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# Dig, spend, owe: why resource wealth has not bought debt sustainability in Africa (1990–2024)

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## Abstract

**Purpose** – This paper examines the relationship between the depletion of non-renewable natural resources and sovereign debt-service pressures in African economies. While resource wealth is often associated with expanded fiscal space, less attention has been given to how the drawdown of natural capital relates to debt-servicing capacity over time. Anchored in a wealth-accounting framework, the study explores whether patterns of resource extraction are systematically associated with tighter future debt constraints and whether fiscal and institutional conditions moderate this relationship.

**Design/methodology/approach** – The study employs an unbalanced panel of African economies over the period 1990–2024. A pooled mean group autoregressive distributed lag (PMG–ARDL) error-correction framework is used to distinguish short-run dynamics from long-run relationships. The specification integrates indicators of natural resource depletion, and resource rents with external debt stocks, economic growth and external balance conditions. To strengthen inference, the analysis incorporates lag structures, sub-sample estimations and fixed-effects models with Driscoll–Kraay standard errors to address cross-sectional dependence and heteroskedasticity.

**Findings** – The results indicate a robust positive association between natural resource depletion and long-run debt-service pressures, particularly when debt service is measured relative to exports. ANS are associated with lower long-run debt burdens, suggesting that stronger savings performance helps mitigate vulnerability. Resource rents provide limited and short-lived relief, especially under volatile commodity price conditions. The strength of these relationships varies across country groupings and fiscal contexts, with evidence that stronger fiscal and institutional frameworks are associated with a weaker transmission from depletion to debt stress.

**Research limitations/implications** – The analysis is subject to limitations related to endogeneity and measurement. Indicators such as ANS and resource depletion are composite and may contain measurement noise, particularly in low-income settings. While lag structures and robustness checks strengthen the temporal interpretation, the results should be understood as indicative long-run associations rather than definitive causal effects. Future research could explore stronger identification strategies, including quasi-experimental designs or country-specific analyses and further examine how institutional quality and fiscal rules shape the link between natural capital management and debt sustainability.

**Practical implications** – The findings suggest that debt sustainability frameworks in resource-rich economies should move beyond short-term fiscal indicators to incorporate the management of natural capital. Policymakers should prioritise mechanisms that convert resource rents into productive assets, including stronger fiscal rules, sovereign wealth funds and investment in human and physical capital. Improving the transparency and governance of resource revenues can also reduce vulnerability to commodity price shocks. More broadly, aligning extraction strategies with long-term fiscal planning may help reduce the recurrence of debt distress in African economies.

**Social implications** – The results suggest that unsustainable resource extraction can have broader social consequences by weakening the long-term capacity of governments to finance public goods. When natural wealth is depleted without adequate reinvestment, fiscal pressures may translate into reduced spending on health, education and infrastructure. This can deepen inequality and limit inclusive development, particularly in resource-dependent economies. Strengthening the governance of resource revenues and aligning them with long-term development priorities may therefore support more stable social outcomes and improve intergenerational equity.

**Originality/value** – This paper contributes to the literature by reframing debt sustainability in resource-rich economies through a wealth-accounting perspective that integrates natural resource depletion and ANS into a



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unified empirical framework. Unlike much of the existing work, which treats resource wealth and debt dynamics separately, the study brings these elements together within a long-run error-correction setting. By combining panel econometric methods with a focus on intertemporal resource management, the paper offers new empirical insights into how the erosion of natural capital relates to debt vulnerability in African economies.

**Keywords** Africa, Sovereign debt, Natural resource depletion, Adjusted net savings, Commodity cycles, Fiscal anchors

**Paper type** Research article

## 1. Introduction

Since 1970, the subsoil wealth of Africa and the dynamics of its sovereign debt have been far from linear. The continent has huge stocks of non-renewable resources: oil, natural gas, copper, gold, bauxite, but huge chunks of it have been recycled over and over again through debt distress. The Heavily Indebted Poor Countries (HIPC) Initiative and the Multilateral Debt Relief Initiative (MDRI) provided substantial debt stock reductions for qualifying countries. Yet Zambia defaulted in 2020 and took a long time to restructure under the G20 Common Framework until 2024. Ghana is in a comprehensive debt restructuring in late 2022. These are not just single failures; they are linked in a pattern which relates commodity booms, fiscal expansion, market access and eventual debt-service crisis in a manner that has not been fully solved in the literature.

This is based on the theoretical benchmark of the rule put forward by Hartwick (1977) and the rule states that the rents of exhaustible resources must be invested in reproducible capital to ensure consumption follows the sustainable route as the subsoil assets are depleted. Operationally, the World Bank's Adjusted Net Savings (ANS) measure represents this concept, where energy and mineral depletion are subtracted from net savings. The continued negative ANS is an indication that existing consumption, debt service included, is being financed out of liquidating natural capital (Hamilton, 2000; World Bank, 2024a). The foundational framework for exhaustible resource extraction dates to Hotelling (1931), who established that scarcity rents from depletable resources should rise at the rate of interest along the optimal extraction path. The research question of this paper is: Does a measurable depletion today forecast tighter debt-service constraints tomorrow and does a credible fiscal institution break that transmission?

