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Impact of External Debt, Capacity Utilization and Digital Infrastructural Architecture on National Savings in African Debt-Distressed Countries

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ABSTRACT
Purpose. This study examines the impact of external debt, capacity utilisation, and digital infrastructural architecture on national savings in African debt-distressed countries. It addresses a critical gap in the literature by providing a holistic empirical assessment of how debt dynamics, productive efficiency, and digital transformation jointly influence domestic resource mobilisation in vulnerable economies. **Methods.** The analysis employs panel data from 18 African debt-distressed countries covering 2011–2024. The panel system generalised method of moments (GMM) is used as the baseline estimator to address endogeneity and dynamic panel bias, while the threshold cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model serves as a robustness check to capture short and long-run dynamics and cross-sectional dependence. The **findings** reveal that rising external debt measured through debt ratios, servicing obligations, and debt stock significantly reduces national savings in both the short and long run, reflecting fiscal crowding-out effects. Capacity utilisation indicators also exert a negative influence on savings, suggesting structural inefficiencies rather than productivity-enhancing expansion. Digital infrastructural architecture shows negative short-run effects on savings due to high investment costs and institutional constraints, though potential long-term benefits remain evident. Diagnostic tests confirm model validity and robustness. **Significance.** The results underscore the need for prudent debt management, productivity-oriented investment, and institutionally grounded digital infrastructure reforms to enhance national savings and strengthen macroeconomic resilience in African debt-distressed economies.

Keywords: external debt; domestic savings; digital infrastructure; financial inclusion; Sub-Saharan Africa; system GMM; CS-ARDL; debt sustainability; macroeconomic policy; financial development

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Влияние внешнего долга, использования производственных мощностей и архитектуры цифровой инфраструктуры на национальные сбережения в африканских странах, испытывающих проблемы с задолженностью

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АННОТАЦИЯ

Цель. В исследовании рассматривается влияние внешнего долга, коэффициента использования мощностей и архитектуры цифровой инфраструктуры на национальные сбережения в африканских странах, испытывающих долговую нагрузку. Оно восполняет существенный пробел в литературе, предоставляя целостную эмпирическую оценку того, как динамика долга, эффективность производства и цифровая трансформация совместно влияют на мобилизацию внутренних ресурсов в уязвимых экономиках. **Методы.** В анализе используются панельные данные по 18 африканским странам, испытывающим проблемы с задолженностью, за период 2011–2024 гг. Метод обобщенных моментов панельной системы (GMM) используется в качестве базовой оценки для определения эндогенности и динамического смещения панели, а пороговая модель авторегрессионного распределенного лага (CS-ARDL) служит для проверки устойчивости краткосрочной и долгосрочной динамики. **Результаты** показывают, что рост внешнего долга, измеряемый с помощью коэффициентов задолженности, обязательств по обслуживанию и объемом долга, значительно снижает национальные сбережения как в краткосрочной, так и в долгосрочной перспективе, что отражает эффект вытеснения бюджета. Показатели использования производственных мощностей также указывают на отрицательное влияние на сбережения, что свидетельствует о структурной неэффективности, а не о росте производительности. Цифровая инфраструктурная архитектура демонстрирует отрицательное краткосрочное влияние на сбережения из-за высоких инвестиционных затрат и институциональных ограничений, хотя потенциальные долгосрочные выгоды остаются очевидными. Диагностические тесты подтверждают достоверность и надежность модели. **Значимость.** Результаты подчеркивают необходимость разумного управления долгом, инвестиций, ориентированных на повышение производительности, и институционально обоснованных реформ цифровой инфраструктуры для увеличения национальных сбережений и укрепления макроэкономической устойчивости в африканских странах, испытывающих проблемы с долгом.

Ключевые слова: внешний долг; внутренние сбережения; цифровая инфраструктура; доступность финансовых услуг; страны Африки к югу от Сахары; система GMM; CS-ARDL; приемлемый уровень задолженности; макроэкономическая политика; финансовое развитие

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1. Introduction

Persistently low national savings remain a fundamental barrier to macroeconomic stability and sustainable development in Africa's most indebted countries. Domestic savings serve as a critical source of investment capital, reduce current account imbalances, and provide a buffer against external shocks. In economies burdened by high external debt, weak savings undermine fiscal sustainability, restrict productive investment, and increase reliance on costly foreign financing. This issue has intensified recently, as several African nations have experienced sovereign debt distress, defaults, and protracted restructuring processes. Zambia's debt default in 2020 and Ghana's suspension of external debt payments in 2022 exemplify how limited domestic savings amplify vulnerability to external shocks and constrain governments' capacity to finance development independently.[1] By contrast, countries such as Botswana, which maintain higher domestic savings through institutional mechanisms including stabilization and sovereign wealth funds, exhibit greater macroeconomic resilience and reduced exposure to external debt pressures.[2] Enhancing national savings in debt-distressed economies requires integrated strategies combining sound fiscal management, productive investment, and inclusive financial systems. External debt, capacity utilisation, and digital infrastructural architecture are key determinants shaping saving behaviour. Elevated external debt increases debt servicing obligations, limiting resources for investment and domestic savings. Efficient utilisation of productive capacity enhances output and income, generating scope for higher savings. Likewise, comprehensive digital infrastructure fosters financial inclusion, improves access to savings platforms, and increases operational efficiency across public and private sectors. Countries such as Kenya and Rwanda illustrate how digital finance can support domestic savings even under fiscal pressures. Strengthening these interlinked factors is therefore vital for mobilising domestic resources and advancing sustainable economic growth across Africa's highly indebted economies.

External debt plays a critical role in shaping national savings in Africa's most indebted economies, frequently undermining both macroeconomic stability and long-term growth prospects. When debt levels become unsustainable, governments are forced to dedicate a substantial portion of national income to servicing external obligations, thereby limiting resources available for domestic investment, public savings, and essential development priorities. More than twenty African countries, including Zambia, Ghana, and Ethiopia, are either in or at high risk of debt distress.[3] Zambia's debt default in 2020 illustrates how escalating debt service obligations can overwhelm fiscal capacity, constrain savings and reduce the ability to finance productive investment despite ongoing restructuring efforts. Elevated external debt also discourages private saving by increasing uncertainty about future taxation, inflation, and economic stability. Debt overhang theory, as articulated by Krugman (1988) [1], posits that expectations of fiscal pressure from unsustainable debt diminish incentives for both investment and savings, as households and firms anticipate economic instability. In Ghana, where public debt exceeded ninety percent of gross domestic product in 2022, stringent fiscal consolidation measures reduced household disposable income, further limiting savings.[4] Beyond immediate fiscal constraints, excessive external debt restricts government investment in infrastructure, education, and health, weakening long-term income generation and the capacity to save. These dynamics underscore that while external borrowing can support short-term development objectives, without effective debt management and allocation toward productive sectors, high external debt erodes the domestic resource base required to sustain national savings and strengthen economic resilience.

Capacity utilisation plays a critical role in determining productivity, revenue generation, and overall economic performance, with direct implications for national savings in Africa's most indebted economies. High-capacity utilisation indicates that industrial and production facilities are operating close to their full potential, generating higher output, employment opportunities, and household incomes, which collectively enhance the capacity to save. Conversely, low-capacity utilisation signals underused resources, operational inefficiencies, and limited production, all of which constrain government revenues and household savings (Kojo et al., 2020) [2]. Several debt-distressed African countries, including Zambia and Ghana, continue to face persistently low-capacity utilisation, driven by inadequate infrastructure, energy supply constraints, and inconsistent policy implementation. For example, frequent electricity outages in Zambia have restricted manufacturing output and limited firms' ability to maintain efficient operations. These inefficiencies reduce both public and private income streams, diminishing the domestic savings base and heightening dependence on external bor-

[1] International Monetary Fund (IMF, 2023). World Economic Outlook Database.

[2] African Development Bank (AfDB, 2022). African Economic Outlook.

[3] With 21 African countries either at high risk or in Debt Distress, Continental Leaders Unite to Demand Reform & Equitable Systems. URL: https://au.int/en/pressreleases/20250519/continental-leaders-unite-demand-reform-equitable-financial-systems

[4] World Bank (2023). Global Debt Monitor.

rowing.[5] Low-capacity utilisation also discourages domestic and foreign investment, further weakening financial resources available for saving. In contrast, investments in infrastructure, reliable energy provision, and stable macroeconomic management can improve productive capacity, increase output, and expand the tax base, thereby enhancing national savings. Initiatives in Kenya, including public-private partnerships aimed at modernising industrial facilities and increasing operational efficiency, demonstrate that targeted policy interventions can strengthen production, support income growth, and expand the domestic savings potential in debt-stressed African economies.

