting that while there is a positive association, it may not be robust. The coefficient for LOGIMPORTS(-1) being 0.2343788 indicates a positive long-run relationship with adjusted net national income per capita, where a 1% increase in imports is associated with about a 0.23% increase in ANNICP. The *t*-statistic of 6.20523 further confirms that this effect is statistically significant. The coefficient for LOGINFLAT(-1) is -0.026044, implying that a 1% increase in inflation correlates with a decrease of approximately 0.03% in adjusted net national income per capita. The *t*-statistic of -1.62007 suggests that this relationship approaches significance but does not robustly support a strong negative impact of inflation on ANNICP at traditional confidence levels. Finally, the negative coefficient for LOGTPOPN(-1) of -0.068047 indicates an inverse relationship between total population and adjusted net national income per capita, where a 1% increase in population is associated with a decrease of around 0.07% in ANNICP. The *t*-statistic of -1.53585 echoes the marginal significance of this relationship, suggesting further investigation may be warranted. Overall, the VECM results highlight complex interrelationships among the variables affecting adjusted net national income per capita, particularly emphasizing the significant negative impact of gross capital formation and the positive contributions of imports.

The second part of the results of Error Correction (EC) in the VECM provides results for the systems of equations for the multiple cointegrated variables. The statistically significant results are shown in Table 9.

Table 9: Results of VECM for the systems of equations, multiple cointegrated variables

Variables		Coefficient	Std. Error	*t*-statistic
CointEq1	D(LOGANNIPC)	-0.716419	0.12453	-5.75288
	D(LOGIMPORTS)	-2.270042	0.52239	-4.34548
D(LOGANNIPC(-1))	D(LOGANNIPC)	0.342483	0.12825	2.67046
	D(LOGCAPITAL)	0.498469	0.18094	2.75491
	D(LOGIMPORTS)	1.766481	0.53798	3.28354
	D(LOGINFLAT)	3.044358	1.41110	2.15744
D(LOGANNIPC(-2))	D(LOGANNIPC)	0.0334154	0.16025	2.08520
D(LOGCAPITAL(-1))	D(LOGANNIPC)	-0.395892	0.12962	-3.05421
	D(LOGIMPORTS)	-1.244111	0.54374	-2.28806
D(LOGIMPORTS(-1))	D(LOGCAPITAL)	-0.133984	0.04488	-2.98540
D(LOGIMPORTS(-2))	D(LOGANNIPC)	0.085489	0.03627	2.35721
D(LOGINFLAT(-1))	D(LOGTPOPN)	-0.352208	0.17486	-2.01425
D(LOGTPOPN(-1))	D(LOGCAPITAL)	-53.85532	17.7831	-3.02846
D(LOGTPOPN(-2))	D(LOGCAPITAL)	35.65852	17.9261	1.98920

The following key inferences can be drawn from the results presented in Table 9. Firstly, the coefficient between CointEq1 and D(LOGANNIPC) is -0.716419, corresponding to a significant *t*-statistic of -5.75288. This indicates that deviations from the long-run equilibrium in ANNIPC have a substantial negative effect on its short-term changes, suggesting that a percentage increase in the error correction term (i.e. the deviation from the long-run relationship) results in a decrease in ANNIPC. Secondly, the coefficient between CointEq1 and D(LOGIMPORTS) of -2.270042, with a *t*-statistic of -4.34548 means that an increase in the error correction term leads to higher imports, contributing to a significant reduction in the short-term growth of imports. This suggests a potential trade-off or adjustment speed regarding imports and income.