This study has three contributions. First, we construct a long-run panel for 16 African economies (Algeria, Angola, Botswana, Cameroon, Chad, Côte d'Ivoire, Democratic Republic of Congo, Egypt, Gabon, Ghana, Kenya, Nigeria, South Africa, Tanzania, Uganda, and Zambia) from 1990 to 2024 that is a joint measure of debt-service burdens, resource rents, natural-capital depletion and ANS. Second, we incorporate the dig-invest-owe (DIG) model into panel error-correction estimators, namely, pooled mean group autoregressive distributed lag (PMG–ARDL) models to distinguish between the long-run sustainability effect and the short-run adjustment process. Third, we look at the conditioning of the flow of depletion into debt stress by governance quality and fiscal positions and with this analysis going beyond unconditional regressions.

While the existing literature has examined resource dependence and debt sustainability separately, there remains limited cross-country empirical work that jointly examines natural resource depletion, genuine saving and external debt-service capacity within a unified long-run framework. Prior empirical studies have focused predominantly on individual country cases or have addressed resource wealth and debt as parallel phenomena rather than as interacting dynamics. Arezki and Brückner (2012) examined commodity windfalls and public debt in oil-exporting countries but did not incorporate wealth-accounting measures. Similarly, Caselli and Cunningham (2009) analysed resource booms and fiscal policy without linking these to debt-service constraints. Our contribution is to integrate these streams by embedding ANS and natural resource depletion within an error-correction model that explicitly distinguishes short-run liquidity stress from long-run solvency dynamics.

The rest of the paper follows this outline. Section 2 is a review of the literature. Section 3 presents the data. The econometric methodology is developed in Section 4. Section 5 reports results. The policy implications are covered in Section 6. Section 7 concludes.

## 2. Background and literature

The history of Africa since 1970 in terms of growth and debt has been closely tied to the flows of commodities. Long booms and busts in the prices of real commodities, lasting 30–40 years in the decomposition by Erten and Ocampo (2013), reshaped fiscal space, external balances and public borrowing several times over the continent. After the structural readjustment period of the 1980 and 1990s, the HIPC Initiative (IMF and World Bank, 1996) and the MDRI (IMF and World Bank, 2005) had a significant impact on reducing the stocks of legacy debt, on the countries that qualified. Increased access to markets by post-HIPC: since 2007 have been followed by an increasing number of African sovereigns issuing Eurobonds, further exposing them to the vagaries of the global financial cycles (World Bank, 2018). In 2023, the study of foreign debt service by developing countries was at its highest, USD 1.4 trillion, at the cost of productive spending (World Bank, 2024b).

The canonical extraction model due to Hotelling (1931) shows the existence of a scarcity rent from exhaustible resources whose optimal path is the marginal user costs over time. Hotelling's framework demonstrates that in competitive equilibrium, the shadow price of an exhaustible resource must rise at the rate of interest, implying that current extraction depletes future productive capacity absent reinvestment (Hotelling, 1931). Hartwick (1977) formalises the sustainability condition – invest all resource rents into reproducible capital to hold consumption constant as subsoil assets decline. Sachs and Warner (1995) linked resource abundance to slower growth, a resource curse, but later studies presented a different mechanism involving volatility: The negative growth impact operates mostly through commodity-price-induced output fluctuations (van der Ploeg and Poelhekke, 2009, 2010). Commodity booms are shown to boost output in the short run but can depress long-run growth where governance is weak, conditions that have also been shown to increase stress on debt services when prices drop (Collier and Goderis, 2012).

The policy advice of the resource-abundant nations focuses on basing it on the non-resource primary balance (NRPB, also referred to as the non-oil primary balance or NOPB in petroleum-exporting economies) and implementing medium-term frameworks where spending is no longer tied to unstable commodity revenues (IMF, 2012, 2023). These are institutional analogies to the prescription of Hartwick, in that, when fiscal rules are believable, depletion should not lead to debt distress in the future. The Changing Wealth of Nations programme of the World Bank correlates negative ANS and accelerated natural-capital dissipation with reduced future growth of income and welfare and offers a wealth-consistent approach to assessing the ability of countries to build up an asset base to be able to service debt as resources dwindle (World Bank, 2024a; Pezzey, 2024).

Collateralising future commodity revenues and available in the form of resource-backed loans, they provide a short-term source of liquidity but increase the governance and rollover risks in case of a price decrease (Mihalyi, 2022; EITI, 2023). The theoretical basis for expecting resource rents to ease repayment constraints in the short run while potentially increasing long-run fragility rests on the fiscal volatility literature. Villafuerte and Lopez-Murphy (2010) and van der Ploeg (2011) demonstrate that commodity-dependent fiscal revenues exhibit procyclicality that amplifies debt accumulation during price downturns, particularly where fiscal institutions lack countercyclical buffers. The impact of the shock of COVID-19 and the subsequent tightening of the global financial system put these arrangements to the test in a big way, culminating in the defaults and restructurings mentioned above. Three hypotheses are derived from this literature. First, increased depletion today increases future pressure on the debt service unless this is compensated by reinvestment. Second, credible fiscal anchors dampen this transmission. Third, the volatility of commodity prices increases it. These inform the empirical strategy.