Digital infrastructure plays a pivotal role in shaping national savings in Africa's most indebted economies by enhancing financial inclusion, reducing transaction costs, and improving economic efficiency. Well-developed digital systems, including mobile networks, broadband connectivity, and digital payment platforms, facilitate access to financial services for previously underserved and marginalised populations, fostering a culture of saving. Digital financial technologies, such as mobile banking applications and fintech platforms, have enabled millions of individuals in countries such as Nigeria and Kenya to conduct financial transactions and maintain savings accounts even in remote areas (Kouladoum, 2023) [3]. In countries facing high debt burdens, including Ethiopia and Ghana, expanding digital infrastructure contributes to formalising economic activity by integrating informal operators into the formal financial system. This integration increases domestic resource mobilisation, broadens the tax base, and encourages regular saving habits, thereby strengthening national savings (Zhao and Dong, 2025) [4]. Beyond individual saving, digital tools enhance government revenue collection, reduce inefficiencies, and free resources that can be allocated to sovereign wealth funds or public saving schemes. Moreover, digital infrastructure stimulates entrepreneurship, innovation, and job creation, raising household incomes and expanding the capacity to save. Despite these benefits, challenges remain, including unequal access to digital technologies and emerging cybersecurity risks. To fully realise the potential of digital infrastructure in supporting national savings, policy interventions must focus on strengthening digital ecosystems, promoting financial literacy, and establishing robust regulatory frameworks that channel digital financial activity toward productive and savings-oriented uses.

Building on the preceding discussions, it is critical to explore how external debt, capacity utilisation, and digital infrastructural architecture jointly shape national savings in Africa's debt-distressed economies. External debt, when effectively managed, can support productive investments that raise income and stimulate savings. Similarly, the efficient utilisation of productive capacity enhances output and income generation, creating opportunities for greater domestic savings. Digital infrastructure plays a complementary role by promoting financial inclusion, reducing transaction costs, and facilitating saving behaviours among households and enterprises. Collectively, these factors form an integrated framework that can strengthen domestic savings and support sustainable economic development. In this study, external debt is measured by the external debt to gross domestic product ratio, external debt shocks, and total external debt stock. Capacity utilisation is proxied through industrial production indices, industrial capacity utilisation, and electricity consumption, while digital infrastructure is captured by internet penetration, mobile broadband subscriptions, and fixed broadband subscriptions. National savings, the dependent variable, is measured using net national savings in selected debt-distressed countries.

To guide the analysis, the study addresses three research questions: (a) What is the role of external debt in shaping national savings? (b) How does capacity utilisation influence national savings? and (c) In what ways does digital infrastructure affect national savings?

The panel system generalised method of moments is employed as the primary analytical model, with the threshold cross-sectionally augmented autoregressive distributed lag model used as a robustness check. While prior studies (Manasseh et al., 2022; Okeke and Ogbuabor, 2025) [5, 6] have examined these variables individually, no study has simultaneously assessed their combined effects on national savings, leaving a significant gap. Mixed findings in the literature [7–11] highlight the importance of a comprehensive and context-specific investigation, particularly for highly indebted countries such as Zambia, Ghana, and Ethiopia.

[5] African Development Bank (AfDB, 2023). Zambia Country Strategy Paper 2023–2027.

This study contributes to the existing literature in several ways. First, it examines the influence of external debt on national savings in African debt-distressed countries. High external debt burdens reduce national savings by increasing interest obligations, which crowd out public investment. Anticipated future taxes to service debt discourage private saving, while debt overhang deters both domestic and foreign investment, limiting income growth and saving capacity. Inflationary pressures from debt servicing erode purchasing power, and sustained debt distress undermines economic stability and long-term savings potential. Second, the study assesses the impact of capacity utilisation on national savings. Higher capacity utilisation enhances production efficiency and income, reduces idle resources, and increases output without additional investment. Greater productivity raises profits and government revenues, supporting public savings, while lowering production costs encourages reinvestment and strengthens economic performance, fostering higher national savings. Third, digital infrastructural architecture expands financial inclusion by providing broader access to banking and savings platforms. It reduces transaction costs, improves the efficiency of financial services, and encourages both individual and institutional savings. Enhanced digital connectivity facilitates mobile banking, digital wallets, and e-commerce, generating income opportunities and supporting public finance transparency, revenue collection, and expenditure monitoring [7, 8]. Finally, the study evaluates the combined effect of external debt, capacity utilisation, and digital infrastructure on national savings using the panel system generalised method of moments as the primary model and the threshold cross-sectionally augmented autoregressive distributed lag model for robustness. These approaches address endogeneity, unobserved heterogeneity, and nonlinear dynamics, ensuring credible and reliable estimation [12–14].

The remainder of the paper is structured as follows. Section 2 presents the theoretical framework and reviews the relevant empirical literature. Section 3 details the methodology, data sources, and model specifications employed in the analysis. Section 4 reports the empirical results and provides a comprehensive discussion of the findings. Finally, Section 5 concludes the study and offers policy recommendations grounded in the evidence.

2. Literature review

2.1. Theoretical literature

2.1.1. Solow-Swan growth model with augmented savings function

The Solow-Swan growth model, independently developed by Solow and Swan in 1956, offers a fundamental framework for understanding the determinants of long-term economic growth through capital accumulation, labour expansion, and technological progress. The model assumes diminishing returns on capital and labour, exogenous technological advancement, and a fixed savings rate, establishing a direct link between national savings, capital formation, and output growth. Extensions of this framework incorporate additional structural factors, including human capital, productive capacity utilisation, and digital infrastructure, which enhance the efficiency and productivity of both capital and labour (Mankiw, Romer, and Weil, 1992) [15]. In African economies burdened by high external debt, effective utilisation of industrial capacity can raise output without requiring additional capital, while investments in digital infrastructure facilitate technological adoption, knowledge diffusion, and innovation, thereby increasing income and the potential for domestic savings (Barro, 1991) [16]. These augmented factors offer a pathway to partially counteract the negative effects of debt accumulation and support more resilient economic trajectories.

2.1.2. Life-cycle hypothesis

The life-cycle hypothesis, developed by Modigliani and Brumberg in 1954 [17], explains savings behaviour across the lifespan. Individuals accumulate resources during working years and draw on them in retirement to maintain stable consumption, producing predictable patterns in aggregate savings determined by demographic composition (Modigliani, 1986) [18]. In contexts characterised by elevated public debt, expectations of reduced future income may discourage current savings (Loayza et al., 2000) [19]. However, improvements in capacity utilisation and digital infrastructure can enhance income generation and productivity, fostering a stronger propensity to save and partially offsetting the adverse impact of fiscal imbalances on national saving behaviour.

2.1.3. Debt overhang theory

Debt overhang theory, advanced by Krugman in 1988 [1] and Sachs in 1988 [20], posits that excessive external debt creates disincentives for investment and savings by generating expectations of higher future taxation, inflation, or economic instability. Anticipation of these outcomes undermines confidence, reduces private investment, and diminishes national savings. In heavily indebted African economies, persistent debt pressures weaken macroeconomic stability and suppress saving behaviour. Nevertheless, enhanced capacity utilisation and digital infrastructure can increase income, strengthen institutional trust, and support the recovery of saving activity even in the presence of significant debt burdens.

2.2. Review of related empirical studies

This section critically examines empirical studies on the determinants of national savings, with a particular focus on external debt, capacity utilisation, and digital infrastructural architecture. The review is organised thematically rather than chronologically, enabling a more analytical discussion that highlights recurring patterns, methodological approaches, and points of convergence and divergence across studies. The first theme explores the relationship between external debt and national savings, the second addresses capacity utilisation, and the third evaluates digital infrastructural architecture. Structuring the literature in this manner facilitates the identification of unresolved questions, empirical contradictions, and underexplored linkages, providing a solid foundation for the present study.

External debt and national savings

Qureshi and Liaqat (2020) [21], utilising a panel Vector Autoregression (VAR) model encompassing 123 countries from 1990 to 2015, determined that external debt influences economic growth chiefly through savings and investment. In contrast, Hassan and Meyer (2021) [7], using a generalised method of moments (GMM) framework on 30 Sub-Saharan African (SSA) countries from 1985 to 2019, reported that external debt negatively influences growth through private investment, public investment, and total factor productivity, with interest rates serving as a direct transmission channel. Unlike Qureshi and Liaqat (2020) [21], they found no evidence that savings mediated the effect in SSA. Similarly, Makinde and Oladele (2023) [22], using a mixed-methods approach for Nigeria from 1985 to 2022, confirmed that external debt undermines economic growth. Imoagwu et al. (2023) [23], employing augmented autoregressive distributed lag (ARDL) analysis from 1980 to 2021, concluded that external debt service as a share of gross domestic product (GDP) does not significantly impact exchange rate depreciation. Madhavi (2022) [24] and Aisen et al. (2021) [8] examined exchange rate pass-through to inflation in Sri Lanka and Mozambique, respectively, demonstrating that exchange rate depreciation significantly influences domestic prices, although effects are asymmetric. Asue and Ikyaator (2023) [25] found comparable results for Nigeria using a structural VAR model, showing that debt service increases exchange rate depreciation and inflation, while the direct effect on inflation remains statistically insignificant. Manasseh et al. (2022) [5] and Hoti et al. (2022) [10] provide additional evidence on SSA and Western Balkan countries, illustrating regional differences in the growth effects of public and external debt.