Thirdly, the positive coefficient of 0.342485 between D(LOGANNIPC(-1)) and D(LOGANNIPC) suggests that past values of ANNIPC have a positive influence on its current level, reinforcing the notion of momentum or inertia in income growth. Fourthly, the results show the coefficients for the lagged effects of ANNIPC on exports, inflation, and population of 0.498469, 1.766481, and 3.044358 respectively. This further illustrates that higher historical values of ANNIPC encourage increases in exports, inflation, and population growth, reflecting the interlinked nature of these economic factors. Fourthly, we observe a negative effect of capital formation (D(LOGCAPITAL(-1)) on D(LOGANNIPC) (-0.395892) suggesting that, in the short term, higher levels of capital formation may not guarantee immediate growth of ANNIPC, possibly due to investment lags or inefficiencies. Additionally, we found a negative coefficient of -1.244111 for inflation indicating that persistent inflation could hinder economic performance, affecting the income level. Fifthly, we note significant import and export dynamics indicated by a negative coefficient between D(LOGIMPORTS(-1)) and D(LOGEXPORTS) (-0.133984) suggesting a potential "crowding out effect" where higher imports negatively impact exports. Conversely, we noted a positive effect of D(LOGIMPORTS(-2)) on D(LOGANNIPC) suggesting that previous periods' imports may enhance income levels but the contemporaneous relationship with exports indicates a more complex interaction.

In this case, we describe the term "crowding out effect" as a situation where an increase in imports leads to a decrease in exports, indicating a displacement of domestic production. This can occur because as a country imports more goods and services, domestic consumers may prefer the imported products over locally produced ones, reducing the demand for exports. Consequently, domestic producers may face lower sales domestically, which can lead to decreased production capacity and ultimately impact their ability to export goods. Moreover, the observed negative coefficient of -0.133984 suggests that changes in imports directly correlate with changes in exports, reinforcing the idea that higher imports might draw resources, focus, or market share away from export-oriented industries. This phenomenon can hinder a country's trade balance and economic growth, as reliance on foreign goods undermines local markets and industries that could otherwise thrive through exportation. It is important to understand the underlying factors contributing to this crowding-out effect (European Central Bank, 2024; Abegaz, 2024). These factors may include relative price changes, consumer preferences, and the overall exchange rate dynamics that could influence import and export activities (Abegaz, 2024; Kemoe *et al*., 2024).

Fifthly, the relationships involving total population (D(LOGTPOPN)) showed variability with a coefficient of -0.352208 for "inflation", D(LOGINFLAT(-1)), influencing the "total population, D(LOGTPOPN). This suggests that inflation potentially constrains population growth. We also observed a significant negative effect (-53.85532) of D(LOGTPOPN(-1)) on D(LOGEXPORTS) suggesting that increasing population figures lead to diminished exports, likely reflecting market saturation or resource allocation challenges. Lastly, we observe long-term export dynamics notably, the interplay of lagged population dynamics affecting imports negatively while exerting a variable impact on exports, illustrated by the mixed signs and magnitudes of the coefficients from D(LOGTPOPN(-2)) and its influence on exports. Overall, these results illustrate complex interdependencies among income, trade variables, inflation, and population dynamics, emphasizing the necessity for careful policy consideration to foster growth in ANNIPC while managing inflationary pressures and the balance of trade.

6. Discussion

6.1 ARDL Long Run Form CEC Regression

The ARDL long-run CEC model results reveal fascinating dynamics in the relationship between adjusted net national income per capita (ANNIPC) and its determinants in SSA. In particular, the observed "mean reversion" phenomenon indicated by the negative coefficient of LOGANNIPC(-1) at -0.766310, suggests that declines often follow periods of high net national income per capita (ANNIPC) in current income levels. This can be interpreted through the lens of economic cycles, where temporary booms are succeeded by corrections, thus emphasizing the need for sustainable economic policies that mitigate volatility in income levels. Conversely, the positive coefficient of LOGANNIPC(-1) at 0.470308 highlights the significance of historical income levels in shaping current economic conditions. This persistence effect aligns with the "path dependence" concept in economic theory, where past performance influences future outcomes (Mahoney, 2000; Pierson, 2000). The robustness of this relationship, underscored by a *t*-statistic of 3.113017 and a *p*-value of 0.0034, points to the critical role that historical net national income plays in the economic fabric of SSA nations. Such findings are consistent with existing literature that emphasizes the importance of historical economic performance in determining current and future income levels, suggesting that countries with a strong historical income base may have a comparative advantage in sustaining growth (Piketty, 2014; Nunn & Qian, 2011; Acemoglu *et al*., 2001).