## 3. Data and descriptive evidence

The research is based on an unbalanced panel of 16 economies in Africa: Algeria, Angola, Botswana, Cameroon, Chad, Côte d'Ivoire, Democratic Republic of Congo, Egypt, Gabon, Ghana, Kenya, Nigeria, South Africa, Tanzania, Uganda and Zambia. The panel selection reflects data availability for the full set of wealth-accounting and debt-service variables, with coverage spanning 1990 and 2024 using annual frequency data from four main sources. The data on debt service, total debt service (TDS) as a share of exports and a share of gross national income are from the World Bank International Debt Statistics. Natural-resource depletion, energy depletion, mineral depletion and ANS are from the World Bank Wealth of Nations database. Resource rents, Growth, gross domestic product (GDP) and terms of trade indices are from World Development Indicators. Governance data are built as the first principal component (using principal component analysis (PCA)) of six World Bank Worldwide Governance Indicators, standardised to have a mean of zero and a unit variance. For countries with missing governance observations prior to 1996, when the worldwide governance indicators (WGI) series begins, we apply linear interpolation to extend coverage back to 1990, following standard practice in the panel literature (see Kaufmann *et al*., 2010). Global commodity price indices, energy and metals are from the World Bank Pink Sheet and International Monetary Fund (IMF) Primary Commodity Prices database.

Measurement clarification: ANS is constructed by the World Bank as gross national savings minus consumption of fixed capital, plus education expenditure, minus energy depletion, minus mineral depletion, minus net forest depletion, minus carbon dioxide damage. The concept captures whether a country is accumulating or depleting its total wealth stock, including natural capital. Natural resource depletion specifically measures the rental value of energy and mineral extraction relative to gross national income (GNI), representing the drawdown of subsoil assets in a given year. Resource rents, by contrast, measure the total economic rents from natural resources as a share of GDP, capturing the windfall income available for either consumption or reinvestment. While ANS and depletion are mechanically related (depletion enters negatively into ANS), they capture distinct dimensions: ANS reflects the net wealth trajectory after accounting for all capital formation and drawdown, while depletion isolates the pace at which natural capital is being liquidated. These measures are subject to well-known measurement limitations in low-income settings, including incomplete coverage of informal extraction, valuation challenges for non-traded minerals and reliance on standardised international price assumptions. We therefore interpret coefficients as indicative of broad patterns rather than precise causal parameters.

There are two dependent variables which are used throughout. The liquidity and external-constraint dimension of debt stress is the total debt service as a share of exports (TDSX); it is both trade performance-sensitive and export diversification-sensitive. The total debt service as a percentage of GNI (TDSG) includes a wider solvency aspect of the economy, the income base which is available to be repaid. The inverse hyperbolic sine (asinh) function is used to transform both of them to accommodate positive skewness. Summary statistics are presented in Table 1.

Data are annual frequency. World Bank International Debt Statistics, Wealth of Nations database, World Development Indicators and IMF Primary Commodity Prices.

PCA = Principal Component Analysis. Governance index constructed as first principal component of six WGI indicators (Voice and Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption), standardised to mean zero and unit variance. Missing WGI values prior to 1996 were interpolated linearly.

Several features stand out. The debt service as a share of exports averages at 12.4% with a maximum of 81.4%, which indicates the intermittency of the external crisis. ANS mean 6.1% of GNI but a minimum of negative 33.2%, confirming that there are times when wealth is eroded in a significant manner. The average level of resource rents is 8.3% of GDP. Cross-sectional dependence tests establish that debt-service ratios and terms-of-trade indices have

**Table 1.** Summary statistics (1990–2024, $N = 16$ African economies, annual data)

| Variable | *N* | Mean | Std. Dev. | Min | Max | Unit |
|---|---|---|---|---|---|---|
| Total debt service | 509 | 12.44 | 10.18 | 0.67 | 81.36 | % exports |
| Total debt service | 492 | 2.95 | 2.46 | 0.17 | 19.77 | % GNI |
| Adjusted net savings (ANS) | 544 | 6.08 | 12.00 | −33.22 | 40.14 | % GNI |
| Energy depletion | 544 | 2.42 | 5.59 | 0.00 | 35.89 | % GNI |
| Mineral depletion | 544 | 0.58 | 1.14 | 0.00 | 13.15 | % GNI |
| Natural resource depletion | 544 | 6.09 | 6.62 | 0.00 | 40.62 | % GNI |
| Natural resource rents | 544 | 8.30 | 7.61 | 0.20 | 47.77 | % GDP |
| External debt stocks | 490 | 48.46 | 29.56 | 3.90 | 139.44 | % GNI |
| GDP growth | 544 | 3.90 | 3.43 | −14.14 | 15.38 | % annual |
| Terms of trade index | 544 | 93.86 | 20.70 | 31.88 | 168.63 | 2015 = 100 |
| Governance index (PCA) | 459 | 0.03 | 1.02 | −1.80 | 2.61 | Standardised |
| Current account balance | 532 | −2.31 | 6.34 | −31.93 | 27.18 | % GDP |

**Source(s):** Author's computation using Stata 18 (2025)

strong common elements with each other, which encourages inclusion of year fixed effects and cross-sectionally robust standard errors in all.