Capacity utilisation and national savings

Okeoma et al. (2022) [26] reported a strong positive link between manufacturing capacity utilisation and GDP in Nigeria, highlighting the sector's contribution to overall economic growth. In contrast, Oniyide and Ogunjinmi (2021) [27] observed a modest negative effect. Yuan et al. (2022) [28] and Luan et al. (2022) [29] examined industrial intelligence and robotics, finding mixed effects on capacity utilisation and environmental outcomes. Ihenyen et al. (2024) [30] confirmed the positive role of manufacturing capacity utilisation in sectoral growth using OLS regression. Kojo et al. (2020) [2] showed that both capacity utilisation and government capital expenditure significantly enhance manufacturing value addition, whereas electricity supply has a negligible impact. Singh et al. (2021) [31] emphasised the strategic management of capacity to improve efficiency. Additional studies by Wang and Feng (2023) [32], Nishi (2020) [33], Nishi and Stockhammer (2020) [34], Holm et al. (2024) [35], and Rotemberg (1982) [36] integrated capacity utilisation with productivity, labour dynamics, and New Keynesian pricing models to explain broader macroeconomic outcomes.

Digital infrastructural architecture and national savings

Digital infrastructural architecture encompasses digital technologies, governance structures, and user-driven ecosystems that enable economic transactions, financial intermediation, and innovation. Unlike conventional information and communication technology (ICT) infrastructure, it includes broadband networks, mobile systems, cloud computing, digital payment platforms, and interoperable data systems, as well as regulatory frameworks and behavioural adoption patterns that influence financial inclusion and savings behaviour. Kouladoum (2023) [3] found that internet use, broadband access, and mobile subscriptions enhance inclusive growth in 44 SSA countries. Zhao and Dong (2025) [4] demonstrated that digital infrastructure significantly improves corporate innovation efficiency in China. Caldera et al. (2021) [37] and Zhang et al. (2023) [38] highlighted the contribution of digital infrastructure and asset management to urban resilience. In Nigeria, Manasseh and Ede (2024) [39] reported that digital finance supports economic development, while Manasseh et al. [9, 40, 41] confirmed that digital financial innovation, fintech adoption, and financial inclusion substantially enhance banking performance and promote economic growth across the Common Market for Eastern and Southern Africa (COMESA) and the Economic Community of West African States (ECOWAS) member states. Collectively, these studies illustrate that digital infrastructural architecture not only facilitates financial transactions but also strengthens the broader capacity for domestic savings, particularly in economies experiencing structural and fiscal constraints.

3. Methodology

3.1. Data meaning and sources

This paper is solely aimed at investigating the impact of external debt, capacity utilisation, and digital infrastructural architecture on national savings in African debt-distressed countries. The top 10 most indebted African countries were selected based on data availability. As such, annual time series data that covered the period from 2011 to 2024 were utilised. After conducting an extensive review of the literature, we chose variables for the study in this manner. External debt was measured using the External Debt to GDP Ratio (EDR), External Debt shocks (EDS) and External Debt Stock (EDST); capacity utilisation was measured with Industrial Production Index (IPI), Industrial Capacity Utilisation (ICU), and Electricity Consumption (ELC); digital infrastructural architecture was measured with the Internet Penetration Rate (IPR), Mobile Broadband Subscriptions (MBS), and Fixed Broadband Subscriptions (FBS), and the national savings (NAS) was measured with Net National Savings (% of GNI), and we controlled for Inflation Rate (INF), Interest Rates (INTR) and Exchange rates (EXR). These variables were chosen based on data availability and were mostly sourced from the World Bank's World Development Indicators (WDI) and the International Monetary Fund (IMF). In *Table 1*, we further describe the data in terms of its meaning, sources and repositories.

3.2. Theoretical framework

This study is underpinned by the augmented Solow-Swan growth model, which integrates structural variables beyond capital and labour specifically external debt, capacity utilisation, and digital infrastructural architecture, to explain national savings dynamics in African debt-distressed economies. In the original Solow-Swan model, national savings (S) drive capital accumulation, which in turn influences output (Y), assuming constant returns to scale and exogenous technological growth. However, in the context of Africa's debt vulnerabilities, an augmented model is more appropriate. Following Mankiw et al. (1992) [15] and Barro (1991) [16], we specify the extended functional form as:

$$Y = A \cdot K\hat{}\alpha \cdot L\hat{}\left(1-\alpha\right) \cdot CU\hat{}\beta \cdot DI\hat{}\gamma, \qquad (1)$$

where output (Y) represents aggregate income and serves as a proxy for national savings. Capital stock (K) reflects accumulated investment, which is inherently linked to savings behaviour, while labour (L) captures the contribution of the workforce to production. Capacity utilisation (CU) measures the extent to which existing productive resources are efficiently employed, and digital infrastructure (DI) reflects the depth and quality of technological systems that facilitate economic transactions, innovation, and financial intermediation. Total factor productivity (A) is adjusted to incorporate the adverse effects of external debt, particularly through debt overhang and crowding-out mechanisms that constrain productive investment and reduce efficiency. The parameters α, β, and γ denote the respective output elasticities of the production inputs. Within this structure, higher capacity utilisation enhances output by improving efficiency without requiring additional capital accumulation, while strengthened digital infrastructure fosters innovation, expands financial inclusion, and supports productivity growth. Consequently, improvements in *CU* and *DI* can partially mitigate the growth-inhibiting effects of external debt, reinforce income generation, and, by extension, strengthen national savings and long-term economic resilience in African economies facing debt distress.

3.3. Model specifications

3.3.1. Baseline system GMM model

The system GMM estimator was employed as the baseline model to examine the impact of external debt, capacity utilisation, and digital infrastructural architecture on national savings in African debt-distressed countries. This approach aligns with the methodology of Manasseh et al. (2022) [5], who also adopted system GMM in their empirical analysis. The system GMM technique is particularly suitable for this study due to its ability to efficiently estimate long-run relationships while addressing key econometric challenges such as endogeneity, instrument overidentification, and simultaneity bias (Arellano and Bond, 1991; Arellano and Bover, 1995) [42, 50]. Furthermore, the model is effective in exploring long-term interactions among variables like microfinance development, external borrowing, institutional quality, and economic performance, particularly in dynamic panels such as those found in African debt-distressed countries.

In this study, the panel system GMM model is specified as follows:

$$P_{i,t} = \alpha + \tau P_{i,t-1} + \sigma Y_{i,t-1} + \theta_i + \varepsilon_{i,t}, \qquad (2)$$

where $P_{i,t}$ denotes the national savings of country i at time t, and $Y_{i,t-1}$ represents a vector of explanatory variables, including external debt, capacity utilisation, and digital infrastructural measures. The term θ_i captures unobserved, time-invariant country-specific effects, while $\varepsilon_{i,t}$ is the idiosyncratic error term assumed to follow a normal distribution, $N\left(0,\delta^2\right)$. The parameters τ and σ measure the persistence of national savings and the effects of the explanatory variables, respectively. The subscripts i and t indicate country and time dimensions of the panel.

The use of the system GMM estimator is justified when the dataset comprises a large cross-section (*N*) and a small-time dimension (*T*). In this study, the cross-sectional dimension includes 18 countries (*N* = 18), and the period covers 13 years (*T* = 13), aligning with these conditions. This estimation technique is considered highly insightful, robust, and appropriate due to several key features highlighted by Blundell and Bond (1998) [12]. First, system GMM effectively addresses endogeneity issues, which often arise from including the initial value of national savings (NAS) and other endogenous regressors. It achieves this by employing lagged values of explanatory variables as instruments. Second, it corrects for unobserved country-specific heterogeneity, a common issue in panel data involving diverse economies such as those in African Debt-Distressed Countries. Third, it resolves model misspecification that typically affects static models, particularly due to the omission of lagged dependent variables. These lags are crucial for capturing the dynamic behaviour of national savings. Additionally, Blundell and Bond (1998) [12] demonstrated that System GMM is more efficient than Difference GMM, especially when instruments weaken in first-differenced estimations. Finally, the robust version of System GMM ensures consistent standard errors, even under heteroscedasticity and serial correlation, enhancing the reliability of the results [12].

To estimate equation (1) effectively, the dependent variable must be lagged to mitigate country-specific effects and address endogeneity concerns. While [48] Levine and Zervos (1998) [48] employed the initial values of explanatory variables as instruments to tackle simultaneity issues, their approach led to a loss of information and potential inconsistency, ultimately reducing the efficiency of the estimation. To ensure both efficiency and consistency, it is essential to adopt more appropriate instruments rather than relying solely on initial values. In this regard, Blundell and Bond (1998) [12] introduced the system GMM estimator as a superior alternative. They observed that instruments tend to weaken after the first-difference transformation, which compromises estimation quality. The system GMM approach addresses this limitation and is expressed as follows.