Thus, this persistence may reflect structural factors inherent in SSA economies, such as institutional quality, investment in human capital, and the effectiveness of governance. For instance, a study by Acemoglu *et al*. (2001) highlights how institutions established in the past can have lasting effects on economic performance. Similarly, the work of Pritchett (2000) emphasizes the role of historical economic conditions in shaping the growth trajectory, reinforcing the notion that past income levels are not merely a reflection of previous performance but are also indicative of the underlying structural factors that influence economic dynamics. These results underscore the complex interplay between historical and current economic conditions in SSA, suggesting that the region's policymakers should consider the long-term implications of economic performance when designing strategies for sustainable growth.

6.2 ARDL Long Run Form Level Equation

The significant positive relationship between gross capital formation (LOGCAPITAL) and adjusted net national income per capita (LOGANNIPC) aligns with existing economic theories that suggest investment in physical capital is essential for stimulating economic growth. This is in line with Solow's (1956) growth model which considers capital accumulation as one of the primary drivers of economic growth, suggesting that countries with robust investment activities are better positioned for growth in per capita income. Various studies have indicated that enhanced capital formation increases productive capacity and efficiency, ultimately contributing to higher income levels (Koopman, & Wacker, 2023; Grozdić *et al*., 2020). Koopman and Wacker (2023) investigated the changes in production factors and productivity before, during, and after 156 growth accelerations they identified in 148 countries between 1950 and 2019. Their focus was particularly on the role of physical capital accumulation, considering the recent attention on investment surges and various investment-led growth models. The authors indicate that, on average, physical capital accumulation contributed to a 9% growth rate increase during periods of acceleration. However, this impact varied across different regions, periods, and the capital-output ratios of the economies. Growth acceleration was mainly a function of the enhancement in total factor productivity. However, the accumulation of physical capital sustained these periods of growth. Similarly, Grozdić *et al*. (2020) demonstrate that firms that invest more in capital tend to have higher productivity and profitability in the long run, reflecting positively on national income metrics.

In our study, we found inflation (LOGINFLAT) to possess a significant positive effect on LOGANNIPC which is somewhat counterintuitive, as traditional economic discourse often regards high inflation as detrimental to economic growth and income levels (Missos *et al*., 2024; Bozkurt, 2014; Dorrance, 1963). Furthermore, the role of inflation as a determinant of income per capita is also supported by the research of Fischer (1993), which suggests that high inflation can erode purchasing power and deter investment, thereby negatively impacting economic growth. However, moderate inflation can signal growing demand, indicating confidence among consumers and investors. This phenomenon is supported by the work of Fischer (1993), who asserts that low to moderate inflation can coexist with economic growth, provided that it does not erode the purchasing power drastically. In the context of SSA countries, where structural adjustments and economic reforms are ongoing, a modest inflation rate may reflect recovery and growth dynamics leading to increased net national income per capita. Moreover, our results of the ARDL model imply that countries in the SSA region that prioritize capital formation and maintain stable inflation rates may experience sustained improvements in economic welfare. This contrasts with the experiences of nations that witness high inflation without concurrent growth strategies, thereby validating the necessity of targeted economic policies that foster investment while managing inflationary pressures.

6.3 ARDL Long Run Form, Bounds Test and ECM

The findings from our ARDL model indicate a significant long-run relationship among the variables under study, reinforcing the notion that economic factors such as gross capital formation, trade dynamics, inflation, and population growth play critical roles in influencing net national income per capita in SSA. This aligns with the broader economic literature, which emphasizes the importance of capital accumulation and trade in fostering economic growth and development. For instance, the positive relationship between gross capital formation and net national income per capita is consistent with the work of Barro (1991), who posited that investment in physical capital is essential for enhancing productivity and, consequently, income levels. Similarly, the significant impact of exports on net national income supports the assertion of Krugman *et al*. (2012), who argue that trade can lead to increased economic efficiency and higher income through comparative advantage. The inclusion of population as a variable is particularly relevant in SSA, where demographic trends can significantly influence economic outcomes. This is echoed in the works of Bloom and Canning (2008), and Bloom *et al*. (2018) which highlight the dual nature of population growth, where it can either serve as a demographic dividend or a burden, depending on the economic context and policy responses.

