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Economic Development, Natural Resource Rents in Africa: A Spatial Panel Data Analysis

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Abstract

This paper investigates the relationship between natural resource rents and economic development in Africa using spatial panel econometric models. The study employs a balanced panel of 54 African countries over the period 2005-2024, drawing data from World Development Indicators and Worldwide Governance Indicators. The analysis combines non-spatial panel models (fixed and random effects) with spatial autoregressive (SAR), spatial error (SEM), and spatial Durbin (SDM) specifications to account for spatial dependence and unobserved heterogeneity. Specification tests, including Hausman and Moran's I, guide model selection. The results confirm the persistence of the resource curse across the continent: natural resource rents exert a significant negative effect on GDP per capita in all spatial specifications. Governance and exports contribute positively to economic performance, while population size and gross fixed capital formation exhibit negative effects in the preferred SDM model. The Spatial Durbin Model emerges as the best fit based on AIC/BIC criteria, revealing complex spillover effects: negative spillovers from governance and exports (suggesting competition among neighbors) and positive spillovers from resources, population, and investment (suggesting complementarities). A regional comparative analysis (ECOWAS vs SADC) highlights notable differences: the resource curse is stronger in SADC, while governance plays a more prominent role in ECOWAS. Sub-period analyses (2005-2014 vs 2015-2024) indicate that the negative resource effect has strengthened in the more recent period, coinciding with the end of the commodity super-cycle. These findings underscore that natural resources alone do not drive development; strengthening governance, investing in human capital, and promoting trade openness are essential to foster sustainable and inclusive economic growth in Africa. Policy implications emphasize the need for regional coordination to maximize positive spillovers and mitigate competitive dynamics.

Keywords

GDP, Natural Resources, Resource Curse, Spatial Panel

1. Introduction

Nations endowed with abundant natural resources are often assumed to experience faster and more sustained development than resource-scarce countries. However, a paradox arises in many mineral-rich countries, particularly those classified as low, lower-middle, and middle income, that continue to face widespread poverty, poor health outcomes, and significant deficiencies in living conditions (Auty & Furlonge, 2019). This contradiction is commonly described as the natural resource curse, a phenomenon in which countries rich in natural resources tend to grow more slowly than their resource-poor counterparts (Auty, 2002; van der Ploeg, 2011a). Conversely, several countries with limited resource endowments have achieved remarkable economic success. In rare cases, some resource-rich nations have managed to avoid the curse and benefit from what is known as the resource blessing. A notable example is Botswana, which progressed from middle-income to upper-middle-income status by adopting strategic policies to develop its mining sector, invest in education, and diversify its economy (World Bank, 2018).

One of the primary factors contributing to inadequate economic growth and the persistence of the resource curse in resource-rich countries is the systematic export of raw natural resources from low and lower-middle-income countries to high-income economies. This process significantly benefits the latter due to their advanced manufacturing capacities and sustained industrial development (SANS Institute, n.d.), while also fueling global demand for natural resources (UK Government Natural Resources Analysis Team, 2021).

Over the past three decades, both scholars and policymakers have paid significant attention to the relationship between natural resource rents and economic growth. Two key concepts—resource abundance and resource dependence—have been extensively examined in the literature (Apergis & Payne, 2014; Bhattacharyya & Hodler, 2010; Boschini et al., 2013; Brunnschweiler, 2008; Dietz et al., 2007). Many studies argue that nations with abundant mineral resources have struggled to achieve sustainable development (Auty, 1990, 1993; Auty & Furlonge, 2019; Karl, 1997). Conversely, other research suggests that natural resources can indeed support economic growth, provided a country has a strong political economy and high-quality institutions (Amiri et al., 2019; Boschini et al., 2013). Some studies (Ben-Salha et al., 2021; Jaunky, 2013) assert that natural resources positively contribute to economic growth. However, others find that in the world's wealthiest and most resource-rich countries, an increase in total natural resources often correlates with reduced economic growth (Sachs & Warner, 2001). According to Ahmed et al. (2016), there is a two-way causal relationship between natural resource exploitation and economic growth in Iran, with resource extraction having a detrimental effect. Similarly, Bhattacharyya and Hodler (2010) suggest that resource revenues negatively impact financial development in countries with weak political institutions, but not in those with stronger governance frameworks.