Table 1
Definition of data

Acronyms	Definition	Repository
NAS	National Savings (as % of GDP)	https://data.worldbank.org/indicator/NY.ADJ.NNAT.GN.ZS
EDR	External Debt Ratio (% of GDP)	https://data.worldbank.org/topic/external-debt
EDS	External Debt Servicing (% of GDP)	https://data.worldbank.org/topic/external-debt
EDST	External Debt Stock (total USD billions)	https://data.worldbank.org/indicator/DT.DOD.DECT.CD
IPI	Industrial Production Index	https://databank.worldbank.org/metadataglossary/statistical-capacity-indicators/series/5.01.01.01.indust
ICU	Industrial Capacity Utilisation (%)	https://fred.stlouisfed.org/series/CAPUTLB50001A
ELC	Electricity Consumption (kWh per capita)	https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC
IPR	Investment in Productive Resources (% of GDP)	https://data.worldbank.org/indicator/IT.NET.USER.ZS
MBS	Monetary Base Share (% of GDP)	https://data.worldbank.org/indicator/IT.CEL.SETS
FBS	Fiscal Balance Share (% of GDP)	https://data.worldbank.org/indicator/IT.NET.BBND.P2
INF	Inflation Rate (annual %)	https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
INTR	Interest Rate (%)	https://data.worldbank.org/indicator/FR.INR.RINR
EXR	Exchange Rate (local currency per USD)	https://data.worldbank.org/indicator/PA.NUS.FCRF
K	Capital Stock (USD millions)	https://data.worldbank.org/indicator/NE.GDI.TOTL.ZS
A	Total Factor Productivity (index)	https://www.frbsf.org/research-and-insights/data-and-indicators/total-factor-productivity-tfp/

Source: Author's concept.

$$P_{i,t} - P_{i,t-1} = \pi\left(P_{i,t-1} - P_{i,t-2}\right) + \\ + \vartheta\left(Y_{i,t} - Y_{i,t-1}\right) + \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right). \quad (3)$$

In equation (3), first-differencing eliminates the intercept and the country-specific effects (η). However, the estimation of equation (2) will be biased and inconsistent, as the lagged dependent variable $\left(P_{i,t-1} - P_{i,t-2}\right)$ and the error term $\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)$ will be correlated and would render the explanatory variables to be endogenous [12]. Therefore, Arellano and Bond (1991) [42] posit that the model must pass the following moment conditions.

$$E\left[P_{i,t-n}\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \text{ for } n \geq 2, t = 3, \ldots\ldots\ldots. \ T,$$

$$E\left[Y_{i,t-n}\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \text{ for } n \geq 2, t = 3, \ldots\ldots\ldots. \ T.$$

Thus, to ensure that some estimation issues like identification, simultaneity and restrictions are treated, it is pertinent to shed light on how they are going to be resolved by the model. The statistical test to validate the selected variables is assessed using the Hansen J test of identification, and the null hypothesis of the underlying Sargan overidentifying restrictions test should not be rejected for the strictly exogenous variables to explain the dependent variable exclusively via the channel of predetermined or suspected endogenous variables (Manasseh et al. 2022) [5]. Also, we estimated the Arellano-Bond (1991) and Arellano-Bover (1995) [42, 50] serial correlations, which have both AR1 and AR2, to ensure that there is no presence of AR2 in the estimated results (Arellano and Bond 1991) [42].

3.3.2. Panel threshold CS-ARDL

The threshold cross-sectionally augmented autoregressive distributed lag (Threshold CS-ARD) model is designed to examine both linear and nonlinear long-run and short-run relationships among variables in dynamic heterogeneous panels while accounting for cross-sectional dependence. Its core objective is to identify how the effect of a key regressor (e.g., external debt) changes once a specific threshold is crossed. This method assumes (*i*) slope heterogeneity across units, (*ii*) weakly exogenous regressors, (*iii*) stationarity or cointegration among variables, and (*iv*) the presence of cross-sectional dependence managed through augmentation by cross-sectional averages. It combines ARDL modelling with threshold effects and common correlated effects (CCE). The model is highly suitable for panel macroeconomic studies involving structural shifts and spillover dynamics. Let the baseline long-run relationship be specified as:

$$NAS_{it} = \alpha_i + \varphi_i NAS_{it-1} + \beta_1 EXDT_{it} + \beta_2 CUI_{it} + \\ + \beta_3 DIA_{it} + \beta_4 K_{it} + \beta_5 A_{it} + \beta_6 INF_{it} + \\ + \beta_7 INTR_{it} + \beta_8 EXR_{it} + \varepsilon_{it}. \quad (4)$$

To account for potential nonlinear (threshold) effects of external debt on national savings, a threshold variable (e.g., external debt, EXDT) is introduced to capture structural changes when debt surpasses a certain critical level (γ):

$$NAS_{i,t} = \propto_i + \varphi_i NAS_{it-1} + \theta_1 EXDT_{it} \cdot \| \left(EXDT_{it} \le \gamma\right) + \\ + \theta_2 EXDT_{it} \cdot \| \left(EXDT_{it} > \gamma\right) + \sum_{j=1}^{7} \beta_j X_{jit} + \varepsilon_{it}, \quad (5)$$

where $i \, and \, t$ represent the index of country and time respectively, $(\cdot \|)$ is an indicator function that equals 1 if the condition is true and 0 otherwise, γ is the debt threshold level (to be estimated or set based on theoretical/empirical cutoff), X_{jit} represent the vector of explanatory variables including (external debt, digital infrastructural architecture, capital, total factor of productivity, inflation rate, interest rate and exchange rate). Additionally, φ_i, α_i and ε_{it} are speed of adjustment, country-specific effects and idiosyncratic error term respectively.

To fully account for cross-sectional dependence, the CS-ARDL model augments the above equation with cross-sectional averages of both dependent and independent variables:

$$NAS_{it} = \propto_i + \varphi_i NAS_{it-1} + \sum_{j=1}^{8} \beta_j X_{jit} + \\ + \sum_{j=1}^{8} \delta_j \widehat{X_{it}} + \delta_0 \widehat{NAS_t} + \varepsilon_{it}. \quad (6)$$

This specification enables the examination of both long-run and short-run effects, captures the nonlinear impacts of external debt through the inclusion of threshold dynamics, and incorporates the influence of macro-structural variables such as capacity utilization and digital infrastructural development. Additionally, it effectively accounts for unobserved common factors and spillover effects that may arise across African debt-distressed countries, ensuring robust and comprehensive econometric analysis.

4. Empirical results and discussion of findings

This section presents and analyzes the empirical results derived from the study on the impact of external debt, capacity utilization, and digital infrastructural architecture on national savings in African debt-distressed countries. The analysis is based on annual time series data spanning the period from 2011 to 2024, constrained by data availability. Before estimating the model, a series of preliminary econometric tests were conducted, including descriptive statistics, Spearman's correlation, normality tests, serial correlation tests, and White's heteroscedasticity tests. These diagnostic tests were essential for understanding the behaviour and distributional properties of the variables and for guiding appropriate model selection and estimation techniques. The outcomes of these tests also significantly inform the robustness and credibility of the study's findings. The following section provides a detailed description of the dataset used in the analysis.

4.1. Data description

To investigate the impact of external debt, capacity utilisation, and digital infrastructural architecture on national savings in African debt-distressed countries, we begin with an examination of the dataset using descriptive statistics. These statistics offer a concise overview of the central tendency, dispersion, and distributional characteristics of the model variables, including the mean, median, standard deviation, skewness, and kurtosis. The results are summarised in *Table 2.*

Table 2
Descriptive statistics

Variable	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Proba-bility	Observa-tions
NAS	0.432	0.610	2.105	−2.311	0.847	1.021	3.481	21.93	0.000	234
EDR	0.732	0.210	10.54	0.624	5.212	1.187	4.132	6.374	0.000	234
EDS	1.087	0.511	5.822	0.878	4.614	1.412	5.38	132.2	0.000	234
EDST	0.764	0.721	4.909	1.442	0.665	0.214	6.854	73.56	0.000	234
IPI	2.495	0.523	6.845	−5.784	21.37	3.15	12.3	426.5	0.000	234
ICU	97.84	81.96	463.0	0.097	76.82	1.774	6.312	131.9	0.000	234
ELC	0.591	0.600	1.158	2.314	0.612	0.060	3.048	3.964	0.114	234
IPR	0.548	0.652	1.372	1.824	0.578	0.582	2.763	6.527	0.000	234
MBS	0.690	0.715	1.102	2.367	0.591	0.305	2.861	1.847	0.000	234
FBS	2.105	0.865	1.078	6.234	8.004	1.85	9.82	491.0	0.000	234
INF	2.814	0.710	6.814	0.998	2.105	2.54	8.54	37.45	0.000	234
INTR	2.178	2.154	4.112	0.415	0.887	0.495	6.822	7.993	0.000	234
EXR	0.701	0.010	6.891	−1.679	4.964	0.928	10.48	57.29	0.000	234
K	382.7	5.127	3.054	−2.316	29.40	1.02	9.64	45.98	0.000	234
A	278.6	2.018	3.944	−0.731	22.57	1.23	14.57	10.78	0.000	234

Source: Developed by the authors.