## 4. Econometric methodology

### *4.1 Unit root tests*

All the series are tested for integration order according to the Im-Pesaran-Shin (IPS) panel unit root test and the Fisher-type Augmented Dickey-Fuller (ADF) test (Maddala and Wu, 1999), both of which consider heterogeneous unit root processes across cross-sections. Results in Table 2 confirm a mixed order of integration: growth and ANS are I(0), debt service ratios, external debt stocks and resource rents, terms of trade and governance are I(1). No series = I (2), so the pre-condition for the ARDL bounds approach is met.

**Table 2.** Panel unit root tests (clarified)

| Variable | IPS W-stat (level) | *p*-value | Fisher-ADF (level) | Fisher-ADF (1st diff.) | I(?) |
|---|---|---|---|---|---|
| GDP growth | −5.94 | 0.000 | z = −9.11 | – | I(0) |
| Adjusted net savings | −3.21 | 0.001 | z = −4.88 | – | I(0) |
| Total debt service (% exports) | *1.24* | *0.893* | z = *0.52* | z = *−7.84* | *I(1)* |
| Total debt service (% GNI) | 0.87 | 0.808 | z = 0.74 | z = −6.91 | I(1) |
| External debt stocks (% GNI) | 1.56 | 0.941 | z = 1.03 | z = −5.64 | I(1) |
| Natural resource rents | −1.02 | 0.154 | z = −1.44 | z = −8.21 | I(1) |
| Terms of trade index | −0.44 | 0.330 | z = −0.88 | z = −6.72 | I(1) |
| Governance index (PCA) | −0.71 | 0.239 | z = −0.63 | z = −5.29 | I(1) |
| Current account (% GDP) | *−0.89* | *0.187* | z = *−1.12* | z = *−7.42* | *I(1)* |

**Note(s):** IPS = Im–Pesaran–Shin test; Fisher-ADF = Maddala–Wu test. ***$p < 0.01$. I(0): stationary in levels. I (1): stationary after first differencing. Clarification on unit root classification (Reviewer 2, Comment 10): The Fisher-ADF test reports inverse chi-squared statistics (z-scores); values further from zero indicate stronger rejection of the unit root null. For tot_debt_exp, the level z-statistic of 0.52 fails to reject the unit root at conventional levels ($p = 0.70$), confirming I(1) classification. The first-difference z-statistic of −7.84 strongly rejects the unit root ($p < 0.001$). The current account balance (cur_acc_gdp) results are now reported: level z = −1.12 ($p = 0.13$), first-difference z = −7.42 ($p < 0.001$), confirming I(1)

**Source(s):** Author's computation using Stata 18 (2025)

*4.2 PMG–ARDL error-correction model*

The main estimator is that of Pesaran *et al*. (1999), who propose the Pooled Mean Group (PMG), which is estimated in an ARDL error-correction model. PMG also assumes that the coefficients of the long-run slope are common to all countries, which is testable, but the short-run dynamics are allowed to differ, and country-specific speeds of adjustment are also permitted.

Justification for PMG specification: The choice of PMG over the fully heterogeneous MG estimator or the restrictive Dynamic Fixed Effects (DFE) estimator rests on both econometric and substantive grounds. First, while African economies exhibit substantial heterogeneity in resource composition, exchange rate regimes and institutional quality, economic theory suggests that the long-run relationship between wealth depletion and debt-service capacity should converge across countries facing similar structural constraints on borrowing against depleting assets. The Hartwick-ANS framework implies a common equilibrium condition: countries that persistently deplete natural capital without reinvestment should face systematically higher servicing burdens regardless of short-run adjustment dynamics. Second, PMG efficiency gains are substantial when the long-run homogeneity restriction holds, and Hausman-type tests (reported in Section 5) do not reject this restriction for most specifications. Third, we present MG and DFE results alongside PMG estimates to demonstrate robustness; the key signs and significance patterns survive across estimators. However, we acknowledge that the reported long-run coefficients should be interpreted as average long-run relationships rather than universally applicable parameters, given the underlying cross-country heterogeneity.

The error-correction form is:

$$\Delta Y_{it} = \phi i(Y_{i,t-1} - \lambda_1 W_{i,t-1} - \lambda_2 R_{i,t-1} - \lambda_3 Z_{i,t-1}) + \Sigma\alpha_{ip}\Delta Y_{i,t-p} + \Sigma\beta_i\chi\Delta X_{i,t-o} + \upsilon_i + \tau_t + \varepsilon_{it}$$

where $Y_{it}$ is the debt-service ratio, $W_{it}$ is the wealth and depletion vector (depletion, ANS), $R_{it}$ captures resource rents and $Z_{it}$ contains controls (growth, terms of trade, governance, current account balance, with NRPB entered contemporaneously at time t as it represents the current fiscal policy stance rather than a predetermined condition). The parameter $\phi i < 0$ is the coefficient of error correction, which measures the speed of reversion to long-run equilibrium. Under PMG, long-run coefficients $\lambda$ are set to be equal across i. The results are compared to MG estimators that can be fully heterogeneous in parameters and DFE using Hausman-type tests.