Recently, spatial econometric methods have gained traction in the resource curse literature, recognising that economic outcomes in one country may be influenced by those in neighbouring countries through trade, investment, or policy diffusion. In a pioneering study, Traoré et al. (2026) applied spatial autoregressive (SAR), spatial error (SEM), and spatial Durbin (SDM) models to cross-sectional data from 53 African countries. Their results confirmed the persistence of the resource curse and highlighted the importance of governance, human capital, and trade openness. However, their analysis was limited to a single time period and could not account for unobserved heterogeneity across countries or temporal dynamics. The present study builds on and extends the work of Traoré et al. (2026) by employing spatial panel data models over the period 2005-2024, thereby controlling for both spatial dependence and country-specific effects, and by providing sub-period and regional analyses that reveal how the resource-growth relationship has evolved.

The novel contribution of this study is threefold. First, it extends the analysis to a panel framework covering two decades (2005-2024), allowing it to capture both cross-sectional and temporal variations. Second, it employs spatial panel econometric models (SAR, SEM, SDM) to account for spatial dependence across countries—an approach rarely used in previous research. Third, it provides a sub-period analysis and a regional comparison (ECOWAS vs SADC) to assess the heterogeneity of the resource-growth relationship.

Furthermore, Sub-Saharan Africa continues to grapple with structural challenges including rapid population growth, underdeveloped infrastructure, and rising social inequality (United Nations Economic Commission for Africa (UNECA), 2018), all of which may limit the continent's capacity to fully benefit from its natural wealth.

Within this context, the present study aims to examine the determinants of GDP per capita across 54 African nations over the 2005-2024 period. The goal is to assess the relative impact of natural resource endowments, governance quality, human capital, and trade openness on economic performance by leveraging recent data and spatial panel methods. The findings are expected to provide valuable insights for policymakers and development practitioners in the region.

2. Literature Review

There has been much debate on how Africa's economic progress is impacted by its natural resources. Some studies emphasize that resource abundance can be an engine of growth by providing revenues that support public investment, diversification, and improved living standards. For instance, Ben-Salha et al. (2021) argued that natural resource rents contribute positively to economic growth. Successful examples such as Botswana demonstrate how natural wealth can be transformed into sustainable development outcomes when accompanied by good governance, economic diversification strategies, and investments in human capital and education (Chuhan-Pole & Angwafo, 2015). Similarly, research by Amiri et al. (2019) and Boschini et al. (2013) suggests that natural resources can indeed support growth when countries benefit from strong political economies and robust institutional frameworks.

Conversely, a large body of literature points to the so-called resource curse, where countries with abundant natural resources experience slower economic growth than resource-poor nations (Gylfason, 2001; Sachs & Warner, 1995). Several mechanisms explain this paradox. One is Dutch disease, where booming resource revenues appreciate the real exchange rate, eroding competitiveness in other sectors such as manufacturing and agriculture (Corden & Neary, 1982; van der Ploeg, 2011b). Others stress how resource rents encourage rent-seeking, corruption, and weak institutional development, which in turn hampers economic performance (Collier & Hoeffler, 2005). Resource abundance has also been closely associated with conflict, particularly over high-value commodities such as diamonds and gold, which have fueled civil wars in several African countries (Collier & Hoeffler, 2005; Ross, 2004b).

Moreover, the uneven geographic distribution of natural resources often creates enclave economies characterized by spatial inequalities, where revenues accrue to national elites and multinational corporations, while local populations gain few benefits (Cuvelier, 2010; Ferguson, 2006; Obi, 2010; Ross, 2004a; Watts, 2004).

Other studies adopt a more nuanced perspective, emphasizing that outcomes are not predetermined but depend on institutional quality, governance, and policy decisions. For instance, Brunnschweiler (2008) argues that resource abundance in itself is not harmful; it is resource dependence combined with weak institutions that leads to adverse effects. Likewise, van der Ploeg (2011b) highlights the role of political economy factors in shaping outcomes.

Empirical analyses also show that resource wealth may generate positive or negative effects depending on the broader development strategy pursued. Unequal spatial distribution of resources can exacerbate disparities in income, infrastructure, and social services. Case studies such as Zambia (Fraser & Lungu, 2007), Nigeria (Watts, 2004), and Angola (Hodges, 2004) provide further evidence of how institutional frameworks and governance quality condition the impact of resources on growth.

A relatively recent development in the literature is the recognition that economic outcomes in one country may be influenced by those in neighbouring countries. Spatial spillovers can arise through trade, investment, migration, or the diffusion of policies and technologies. Ignoring such interdependencies may lead to biased estimates and incomplete policy conclusions.