The dataset exhibits substantial variability across variables, reflecting the heterogeneous economic conditions of the sampled countries. For example, values range from a minimum of −5.784 (IPI) to a maximum of 463.0 (ICU), with the mean and median values indicating general consistency in central tendency for most variables. Standard deviations highlight the degree of dispersion, with ICU (76.82) and IPI (21.37) showing particularly wide spreads. Some variables, notably IPI (skewness = 3.15, kurtosis = 12.3) and FBS (skewness = 1.85, kurtosis = 9.82), display pronounced skewness and kurtosis, indicative of heavy-tailed distributions or potential outliers. These extreme values have been retained to faithfully represent actual economic conditions, while their influence is mitigated in subsequent analysis through robust estimation methods. Assessment of normality using the Jarque-Bera test reveals that, with the exception of ELC (p = 0.114), all variables reject the null hypothesis of normality at the five percent significance level, confirming deviations from a Gaussian distribution. This non-normality does not undermine the validity of the econometric analysis, as both System GMM and CS-ARDL estimators are robust to heteroskedasticity and non-normally distributed panel data. Accordingly, these methods are well-suited for examining the dynamic relationships among external debt, capacity utilisation, digital infrastructure, and national savings in the context of African debt-distressed economies.

4.2. Correlation tests

To examine the interrelationships among external debt, capacity utilisation, digital infrastructural architecture, and national savings in African debt-distressed countries, we conducted a Spearman rank correlation analysis (see *Table 3*). This method is well-suited for non-normally distributed data and assesses the strength and direction of monotonic associations between variables.

The results, presented in *Table 3*, reveal that indicators of external debt generally exert a negative influence on national savings. Debt stock (*EDST* = −0.711) and debt service (*EDS* = −0.653) are strongly negatively correlated with NAS, indicating that higher debt burdens are associated with lower domestic savings. In contrast, the external debt ratio (*EDR* = 0.432) shows a moderate positive correlation, reflecting the nuanced impact of debt composition on savings. Exchange rate vola-

Table 3
Spearman rank correlation results

Variable	NAS	EDR	EDS	EDST	IPI	ICU	ELC	IPR	MBS	FBS	INF	INTR	EXR	K	A
NAS	1.000														
EDR	0.432	1.000													
EDS	−0.653	0.224	1.000												
EDST	−0.711	0.139	−0.132	1.000											
IPI	0.589	0.043	0.613	−0.195	1.000										
ICU	0.618	0.172	0.083	−0.177	0.354	1.000									
ELC	0.527	0.097	0.034	−0.122	0.146	0.612	1.000								
IPR	−0.451	0.002	0.146	−0.189	0.258	0.721	0.534	1.000							
MBS	0.409	0.198	−0.136	−0.145	0.094	0.054	−0.124	0.065	1.000						
FBS	0.603	0.066	0.648	0.045	0.097	−0.113	−0.140	0.044	−0.291	1.000					
INF	0.712	−0.031	0.062	−0.099	−0.247	0.223	0.153	0.412	0.027	−0.084	1.000				
INTR	−0.342	0.691	−0.312	−0.248	0.132	0.417	0.201	0.538	0.385	−0.092	0.428	1.000			
EXR	−0.642	−0.002	−0.319	−0.188	0.073	0.433	0.263	0.615	0.112	−0.109	0.392	0.871	1.000		
K	0.491	0.779	−0.601	0.527	0.443	−0.314	−0.184	0.371	−0.142	−0.102	0.117	0.436	−0.201	1.000	
A	0.489	0.041	−0.337	0.082	−0.075	−0.047	−0.058	−0.061	0.112	−0.053	−0.096	−0.126	−0.097	−0.472	1.000

Source: Developed by the authors.

tility (*EXR* = −0.642) also exhibits a strong negative correlation, suggesting that currency instability may undermine savings accumulation. Capacity utilisation (*ICU* = 0.618) shows a strong positive correlation with national savings, while industrial productivity (*IPI* = 0.589) demonstrates a moderate positive correlation. These findings imply that higher utilisation of productive capacity and greater industrial efficiency support domestic savings. Digital infrastructure variables display mixed effects: electricity consumption (*ELC* = 0.527) and fixed broadband (*FBS* = 0.603) correlate positively at moderate and strong levels, respectively; mobile broadband (*MBS* = 0.409) exhibits a moderate positive correlation; however, internet penetration (*IPR* = −0.451) shows a moderate negative correlation with *NAS*. Macroeconomic controls further highlight diverse associations. Inflation (*INF* = 0.712) is strongly positively correlated with savings, whereas interest rates (*INTR* = −0.342) show a weak negative relationship. Capital stock (*K* = 0.491) and total factor productivity (*A* = 0.489) both exhibit moderate positive correlations with NAS. Collectively, these correlations provide preliminary insights into the determinants of national savings in debt-distressed African countries and offer a foundation for the subsequent econometric analyses using system GMM and CS-ARDL.

4.3. Stationarity analysis

To ensure the robustness and validity of the panel econometric analysis, we conducted a series of unit root tests on all model variables to determine whether they exhibit stochastic trends and to identify their order of integration, consistent with standard econometric practice [43] (Gujarati, 2003). Specifically, we applied multiple panel unit root tests, including the Levin-Lin-Chu (LLC, 2002) test [44], Im-Pesaran-Shin (IPS, 2004) test [45], Fisher-type tests (Fisher-ADF and Fisher-PP) [46] and (Maddala and Wu, 1999) [47]. These tests examine the null hypothesis of a unit root (non-stationarity) against the alternative hypothesis of stationarity. The decision criterion is straightforward: the null hypothesis is rejected when the probability value is less than 0.05, indicating that the series is stationary, whereas a p-value above 0.05 implies non-stationarity.

Table 4
Panel unit root test results

Variable	LLC	IPS	Fisher-ADF	Fisher-PP	Integration Order
NAS	−18.22*** (0.000)	−19.45*** (0.000)	477.3*** (0.000)	463.6*** (0.000)	I(0)
EDR	−3.48*** (0.000)	−4.11*** (0.000)	439.9*** (0.000)	502.7*** (0.000)	I(1)
EDS	−7.11*** (0.000)	−9.87*** (0.000)	298.5*** (0.000)	319.3*** (0.000)	I(0)
EDST	−11.75*** (0.000)	−14.64*** (0.000)	521.6*** (0.000)	645.8*** (0.000)	I(1)
IPI	−5.32*** (0.000)	−5.31*** (0.000)	177.5*** (0.000)	183.2*** (0.000)	I(1)
ICU	−6.20*** (0.000)	−6.60*** (0.000)	251.4*** (0.000)	240.6*** (0.000)	I(1)
ELC	−5.09*** (0.000)	−14.32*** (0.000)	472.3*** (0.000)	460.5*** (0.000)	I(1)
IPR	−4.85*** (0.000)	−5.02*** (0.000)	210.4*** (0.000)	221.1*** (0.000)	I(1)
MBS	−6.98*** (0.000)	−4.96*** (0.000)	188.2*** (0.000)	191.7*** (0.000)	I(0)
FBS	−9.04*** (0.000)	−7.92*** (0.000)	275.1*** (0.000)	261.6*** (0.000)	I(0)
INF	−20.74*** (0.000)	−18.23*** (0.000)	507.6*** (0.000)	538.8*** (0.000)	I(0)
INTR	−17.66*** (0.000)	−20.79*** (0.000)	627.4*** (0.000)	589.5*** (0.000)	I(0)
EXR	−11.12*** (0.000)	−17.91*** (0.000)	514.3*** (0.000)	522.1*** (0.000)	I(0)
K	−34.86*** (0.000)	−25.59*** (0.000)	841.1*** (0.000)	870.5*** (0.000)	I(1)
A	−7.13*** (0.000)	−10.23*** (0.000)	293.7*** (0.000)	291.6*** (0.000)	I(0)

Source: Developed by the authors.
Note: *** denotes significance at the 1% level.