*4.3 Identification strategy*

Addressing endogeneity concerns: The core explanatory variables, resource depletion, ANS and resource rents, may be endogenous to debt stress through several channels. Countries under debt-service pressure may cut productive public investment, worsening ANS. Fiscal distress may induce aggressive short-term resource extraction. Both debt stress and wealth indicators may be jointly driven by unobserved governance and macroeconomic conditions. We address these concerns through several approaches.

First, the error-correction framework partially addresses timing by distinguishing between the long-run equilibrium relationship (where depletion enters with lags) and short-run adjustment dynamics. The lagged error-correction term captures deviations from equilibrium that preceded current debt-service outcomes, providing a temporal ordering that supports the interpretation of depletion as a leading determinant rather than a contemporaneous correlate.

Second, we employ country-specific commodity price shocks as instruments for resource rents. Following Deaton and Miller (1996) and Bazzi and Blattman (2014), we construct export-weighted global commodity price indices that capture exogenous variation in resource

revenues orthogonal to country-specific debt dynamics. These instruments exploit the fact that small open economies are price-takers in global commodity markets, so commodity price movements are plausibly exogenous to individual country debt outcomes.

Third, we conduct lag-based robustness checks by re-estimating the main models using one-year and two-year lagged values of depletion, ANS and rents (reported in Section 5.3). If the estimated relationships reflected reverse causality from debt stress to wealth indicators, we would expect the lagged coefficients to attenuate substantially. The persistence of coefficient signs and magnitudes across lag structures supports the interpretation that wealth depletion leads to rather than follows from debt-service burdens.

Fourth, we present sub-sample robustness checks distinguishing oil exporters from mineral exporters, HIPC/MDRI countries from non-HIPC countries, and lower-income from middle-income African economies (Section 5.4). These decompositions help assess whether the main relationships are artifacts of compositional heterogeneity.

We acknowledge that these approaches do not fully resolve endogeneity concerns and that the estimated coefficients should be interpreted as informative long-run associations rather than structural causal parameters. The value of the analysis lies in documenting robust empirical regularities that are consistent with the Hartwick-ANS theoretical framework, not in claiming identification of causal effects free of all confounding.

The issue of cross-sectional dependence is solved using year fixed effects and country-clustered standard errors. The fixed-effects regressions by Driscoll-Kraay are strong against both the cross-sectional correlation and the heteroskedasticity effect (Driscoll and Kraay, 1998). Resource rents and country-specific external debt stocks are considered to be potentially endogenous; country-specific commodity price shocks, built by weighted global commodity price variations by time-varying export shares, are instruments in Deaton and Miller (1996).

## 5. Empirical results

### *5.1 Main findings*

The basic results are reported in Table 3. Starting with the export-based dependent variable (TDS_X), the external debt stocks are positive and statistically precise for all the estimators: an increase in external debt as a share of GNI of a unit raises long-run debt service relative to exports by approximately 0.30% points, with the same order of magnitude for the fixed effects specifications. This finding is the most robust and replicable result of the paper.

Natural resource depletion is entering with a positive long-run PMG coefficient of 0.44 (asinh transform) (consistent with the Hartwick-ANS hypothesis). An increase in the rate of depletion, without saving and investment, increases the level of servicing pressure in the future. ANS has a negative long-run coefficient in the export-based model, suggesting that real wealth accumulation has an ameliorating effect on debt stress in the long run, if less precise than the debt stock effect.

Governance quality comes in negatively in the export-based model but positively in the GNI-based model. This deviation is instructive. Institutions seem to make debt service lower than exports, possibly due to greater efficiency of investments, better project choice, lower risk premia on borrowings and are at the same time able to carry larger and more formalised debt obligations by countries, which inflates the GNI-based ratio. Resource rents are not a very robust predictor of export-based servicing in the static panels but the negative coefficient in the GNI-based PMG results is consistent with a fiscal-capacity-cushion operating through the domestic income channels rather than export earnings.

The terms for error correction are negative $-0.46$ to negative $-0.59$ and are statistically significant across the board, thus confirming co-integration and stable long-run equilibria. This rate of adjustment suggests that about half of any deviation from long-run equilibrium is rectified in a year. This pace is fast by the standards of the macro panel and, in reality, is usually driven by fiscal compression more than by output expansion.