The significant speed of adjustment captured in our ECM results highlights the responsiveness of net national income to shocks and policy changes. This rapid adjustment underscores the importance of timely and effective policy interventions, as the economic landscape in SSA is often characterized by volatility and uncertainty. Policymakers in the region should be cognizant of the immediate impacts of their decisions, ensuring that they are equipped to address short-term fluctuations while keeping an eye on long-term growth objectives.

6.4 VECM Analysis

The results of VECM analysis substantiate the long-run dynamics observed in the ARDL model, providing additional insights into the short-run adjustments towards equilibrium. The cointegration among the variables suggests that while short-term fluctuations may occur, there exists a stable long-run relationship that policymakers can target for sustainable economic development. Overall, the findings from the ARDL and VECM analyses underscore the critical role that gross capital formation plays in influencing net national income per capita in SSA. The estimated coefficients reveal a significant positive relationship between capital formation and income levels, suggesting that increased investments in physical capital are imperative for fostering economic growth. This aligns with the theoretical framework posited by endogenous growth models, which emphasize the importance of capital accumulation as a driver of economic performance (Romer, 1990). Moreover, the results indicate that exports of goods and services also contribute positively to net national income per capita. This finding aligns with existing literature emphasizing the advantages of trade liberalization and export diversification for strengthening economic resilience and promoting growth (Krugman, 1991; Rodriguez & Rodrik, 2001). The positive effects of exports indicate that implementing policies to enhance trade conditions could help achieve sustainable income growth.

Conversely, the role of imports appears to be more nuanced. While imports can facilitate access to capital goods and technology, they may also pose a risk of crowding out domestic industries. The negative relationship between imports and net national income in our findings echoes concerns raised in previous studies regarding the potential adverse effects of excessive reliance on foreign products (Thirlwall, 1979; Balassa, 1965). Thus, a balanced approach to trade policy is essential, ensuring that import levels support rather than hinder domestic economic activities. Inflation, as indicated by the negative coefficient, further complicates the income dynamics. High inflation rates can erode purchasing power and deter investment, ultimately stifling economic growth. This relationship is well-documented in the literature, with numerous studies linking inflation to reduced economic performance in developing countries (Fischer, 1993; Barro, 1995). Policymakers must therefore prioritize measures to maintain price stability as a foundation for fostering sustainable income growth.

6.5 A Synthesis of ARDL and VECM Results

The role of imports appears more nuanced. While imports can facilitate access to capital goods and technology, they may also cause crowding out of domestic industries. The negative relationship between imports and net national income in our findings echoes concerns in previous studies regarding the potential adverse effects of excessive reliance on foreign products (Thirlwall, 1979; Balassa, 1965). Thus, a balanced approach to trade policy is essential, ensuring that import levels support rather than hinder domestic economic activities. Inflation, indicated by the negative coefficient, complicates income dynamics.

High inflation rates erode purchasing power and deter investment, ultimately stifling economic growth. This relationship is well-documented in the literature, with numerous studies linking inflation to reduced economic performance in developing countries (Fischer, 1993; Barro, 1995). Policymakers must therefore prioritize measures to maintain price stability as a foundation for fostering sustainable income growth.