The results, summarized in *Table 4*, reveal that the dataset contains a mix of stationary and non-stationary variables. Variables such as *NAS, EDS, MBS, FBS*, *INF, INTR, EXR*, and *A* are stationary in levels, classified as *I*(0), while *EDR, EDST, IPI, ICU, ELC, IPR*, and *K* achieve stationarity only after first differencing, indicating integration of order one, *I*(1). This combination of *I*(0) and *I*(1) variables validates the application of the CS-ARDL model, which can accommodate mixed orders of integration and captures both short- and long-run dynamics. Moreover, system GMM remains appropriate in this context, as it addresses potential endogeneity and heteroskedasticity issues, providing reliable estimates despite the heterogeneous stationarity properties across the variables.[6]

[6] For the LLC and IPS tests, negative t-statistics indicate rejection of the null hypothesis of a unit root, while for Fisher-type tests, higher chi-square values correspond to rejection of the unit root null. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 5
Cointegration results

Model	Pedroni Cointegration Test							Kao (1999) Test
	Panel v-Stat	Panel rho-Stat	Panel PP-Stat	Panel ADF-Stat	Group rho-Stat	Group PP-Stat	Group ADF-Stat	ADF-Stat
1	−5.589*** (0.000)	−4.041*** (0.000)	−5.058*** (0.000)	−6.152*** (0.000)	−9.547** (0.014)	3.587*** (0.000)	0.745 (0.227)	−1.759 (0.960)
2	−0.996 (0.159)	−1.591 (0.055)	−1.082 (0.139)	−0.425 (0.335)	0.057 (0.365)	7.254*** (0.000)	7.119*** (0.000)	2.348*** (0.006)
3	−17.86*** (0.000)	−18.01*** (0.000)	−18.61*** (0.000)	−16.78*** (0.000)	0.745 (0.227)	−1.759 (0.960)	−13.11*** (0.000)	−2.827*** (0.002)

Source: Developed by the authors.

Note: ***, ** and * denote the 1%, 5% and 10% significant levels, respectively. Number in brackets represents the probability test.

4.4. Cointegration test

To further assess the existence of a long-run equilibrium relationship among external debt, capacity utilisation, digital infrastructural architecture [53], and national savings in African debt-distressed countries, panel cointegration tests were conducted. This step is particularly important given the mixed integration properties of the variables identified in the unit root analysis, which necessitate formal testing for long-run comovement. The analysis employs the Pedroni (2004) [48] panel cointegration test as the primary method, alongside the Kao (1999) test [49] as a robustness check. The Pedroni [48] framework comprises seven statistics, including four within-dimension statistics (panel v, panel rho, panel Phillips-Perron (PP), and panel Augmented Dickey-Fuller (ADF) and three between-dimension statistics (group rho, group PP, and group ADF). These tests evaluate the null hypothesis of no cointegration against the alternative of a long-run cointegrating relationship, with rejection of the null determined at the 5 percent significance level.

The results, reported in *Table 5*, reveal heterogeneous cointegration outcomes across model specifications rather than uniform evidence of long-run association. For Model 1, the majority of the Pedroni (2004) [48] within-dimension statistics are statistically significant; however, the group ADF statistic and the Kao (1999) [49] ADF statistic are not significant ($p = 0.960$). Consequently, the null hypothesis of no cointegration cannot be rejected conclusively for this specification, indicating weak and inconsistent evidence of cointegration. In contrast, Model 2 presents stronger and more consistent evidence of cointegration. Although several Pedroni (2004) [48] statistics are insignificant, both the group ADF statistic and the Kao (1999) [49] ADF statistic are highly significant at the 1 percent level, providing support for rejecting the null hypothesis of no cointegration in this model. For Model 3, the evidence of cointegration is most robust. All within-dimension Pedroni statistics are statistically significant, and both the group ADF and Kao ADF statistics strongly reject the null hypothesis at conventional significance levels. This pattern confirms the presence of a stable long-run relationship among the variables in this specification. Thus, the cointegration results suggest that long-run relationships exist in selected model specifications rather than uniformly across all models. These findings justify proceeding with estimation techniques such as CS-ARDL, which accommodate heterogeneous long-run dynamics, and system GMM, which remains suitable for addressing endogeneity concerns in dynamic panel settings. Importantly, the model-specific nature of the cointegration evidence is explicitly acknowledged, ensuring accurate interpretation and alignment with the reported test statistics.

4.5. Baseline model — system GMM analysis

This study investigates the influence of external debt, productive capacity, and digital infrastructure on national savings in African economies experiencing debt distress. The analysis employs the panel system generalised method of moments estimator, which is well suited for dynamic panel data where endogeneity, omitted variables, measurement error, and reverse causality are potential concerns (Arellano and Bond, 1991; Blundell and Bond, 1998) [42, 12]. By incorporating the lagged dependent variable and using internal instruments, the estimator controls for unobserved country effects and captures the persistence that characterises savings behaviour. The approach also reduces simultaneity bias between savings and macroeconomic variables, thereby strengthening the credibility of the estimated relationships.

The findings reported in *Table 6* confirm that national savings in the sampled economies exhibit strong dynamic properties. The coefficient of the lagged savings variable is positive and statistically significant in all three specifications. This result indicates that past savings performance exerts a substantial influence on current savings outcomes. The stability of the coefficient across models supports the appropriateness of the dynamic specification and suggests a gradual adjustment process toward equilibrium. This pattern is consistent with the persistence documented by Qureshi and Liaqat (2020) [21], although it differs from the more limited transmission effects identified by Hassan and Meyer (2021) for Sub Saharan Africa. Measures of external debt display a consistent and statistically significant negative association with national savings. In the first specification, the external debt ratio reduces savings, indicating that higher debt burdens constrain domestic saving capacity. In the second specification, external debt servicing also depresses savings, reflecting the fiscal pressure created by repayment obligations. The third specification shows that external debt stock similarly undermines savings performance. The consistency of these results across alternative debt indicators strengthens the conclusion that excessive external borrowing weakens domestic savings in debt distressed economies. These findings accord with the evidence presented by Manasseh et al. (2022) [5], Manasseh et al. (2019) [49], and Makinde and Oladele (2023) [22], who emphasise the adverse macroeconomic consequences of high debt exposure. The effects of productive capacity and digital infrastructure are more varied but remain economically meaningful. Industrial production in the first model is associated with a reduction in savings, suggesting that in heavily indebted econo-

Table 6
Estimated system GMM results

Variable	Model 1	Model 2	Model 3
NAS (−1)	0.421*** (0.000)	0.398*** (0.000)	0.367*** (0.001)
EDR	−0.614*** (0.000)		
EDS		−0.462*** (0.000)	
EDST			−0.531*** (0.000)
IPI	−0.218*** (0.000)		
ICU		−0.176*** (0.001)	
ELC			−0.185*** (0.000)
IPR	−0.493*** (0.004)		
MBS		−0.071 (0.311)	
FBS			−0.229*** (0.000)
INF	−0.584*** (0.000)	0.267*** (0.000)	−0.702*** (0.000)
INTR	−0.098 (0.214)	−0.041 (0.742)	−0.136 (0.188)
EXR	−0.693** (0.021)	0.582** (0.027)	0.601** (0.032)
K	0.036 (0.481)	0.514*** (0.000)	−0.841*** (0.000)
A	−0.226*** (0.000)	−0.214*** (0.000)	0.193** (0.041)
Instruments	22	24	23
AR(1)	−2.91*** (0.004)	−2.77*** (0.006)	−2.68*** (0.007)
AR(2)	−1.21 (0.226)	−1.08 (0.281)	−1.15 (0.249)
Hansen J	18.37 (0.421)	20.11 (0.312)	17.84 (0.463)

Source: Authors' conception.

Note: AR tests follow Arellano-Bond (1991). Instrument matrix is collapsed and lag depth restricted. (.) is the probability value, and the variables are expressed in natural logarithm. All continuous variables were transformed into natural logarithms, except for inflation, interest rate, and ratio variables. This approach facilitates interpretation in elasticity terms while avoiding distortions associated with variables that can take negative or bounded values.
Note: ***, ** denote significance at the 1% and 5% levels, respectively.

mies, expansion in output may be financed through borrowing or increased consumption rather than through higher savings. Capacity utilisation in the second model also shows a negative effect on savings, contrasting with the positive relationship reported by Okeoma et al. (2022) [26]. This outcome may reflect structural constraints in debt distressed environments, where higher utilisation does not necessarily translate into improved saving behaviour at the household or public level.

Digital infrastructure variables produce differentiated results. Internet penetration in the first model reduces savings, and fixed broadband subscriptions in the third model show a similar negative effect. These findings suggest that digital expansion may initially encourage consumption and financial access in ways that reduce short term savings. Although digital inclusion has been linked to broader development gains (Kouladoum, 2023) [3], the present evidence indicates that its immediate effect on aggregate savings in debt distressed settings may be negative. In contrast, mobile broadband subscriptions do not show a statistically significant relationship with savings in the second model, implying that not all forms of digital development exert a direct measurable impact on aggregate saving behaviour. Macroeconomic control variables reveal additional insights. Inflation reduces savings in the first and third specifications, consistent with the erosion of real income and macroeconomic instability. In the second model, however, inflation is positively associated with savings, which may reflect precautionary behaviour under certain fiscal conditions. Exchange rate movements also display varying effects. Currency depreciation reduces savings in the first specification but increases savings in the second and third specifications, possibly reflecting differences in debt composition and capital flow dynamics. These patterns illustrate the structural complexity of debt distressed economies.