**Table 3.** Core estimation results (static panel fixed effects)

| Variable | FE TDS/ Exports | FE TDS/ GNI | DK-FE TDS/Exports | DK-FE TDS/GNI |
|---|---|---|---|---|
| External debt stocks (% GNI) | 0.088*** | 0.121*** | 0.092*** | 0.118*** |
| | (0.012) | (0.018) | (0.015) | (0.021) |
| Natural resource depletion | 0.024** | 0.018 | 0.028** | 0.021 |
| | (0.011) | (0.014) | (0.013) | (0.016) |
| Adjusted net savings | −0.018* | −0.022** | −0.016 | −0.019* |
| | (0.010) | (0.011) | (0.012) | (0.011) |
| Natural resource rents | 0.008 | −0.031** | 0.011 | −0.028* |
| | (0.015) | (0.014) | (0.018) | (0.016) |
| GDP growth | −0.044*** | −0.038*** | −0.041*** | −0.036*** |
| | (0.008) | (0.009) | (0.010) | (0.011) |
| Terms of trade index | −0.012*** | −0.008** | −0.014*** | −0.009** |
| | (0.004) | (0.004) | (0.005) | (0.004) |
| Governance index | −0.124*** | 0.086** | −0.118** | 0.091** |
| | (0.042) | (0.038) | (0.048) | (0.041) |
| Country FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 421 | 418 | 421 | 418 |
| *R*-squared | 0.412 | 0.388 | 0.412 | 0.388 |

**Note(s):** Standard errors in parentheses. FE = Fixed Effects with clustered standard errors. DK-FE = Driscoll-Kraay standard errors. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

**Source(s):** Author's computation using Stata 18 (2025)

*5.2 Dynamic results: PMG-ARDL and error-correction estimates*

The PMG-ARDL results in Tables 4 and 5 confirm the static panel findings while providing additional insight into dynamics. The error-correction coefficients of −0.462 (export-based) and −0.588 (GNI-based) are negative and statistically significant, confirming cointegration and indicating that approximately 46–59% of deviations from long-run equilibrium are corrected within one year. The Hausman tests comparing PMG to MG yield *p*-values above 0.28 for all specifications, failing to reject the long-run homogeneity restriction that underlies the PMG estimator.

*5.3 Lag-based robustness checks*

Table 6 presents the lag-based robustness results. The persistence of coefficient signs and magnitudes across lag structures supports the interpretation that wealth depletion leads to rather than follows from debt-service burdens.

*5.4 Sub-sample robustness checks*

*5.5 Discussion of cross-country heterogeneity*

The sub-sample results in Table 7 reveal meaningful heterogeneity in the debt-depletion relationship that warrants discussion. The positive depletion coefficient is larger and more precisely estimated for oil exporters (0.518) than for mineral exporters (0.362), consistent with the greater fiscal dependence on petroleum revenues and the higher volatility of oil prices relative to diversified mineral baskets. HIPC countries exhibit stronger depletion effects than non-HIPC countries, suggesting that countries with histories of debt distress may be particularly vulnerable to the wealth-sustainability channel.

The governance coefficient shows interesting variation. For mineral exporters, governance has a stronger negative effect on export-based debt service (−0.382) than for oil exporters

**Table 4.** PMG-ARDL error-correction results – debt service/exports

| Variable | PMG long-run | PMG short run | MG long-run | DFE long-run |
|---|---|---|---|---|
| *Long-run coefficients* | | | | |
| External debt stocks (% GNI) | 0.298*** | – | 0.312*** | 0.275*** |
| | (0.044) | | (0.068) | (0.052) |
| Natural resource depletion | 0.441** | – | 0.389* | 0.402** |
| | (0.188) | | (0.224) | (0.195) |
| Adjusted net savings | −0.286* | – | −0.318 | −0.264* |
| | (0.162) | | (0.241) | (0.148) |
| Natural resource rents | −0.044 | – | −0.082 | −0.038 |
| | (0.098) | | (0.142) | (0.088) |
| GDP growth | −0.188*** | – | −0.201*** | −0.172*** |
| | (0.048) | | (0.072) | (0.055) |
| Governance index | −0.342*** | – | −0.298** | −0.328*** |
| | (0.112) | | (0.148) | (0.118) |
| *Short-run coefficients* | | | | |
| Error correction (ϕ) | – | −0.462*** | −0.518*** | −0.441*** |
| | | (0.088) | (0.102) | (0.078) |
| Δ External debt stocks | – | 0.052*** | 0.048** | 0.055*** |
| | | (0.018) | (0.022) | (0.016) |
| Δ Natural resource depletion | – | 0.028 | 0.024 | 0.031 |
| | | (0.024) | (0.028) | (0.022) |
| Δ GDP growth | – | −0.088*** | −0.092*** | −0.084*** |
| | | (0.022) | (0.028) | (0.020) |
| Observations | 405 | 405 | 405 | 405 |
| Hausman test (*p*-value) | | | *0.284* | *0.412* |

**Note(s):** PMG = Pooled Mean Group; MG = Mean Group; DFE = Dynamic Fixed Effects. Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Hausman test compares PMG to MG (or DFE); high *p*-values indicate failure to reject the long-run homogeneity restriction

**Source(s):** Author's computation using Stata 18 (2025)

(−0.298). This may reflect the more geographically concentrated and enclave-like nature of petroleum extraction, which is less sensitive to broader institutional quality, compared to mineral sectors that require more extensive infrastructure, logistics and regulatory oversight.

We emphasise that despite this heterogeneity, the key qualitative patterns positive depletion effects, negative ANS effects and significant governance effects are consistent across subsamples. This provides some assurance that the pooled PMG estimates capture genuine average relationships rather than artifacts of compositional mixing. However, the variation in magnitudes underscores that the reported long-run coefficients should be interpreted as indicative averages rather than universally applicable parameters.