Importantly, inflation (LOGINFLAT) emerges as a critical determinant of ANNIPC, illustrating the delicate balance policymakers must maintain between stimulating growth and controlling price levels. High inflation can diminish purchasing power and create uncertainty, potentially stifling investment and savings. This finding resonates with the work of Fischer (1993), who argued that moderate inflation can be conducive to growth, but excessive inflation can lead to economic instability. The impact of population dynamics (LOGTPOPN) on national income (ANNIPC) is significant (Brida *et al*., 2024). An increasing population can lead to a higher demand for goods and services (Frejka, 2001). If this demand is met with adequate supply and investment, it can stimulate economic growth (Ali & Asfaw, 2023). However, if rapid population growth is not managed properly, it can strain resources and infrastructure (Pang *et al*., 2024), causing negative effects on income levels (UN, 2021).

The interdependencies among income, trade, inflation, and population dynamics call for comprehensive policy frameworks that address these variables holistically. Policymakers in SSA must consider these complex relationships when devising strategies to enhance ANNIPC, ensuring that trade policies, inflation control measures, and capital investments are aligned to promote sustainable economic growth. The evidence from our study suggests that targeted policies aimed at enhancing capital investment and export performance, while maintaining economic stability, could significantly contribute to sustainable income growth in SSA.

7. Conclusion and Policy Implications for SSA

The Adjusted Net National Income Per Capita (ANNIPC) dynamics in SSA underscore the intricate relationships among capital formation, trade, inflation, and demographic factors. The empirical evidence from the ARDL and VECM models reveals that enhancing gross capital formation and maintaining moderate inflation levels can positively influence ANNIPC. Given these insights, policymakers in SSA should prioritize strategies that bolster capital investments while ensuring that inflation remains manageable. Policies that stimulate gross capital formation, such as infrastructure development, investment incentives, and access to financial resources, could be vital for sustainable economic growth in SSA. Moreover, efforts to enhance export capacities and improve trade balances are essential, as our findings indicate their significance in promoting overall income levels. The pronounced effects of population dynamics warrant additional scrutiny; therefore, strategies that enhance human capital through education and skills training should be integrated into broader economic policies to harness demographic potential.

Furthermore, the evidence of swift adjustment towards long-run equilibrium suggests that short-term economic shocks can be mitigated through informed and responsive policymaking. The SSA governments must be vigilant and proactive in managing these variables to create a stable economic environment conducive to growth. In this regard, a multi-faceted approach that considers the interplay of these determinants will be essential for the region's policymakers. Careful policy consideration is paramount to navigating the challenges of inflation and trade imbalances while driving growth in ANNIPC, ultimately contributing to the broader goal of economic resilience and prosperity in SSA.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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SUPPLEMENTARY TABLE

Supplementary Table 1: List of Sub-Saharan Africa countries used in the study

S/N	Country Name	Country Code	S/N	Country Name	Country Code
1	Angola	AGO	25	Liberia	LBR
2	Benin	BEN	26	Madagascar	MDG
3	Botswana	BWA	27	Malawi	MWI
4	Burkina Faso	BFA	28	Mali	MLI
5	Burundi	BDI	29	Mauritania	MRT
6	Cabo Verde	CPV	30	Mauritius	MUS
7	Cameroon	CMR	31	Mozambique	MOZ
8	Central African Republic	CAF	32	Namibia	NAM
9	Chad	TCD	33	Niger	NER
10	Comoros	COM	34	Nigeria	NGA
11	Congo, Rep.	COG	35	Rwanda	RWA
12	Cote d'Ivoire	CIV	36	Sao Tome and Principe	STP
13	Congo, Dem. Rep.	COD	37	Senegal	SEN
14	Equatorial Guinea	GNQ	38	Seychelles	SYC
15	Eritrea	ERI	39	Sierra Leone	SLE
16	Eswatini	SWZ	40	Somalia	SOM
17	Ethiopia	ETH	41	South Africa	ZAF
18	Gabon	GAB	42	South Sudan	SSD
19	Gambia, The	GMB	43	Sudan	SDN
20	Ghana	GHA	44	Tanzania	TZA
21	Guinea	GIN	45	Togo	TGO
22	Guinea-Bissau	GNB	46	Uganda	UGA
23	Kenya	KEN	47	Zambia	ZMB
24	Lesotho	LSO	48	Zimbabwe	ZWE