Table 6 results also revealed that capital stock and total factor productivity exhibit differences across specifications. Capital accumulation enhances savings in the second model but reduces savings in the third model, suggesting that the financing structure of investment may differ depending on the debt measure employed. Total factor productivity reduces savings in the first two models but increases savings in the third, supporting the argument advanced by Hassan and Meyer (2021) [7] that debt conditions can influence savings through investment and productivity channels. The interest rate variable is not statistically significant in any of the specifications. This outcome indicates that monetary policy instruments may not have a strong direct effect on aggregate savings in the sampled economies. Recognising this lack of significance contributes to a balanced interpretation of the findings. Diagnostic tests support the reliability of the estimation. The Arellano Bond tests show significant first order serial correlation, which is expected in differenced dynamic panels, and no evidence of second order serial correlation, thereby validating the underlying moment conditions. The Hansen test statistics indicate that the null hypothesis of instrument validity cannot be rejected. Instruments were limited and structured to ensure that their number remained below the number of cross-sectional units, which strengthens confidence in the results. In summary, the evidence indicates that high levels of external debt, inflationary pressures, and certain aspects of digital expansion are associated with weaker national savings in African economies facing debt distress. Productive capacity and structural variables display varying effects depending on model specification. The persistence of savings and the satisfactory performance of diagnostic tests support the theoretical coherence and econometric soundness of the model.

4.6. Threshold CS-ARDL analysis

This study investigates the impact of external debt, capacity utilisation, and digital infrastructural architecture on national savings in African debt-distressed countries. To ensure the robustness of findings, the panel cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model is employed as a robustness check. The CS-ARDL technique accounts for cross-sectional dependence, heterogeneity, and nonstationarity features common in macro-panel data (Chudik et al. 2016) [13]. Its ability to capture both short-run and long-run dynamics enhances the reliability of empirical estimates. This is particularly valuable in African contexts, where countries often exhibit heterogeneous structural characteristics. Moreover, CS-ARDL effectively mitigates omitted variable bias by incorporating cross-sectional averages. Thus, it offers a more credible validation of the GMM-based results.

While system GMM provides valuable insights into the short-run dynamics of national savings and effectively addresses endogeneity, it is limited in its ability to explicitly account for cross-sectional dependence and to separate long-run equilibrium relationships from short-run adjustment processes. To address these limitations and strengthen the robustness of the empirical findings, this study employs the panel cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model as a complementary estimation framework. The CS-ARDL approach is particularly suited for macroeconomic panel data because it accommodates cross-sectional dependence, parameter heterogeneity, and mixed orders of integration (Chudik et al. 2016) [13]. By incorporating cross-sectional averages of dependent and independent variables, the model effectively controls for unobserved common factors, including regional policy spillovers, synchronized shocks, and global financial turbulence. These features are especially pertinent in African debt-distressed economies, where macroeconomic outcomes are strongly shaped by regional interdependencies, global financial cycles, and coordinated policy responses. In this context, the CS-ARDL framework provides insights that system GMM cannot, particularly regarding long-run elasticities, equilibrium relationships, and the persistence of effects under cross-sectional interdependence. Hence, the estimated results of the cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model are presented in *Table 7*.

The long-run CS-ARDL estimates, presented in *Table 7*, reveal persistent structural relationships that are obscured in short-run analyses. External debt measures, including the external debt ratio (*EDR*), external debt servicing (*EDS*), and external debt stock (*EDST*), consistently exert negative and statistically significant effects on national savings. The magnitude of these coefficients demonstrates that increasing external obligations systematically erode domestic saving capacity, even after accounting for global and regional shocks. Unlike short-run fluctuations, these long-term effects do not dissipate, confirming the enduring consequences of external debt on savings accumulation in debt-distressed African economies such as Nigeria, Kenya, and Ghana. These results are consistent with Qureshi and Liaqat (2020) [21], who emphasise a global savings-debt-growth nexus, and with Makinde and Oladele (2023) [22], who document similar patterns in Nigeria. While Hassan and Meyer (2021) [7] argue that debt primarily affects growth through investment and productivity channels, the CS-ARDL results show that external debt directly suppresses national savings over the long term in highly indebted African contexts.

Capacity utilisation variables also exhibit negative and statistically significant long-run effects, particularly through the industrial capacity utilisation rate (ICU). This finding suggests that persistent inefficiencies in production and energy use prevent increases in productive capacity from translating into sustained savings accumulation. Although Okeoma et al. (2022) [26] report positive associations between capacity utilisation and output growth, the present evidence indicates that growth-enhancing effects may not lead to higher savings when economies are burdened by chronic debt pressures and energy inefficiencies. Similarly, digital infrastructural variables, including the industrial production index (*IPI*), electricity consumption (*ELC*), and internet penetration rate (*IPR*) exert negative long-run relationship, implying that current digital investments may impose substantial costs without immediate returns in savings. This contrasts with the long-term developmental and financial inclusion benefits reported by Kouladoum (2023) [3], Manasseh et al. (2023) [40] and Nwakoby et al. (2026) [48], suggesting that in debt-constrained African economies, the savings gains from digitalisation may lag behind broader economic growth and development outcomes.

The short-run CS-ARDL estimates complement the long-run findings by highlighting adjustment dynamics. Across all short-run specifications, changes in external debt measures, including *EDR, EDS,* and *EDST*, exert negative and statistically significant effects on national savings. This indicates that increases in debt obligations immediately constrain domestic saving capacity, even after accounting for cross-sectional dependence and heterogeneous country responses. These short-run effects reinforce Qureshi and Liaqat (2020) [21], who highlight the adverse impact of rising debt on savings, and complement Hassan and Meyer (2021) [7], who emphasise debt's inhibitory effects on investment and productivity. Short-run capacity utilisation indicators, such as *IPI, ICU,* and *ELC*, also negatively affect national savings. This suggests that increases in productive activity may

Table 7
Estimated results of CS-ARDL

Variable	Long-Run			Variable	Short-Run (Δ)		
	1	2	3		4	5	6
NAS (−1)	0.487*** (0.000)	0.822*** (0.000)	0.603*** (0.000)	ΔNAS (−1)	−0.392** (0.016)	−0.334** (0.019)	0.384** (0.015)
EDR	−1.487*** (0.000)			ΔEDR	−0.695*** (0.000)		
EDS		−0.902*** (0.000)		ΔEDS		−0.439*** (0.000)	
EDST			−1.122*** (0.000)	ΔEDST			−0.545*** (0.000)
IPI	−0.582*** (0.000)			ΔIPI	−0.243*** (0.000)		
ICU		−0.402*** (0.000)		ΔICU		−0.188*** (0.000)	
ELC			−0.416*** (0.000)	ΔELC			−0.193*** (0.000)
IPR	−1.106*** (0.001)			ΔIPR	−0.714*** (0.008)		
MBS		−0.228 (0.581)		ΔMBS		−0.123 (0.585)	
FBS			−0.531*** (0.000)	ΔFBS			−0.243*** (0.000)
INF	−1.103*** (0.000)	0.544*** (0.000)	−1.634*** (0.000)	ΔINF	−0.615*** (0.000)	0.243*** (0.000)	−0.756*** (0.000)
INTR	−0.209 (0.215)	−0.038 (0.915)	−0.879 (0.118)	ΔINTR	−0.115 (0.229)	−0.019 (0.926)	−0.453 (0.123)
EXR	−1.343** (0.042)	1.219** (0.033)	1.281** (0.038)	ΔEXR	−0.820** (0.035)	0.611** (0.025)	0.635** (0.031)
K	0.045 (0.582)	0.890*** (0.000)	−1.762*** (0.000)	ΔK	0.019 (0.594)	0.541*** (0.000)	−0.992*** (0.000)
A	−0.527*** (0.000)	−0.498*** (0.000)	0.436** (0.031)	ΔA	−0.241*** (0.000)	−0.238*** (0.000)	0.205** (0.036)
Normality	1.238 (0.537)	0.982 (0.612)	1.450 (0.484)	ECM(−1)	−0.684*** (0.000)	−0.743*** (0.000)	−0.689*** (0.000)
Serial Correlation	−1.933 (0.853)	−1.560 (0.988)	−1.623 (0.884)				
Heteroscedasticity	2.319 (0.128)	1.744 (0.198)	2.094 (0.147)				
Ramsey RESET	1.423 (0.244)	1.884 (0.162)	1.730 (0.181)				
Hausman Test	0.013 (0.547)	0.292 (0.369)	0.078 (0.588)				

Source: Authors' conception.

Note: ***, ** represent the 1% and 5% significant levels, respectively, numbers in brackets are the probability values, and the variables are expressed in natural logarithms.

be financed through borrowing or consumption rather than through savings mobilisation, weakening short-term saving outcomes. The findings support Oniyide and Ogunjinmi (2021) [27], who report slightly negative effects of capacity utilisation on economic growth, and underscore structural inefficiencies common in African economies facing heavy debt burdens. In contrast to conventional growth narratives, higher capacity utilisation does not automatically translate into improved saving behaviour where fiscal constraints dominate.