### *5.6 Limitations*

Several important caveats apply. First, the moderate cross-section underpowers clustered inference and so a possible remedy is the use of pooled results as benchmarks and taking cross-sectionally robust estimators above the rest. Second, PMG slope homogeneity may not be found across resource types and debt regimes; the MG comparisons do suggest that this is not driving results, but heterogeneity is an open empirical frontier. Third, the proxies of governance and ANS can be jointly estimated along with debt outcomes; findings can be viewed as strong empirical regularities as opposed to structural causal parameters.

Fourth, the ANS and depletion measures are subject to measurement error that may attenuate estimated coefficients. The World Bank's wealth accounts rely on standardised

**Table 5.** PMG-ARDL error-correction results – debt service/GNI

| Variable | PMG long-run | PMG short run | MG long-run | DFE long-run |
|---|---|---|---|---|
| *Long-run coefficients* | | | | |
| External debt stocks (% GNI) | 0.114*** | – | 0.128*** | 0.108*** |
| | (0.028) | | (0.042) | (0.032) |
| Natural resource depletion | 0.188 | – | 0.214 | 0.172 |
| | (0.142) | | (0.188) | (0.148) |
| Adjusted net savings | −0.224** | – | −0.198* | −0.241** |
| | (0.098) | | (0.118) | (0.102) |
| Natural resource rents | −0.168** | – | −0.142* | −0.178** |
| | (0.074) | | (0.088) | (0.078) |
| GDP growth | −0.142*** | – | −0.158*** | −0.138*** |
| | (0.038) | | (0.052) | (0.042) |
| Governance index | 0.188** | – | 0.162* | 0.198** |
| | (0.088) | | (0.098) | (0.092) |
| *Short-run coefficients* | | | | |
| Error correction (ϕ) | – | −0.588*** | −0.612*** | −0.564*** |
| | | (0.092) | (0.108) | (0.085) |
| Δ External debt stocks | – | 0.038*** | 0.042** | 0.036*** |
| | | (0.012) | (0.018) | (0.011) |
| Δ Natural resource depletion | – | 0.018 | 0.022 | 0.016 |
| | | (0.018) | (0.024) | (0.016) |
| Δ GDP growth | – | −0.062*** | −0.068*** | −0.058*** |
| | | (0.018) | (0.024) | (0.016) |
| Observations | 402 | 402 | 402 | 402 |
| Hausman test (*p*-value) | | | *0.342* | *0.518* |

**Note(s):** PMG = Pooled Mean Group; MG = Mean Group; DFE = Dynamic Fixed Effects. Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Hausman test compares PMG to MG (or DFE); high *p*-values indicate failure to reject the long-run homogeneity restriction

**Source(s):** Author's computation using Stata 18 (2025)

international price assumptions and may not fully capture country-specific extraction costs or informal sector activity. As a partial check, Appendix Table A1 shows that the main patterns are broadly consistent when using gross savings and gross fixed capital formation as alternative wealth indicators, though these are not direct substitutes for the ANS concept.

Fifth, while the lag-based and instrumental variable approaches address some endogeneity concerns, we cannot rule out all sources of reverse causality or omitted variable bias. The estimated relationships should be interpreted as informative associations that are consistent with the Hartwick-ANS theoretical framework, rather than as definitive causal parameters.

## 6. Policy discussion: implications for the DIG framework

The DIG model enquires the interaction of the decision regarding resource extraction with investment options and long-run debt accretion. The empirical results provide the African economies with concrete quantitative content to this question.

Debt stock management is the major lever. External debt stocks are the most stable and strong predictor of servicing burdens for all the estimators and both the metrics. Strategies targeting the terms, maturity profile and currency composition of external liabilities, e.g. maturity extension, proactive liability management, limits on non-concessional borrowing during commodity upswings and strengthening debt transparency regimes are likely to dominate marginal reforms elsewhere. The long-drawn G20 Common Framework

**Table 6.** Robustness to lagged explanatory variables

| Variable | Baseline | 1-Year lag | 2-Year lag |
|---|---|---|---|
| *Panel A: TDS/Exports* | | | |
| Natural resource depletion | 0.441** | 0.428** | 0.398* |
| | (0.188) | (0.192) | (0.208) |
| Adjusted net savings | −0.286* | −0.298* | −0.312* |
| | (0.162) | (0.168) | (0.182) |
| Natural resource rents | −0.044 | −0.052 | −0.068 |
| | (0.098) | (0.102) | (0.112) |
| *Panel B: TDS/GNI* | | | |
| Natural resource depletion | 0.188 | 0.172 | 0.156 |
| | (0.142) | (0.148) | (0.158) |
| Adjusted net savings | −0.224** | −0.238** | −0.252** |
| | (0.098) | (0.104) | (0.112) |
| Natural resource rents | −0.168** | −0.178** | −0.192** |
| | (0.074) | (0.078) | (0.084) |

**Note(s):** PMG long-run coefficients reported. Controls included but not shown. Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. The persistence of coefficient signs and magnitudes across lag structures supports the interpretation of wealth depletion as a leading determinant of debt-service burdens rather than a contemporaneous correlate or reverse-causal outcome

**Source(s):** Author's computation using Stata 18 (2025)

**Table 7.** Sub-sample analysis by resource type and debt history

| Variable | Oil exporters | Mineral exporters | HIPC countries | Non-HIPC |
|---|---|---|---|---|
| *Panel A: TDS/Exports (PMG Long-run)* | | | | |
| External debt stocks | 0.312*** | 0.284*** | 0.328*** | 0.268*** |
| Natural resource depletion | 0.518** | 0.362* | 0.488** | 0.392* |
| Adjusted net savings | −0.328* | −0.248 | −0.312* | −0.262 |
| Governance index | −0.298** | −0.382*** | −0.268** | −0.412*** |
| Observations | 168 | 153 | 224 | 181 |
| *Panel B: TDS/GNI (PMG Long-run)* | | | | |
| External debt stocks | 0.124*** | 0.098*** | 0.132*** | 0.098*** |
| Natural resource depletion | 0.228 | 0.148 | 0.212 | 0.162 |
| Adjusted net savings | −0.268** | −0.188* | −0.248** | −0.198* |
| Natural resource rents | −0.198** | −0.142* | −0.182** | −0.158* |
| Observations | 165 | 151 | 222 | 180 |

**Note(s):** Oil exporters: Algeria, Angola, Cameroon, Chad, Egypt, Gabon, Nigeria. Mineral exporters: Botswana, DRC, Ghana, South Africa, Tanzania, Zambia. HIPC countries: Cameroon, Chad, Côte d'Ivoire, DRC, Ghana, Tanzania, Uganda, Zambia. The main coefficient patterns are broadly consistent across sub-samples, though magnitudes vary. The depletion effect is larger for oil exporters, consistent with the greater fiscal dependence on exhaustible resources. The governance effect is stronger for mineral exporters, possibly reflecting the more concentrated nature of mineral extraction and associated governance challenges

**Source(s):** Author's computation using Stata 18 (2025)

negotiations in the Zambia and Ghana examples show how expensive it is for stock management to be delayed once debt distress is acute.

Growth is an important short-run relief mechanism. The consistently negative short-run growth effects imply that policies for stabilising output and export capacity provide near-term

debt service relief. However, the feedback is two-way since high servicing burdens depress growth through fiscal compression and crowd out investment. The results of error correction show that this adjustment is within a year, so spending gets crunched before investment produces returns. Preservation of productive investment in times of adjustment is not a luxury but a fiscal survival need in the DIG prism.

Governance is important where the external constraint is binding. The export-denominated results show reduced pressure to debt service by institutions through channels to improve performance of tradables and enhance the efficiency of investment and financing terms. In DIG terms, it is not digging itself that is determining servicing capacity but the disciplined nature of the investing and export enhancing, which is fundamentally institutional.

Resource rents are a long-run cushion but it a short-run risk if they are pro-cyclical. The negative association between rents and income-based servicing in the long run is consistent with some form of fiscal capacity effect. Yet the lack of strong contemporaneous effects using Driscoll Kraay estimation indicates that rent dependence alone is not immediately servicing. The policy implication is to empower stabilisation institutions that are pegged to the NRPB, sovereign wealth funds and countercyclical buffers to ensure that the abundance of resources is translated into resilience as opposed to volatility-induced borrowing.

## 7. Conclusion

This study examined the debt-service burden of Africa in the DIG perspective as a test that resource dependence, sustainability capacity, the quality of governance and macroeconomic performance determine servicing pressures related to external indebtedness. The analysis uses a tiered econometric strategy and a panel of 16 African economies based on approximately 420 observations to come up with three findings.

The debt-service burden faced by Africa is essentially stock-based. External debt stocks are always positive and accurately estimated among all estimators and the two dependent variables. The PMG long-run coefficients affirm that servicing pressure is pegged on the net of accumulated liabilities as opposed to existing borrowing flows, which provide some quantitative substance to the owe ingredient of DIG.

Growth and institutions also work in denominator-specific manners on the repayment capacity. In the short-run, GDP growth always slashes the debt service. The quality of governance is most significant in cases where service is satisfied in terms of exports, and it is said that institutions alleviate the external pressure with the help of tradables performance and investment efficiency. These findings will help understand the step of investing in DIG: It is not the extent of how much countries are borrowing but turn borrowing and national capabilities into productive capacity that supports repayment.

Depletion and sustainability proxies have a long-run indirect role. The rents on resources are not strong predictors of export-based service in the static panels and minimise long-run service in comparison with GNI in the PMG findings. ANS is only significant in the income-based long-run specification. These trends together establish the fact that the channel of joining the diggers influences the debt stresses not as much by the direct impact of rent flows on them but by the interaction of rents with institutions, borrowing behaviour and macroeconomic volatility.

In the case of research, the findings encourage extensions which permit long-run heterogeneity between debt regimes and resource types and explicitly represent non-linearities in the resource-debt nexus. In the case of policy, they give priority to the prudent management of debt stocks, reforms in governance to increase the ratio of investment to export conversion and countercyclical fiscal anchors.

**Supplementary material**

The supplementary material for this article can be found online.

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