Digital infrastructure variables display heterogeneous short-run effects. Internet penetration (*IPR*) and fixed broadband subscriptions (*FBS*) negatively affect national savings, whereas mobile broadband subscriptions (*MBS*) remain statistically insignificant. This suggests that certain forms of digital expansion may initially encourage consumption, facilitate credit access, or increase engagement with digital services in ways that reduce short-term savings. These short-run effects contrast with the long-term benefits of digital inclusion reported by Kouladoum (2023) [3] and Manasseh et al. (2023) [40], indicating that savings benefits from digitalisation may only materialise once sufficient scale, network maturity, and financial integration are achieved. Inflation (*INF*) and exchange rate movements (*EXR*) further amplify short-term declines in national savings, consistent with [25] Asue and Ikyaator (2023), who link debt accumulation to heightened inflationary pressures and currency volatility in African economies. The robustness of the CS-ARDL estimates is supported by diagnostic tests. Jarque-Bera statistics indicate approximate normality of residuals across all specifications, suggesting that extreme descriptive values do not distort coefficient estimates. Serial correlation tests fail to reject the null hypothesis of no residual autocorrelation, confirming that the dynamic specification adequately captures short-run adjustment processes. White heteroscedasticity tests show homoscedastic residuals, indicating reliable standard errors and efficient coefficient estimates. The Ramsey RESET test shows no evidence of functional form misspecification, and the Hausman test supports the consistency of the selected estimator. Collectively, these diagnostics confirm that the CS-ARDL estimates are robust, resilient to cross-country heterogeneity, and not driven by statistical artefacts.

In conclusion, while system GMM captures average short-run dynamics under conditions of endogeneity control, the CS-ARDL framework provides complementary insights by uncovering long-run equilibrium relationships, quantifying persistent effects, and explicitly accounting for cross-sectional dependence. By integrating unobserved common factors and heterogeneous country responses, the CS-ARDL results offer a more comprehensive and policy-relevant understanding of how external debt, capacity utilisation, and digital infrastructural architecture shape national savings in African debt-distressed economies. This dual-estimation approach strengthens confidence in the findings and underscores the importance of debt management, productive efficiency, and strategic digital investments in fostering sustainable saving behaviour.

4.7. Discussion of findings

This study examined the influence of external debt, capacity utilisation, and digital infrastructural architecture on national savings in eighteen African debt-distressed countries over the period 2011 to 2024, employing the panel system generalised method of moments (GMM) as the baseline estimation technique and the panel cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model as a robustness check. The panel system GMM results offer substantial insights into the determinants of national savings in these economies. The consistently negative and statistically significant coefficient of lagged national savings across all specifications indicates strong persistence in saving behaviour, supporting the observations of Qureshi and Liaqat (2020) [21], while diverging from Hassan and Meyer (2021) [7], who reported weak savings transmission in Sub-Saharan Africa.

In Model 1, the external debt ratio (*EDR*), inflation (*INF*), internet penetration (*IPR*), industrial production index (*IPI*), and exchange rate depreciation (*EXR*) significantly reduce national savings, highlighting the destabilising effects of macroeconomic imbalances, consistent with Manasseh et al. (2022) [5] and Makinde and Oladele (2023) [22]. Model 2 identifies external debt servicing (*EDS*), inflation, and capacity utilisation (*ICU*) as key detractors of savings, suggesting that in contexts of high debt, excess productive capacity may signal inefficiencies rather than growth, contrary to the findings of Okeoma et al. (2022) [26]. In Model 3, external debt stock (*EDST*), inflation, and electricity consumption (*ELC*) negatively affect savings, corroborating Asue and Ikyaator (2023) [25] on the inflation and exchange rate transmission channels. Fixed broadband subscriptions (*FBS*) also exhibit a negative impact, indicating that digital infrastructure investments may initially stimulate consumption rather than savings accumulation. Capital formation (*K*) and total factor productivity (*A*) display mixed effects, reflecting the complex transmission mechanisms between investment, productivity, and savings. Diagnostic assessments further validate the robustness of the models: the AR (1) test is significant, AR (2) is insignificant, and Hansen test p-values confirm instrument validity, with Models 2 and 3 demonstrating relatively higher statistical reliability.

The CS-ARDL robustness checks reveal both short- and long-run dynamics that complement and extend the GMM findings. In the long run, external debt measures including *EDR, EDS,* and *EDST* exert consistently negative and statistically significant effects on national savings, demonstrating that rising debt obligations structurally erode domestic saving capacity. These long-term results align with Qureshi and Liaqat (2020) [21] and Makinde and Oladele (2023) [22] while extending the argument of Hassan and Meyer (2021) [7] by highlighting direct debt-savings transmission mechanisms in African debt-distressed contexts. Capacity utilisation, particularly *ICU*, maintains a negative long-run effect, reflecting persistent inefficiencies in production and energy use that prevent capacity expansion from translating into sustainable savings growth. Digital infrastructural variables, including *IPI*, ELC, and *IPR* also retain negative long-run coefficients, suggesting that despite their potential developmental benefits, current digital investments may not yet support savings accumulation, consistent with the notion that the savings returns of digitalisation may lag broader growth outcomes by Kouladoum (2023) [3].

In the short run, the CS-ARDL estimates demonstrate that fluctuations in external debt indicators continue to suppress national savings, reinforcing the short-term constraints imposed by rising debt burdens. Capacity utilisation indicators (*IPI, ICU, ELC*) also display negative short-run effects, consistent with structural inefficiencies that hinder savings mobilisation, supporting Oniyide and Ogunjinmi (2021) [27]. Digital infrastructure variables present mixed short-run outcomes: *IPR* and *FBS* significantly reduce savings, while mobile broadband subscriptions (*MBS*) remain statistically insignificant, indicating that early-stage digital expansion may initially encourage consumption and credit access rather than savings. Inflationary pressures (*INF*) and exchange rate volatility (*EXR*) further reinforce short-term declines in national savings, corroborating Asue and Ikyaator (2023) [25] on the inflationary and currency destabilisation effects associated with debt accumulation. Conclusively, the CS-ARDL results highlight that in African debt-distressed countries, external debt, structural capacity constraints, and immature digital infrastructure consistently undermine national savings in both the short and long run. By capturing cross-sectional interdependencies and providing clear distinction between short-run adjustments and long-run equilibrium effects, the CS-ARDL framework complements the GMM estimates and provides a richer, policy-relevant understanding of the macroeconomic determinants of savings. These findings underscore the importance of prudent debt management, efficiency in capacity utilisation, and the strategic development of digital infrastructure to strengthen domestic savings and promote financial stability across the continent.

5. Conclusion and policy recommendations

This study examined the dynamic effects of external debt, capacity utilisation, and digital infrastructural architecture on national savings in eighteen African debt-distressed countries over the period 2011 to 2024, using both panel system GMM and threshold cross-sectionally augmented autoregressive distributed lag (CS-ARDL) estimations. The empirical findings provide clear and robust answers to the study's research questions. First, external debt, measured through debt ratios, debt servicing obligations, and debt stock, consistently exerts negative and statistically significant effects on national savings in both the short and long run. These results confirm the presence of debt overhang and fiscal crowding out; whereby rising debt obligations reduce domestic resource mobilisation and undermine macroeconomic stability. Second, capacity utilisation indicators show a negative association with national savings, suggesting that industrial capacity in many African debt-distressed economies reflects structural inefficiencies, including energy shortages and production bottlenecks, rather than productive expansion that enhances savings. Third, digital infrastructural architecture demonstrates negative short-run effects on national savings, likely due to high initial investment costs, limited institutional readiness, and consumption-oriented digital adoption. However, the long-term potential of digital infrastructure to support productivity and savings accumulation remains evident, particularly when linked with formal financial systems and effective regulatory frameworks.

These findings have specific policy implications. To mitigate the negative impact of external debt on savings, governments should pursue prudent debt management strategies, including keeping external debt at sustainable levels, ideally below fifty percent of GDP in highly vulnerable economies, conducting comprehensive debt audits, and prioritising loans that finance productive infrastructure rather than consumption. To improve capacity utilisation, public investment should focus on eliminating structural bottlenecks, particularly by expanding energy supply, upgrading industrial infrastructure, and enhancing maintenance and logistics systems, ensuring that increases in industrial capacity translate into sustained savings and productivity gains. In relation to digital infrastructure, policymakers should integrate digital expansion with formal financial inclusion by promoting digital finance platforms that encourage savings, strengthening digital literacy, and enforcing regulatory measures that channel digital activity toward investment and productive applications rather than short-term consumption.

This study contributes to the literature by providing a comprehensive assessment of how external debt dynamics, productive efficiency, and digital transformation jointly shape national savings in African debt-distressed economies. Addressing these structural and policy gaps is essential for mobilising domestic savings, improving macroeconomic resilience, and supporting sustainable long-term development across the continent. Future research could build on this analysis in several ways. Country-specific studies could examine the heterogeneous effects of debt and capacity utilisation across African subregions. The role of institutional quality, governance, and political stability as mediators in the relationship between digital infrastructure and savings warrants further investigation. Finally, as digital finance and fintech adoption continue to expand in Africa, longitudinal studies could explore how mobile banking, digital wallets, and financial literacy initiatives influence savings behaviour over time, providing evidence to guide targeted policy interventions in local contexts.

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