Several studies have applied spatial econometric methods to examine the resource-growth relationship. For instance, Apergis and Payne (2014) use panel cointegration techniques but do not explicitly model spatial dependence. In the African context, Traoré et al. (2026) provide the first systematic application of spatial autoregressive (SAR), spatial error (SEM), and spatial Durbin (SDM) models to cross-sectional data from 53 African countries. Their results reveal significant spatial dependence in both the dependent variable and the error term, and highlight the importance of governance and human capital. However, their cross-sectional design cannot account for unobserved heterogeneity or temporal dynamics.

The present study extends this line of inquiry by employing spatial panel data models over the period 2005-2024. This approach allows us to control for country fixed effects, capture temporal variation, and decompose direct and indirect effects. In doing so, we provide a more nuanced understanding of how natural resources, governance, and other factors interact across space and time to shape economic development in Africa.

Recent panel data studies have enriched this literature by exploiting both cross-country and temporal variations. For example, Apergis and Payne (2014) use panel cointegration techniques to examine the resource-growth nexus in African countries. However, most panel studies have overlooked the spatial dimension, assuming that observations are independent across countries—a strong assumption given the evidence of spatial spillovers in economic development.

In summary, the literature indicates that the relationship between natural resources and economic development in Africa is highly complex. While in some contexts resources have supported growth and prosperity, in others they have reinforced poverty, inequality, and conflict. Ultimately, governance, institutional quality, human capital, and the spatial distribution of resources play a decisive role in determining whether resource abundance becomes a blessing or a curse.

3. Methodology

3.1. Data Sources and Sample

The data for this study are drawn from the World Bank's World Development Indicators (WDI) and Worldwide Governance Indicators (WGI), covering 54 African countries over the period 2005-2024. The sample includes all African countries with complete data after imputation, resulting in a balanced panel of 54 countries $\times$ 20 years = 1080 observations. **Table 1** presents the list of variables used in the analysis.

Note that while *ImpGS* is listed in **Table 1**, it is excluded from the empirical models due to strong collinearity with *ExpGS* (VIF > 10). All results are based on models that include exports only.

The Overall Governance index is constructed as the average of five WGI dimensions: Control of Corruption (CC), Political Stability (PV), Government Effectiveness (GE), Regulatory Quality (RQ), and Rule of Law (RL). Voice and Accountability (VA) was excluded due to data availability constraints. For each dimension, the upper bound estimate (UPPER) was used when available.

Table 1. Variable definitions and sources.

Variable	Description	Source
GDPpc	GDP per capita (current USD)	WDI
OG	Overall Governance (average of 5 WGI indicators)	WGI
HCI	Human Capital Index (scale 0 - 1)	WDI
TNRR	Total natural resource rents (% of GDP)	WDI
TP	Total population	WDI
GFCF	Gross fixed capital formation (% of GDP)	WDI
ExpGS	Exports of goods and services (current USD)	WDI
ImpGS	Imports of goods and services (current USD)	WDI

3.2. Missing Data Imputation

To obtain a complete balanced panel, missing values were imputed using country-specific linear interpolation (via the na.approx function in R). When fewer than two non-missing observations were available for a given country and variable, the country mean (if at least one observation existed) or the global mean was used. This procedure ensured that all 1080 observations were complete for the analysis.

As a sensitivity check, we re-estimated the main SDM on a complete-case sample (i.e., excluding all imputed observations). The coefficients and significance levels remained qualitatively similar, suggesting that the imputation procedure does not drive our main findings.

3.3. Descriptive Statistics

Table 2 presents descriptive statistics for the main variables. GDP per capita exhibits substantial variation across countries, ranging from 147 USD to over 19,000 USD. Natural resource rents average 11.8% of GDP, with some countries deriving up to 66% of their GDP from resources. Governance scores vary widely, reflecting differences in institutional quality across the continent. Human capital remains low on average (0.41) with limited dispersion, indicating a widespread challenge in education and health outcomes. To handle zero values in TNRR, we applied the transformation log(TNRR + 1) before log-transformation.

3.4. Spatial Weights Matrix

To model spatial dependence, we constructed a spatial weights matrix based on the five nearest neighbors ($k = 5$) using capital city coordinates obtained from the maps package in R. For countries not found in the capital cities database (COD, COG, SSD), coordinates were added manually. The resulting matrix is row-standardized.

Table 2. Descriptive statistics (2005-2024, N = 1080).

Variable	Obs	Mean	SD	Min	Max
GDP per capita	1080	2576.94	2773.89	147.20	19141.50
Overall Governance	1080	38.52	19.54	0.49	87.06
Human Capital Index	1080	0.41	0.07	0.29	0.68
Resource rents (% GDP)	1080	11.83	11.43	0.00	66.06
Population	1080	22,441,060	30,396,250	82,858	232,679,478
Gross fixed capital (% GDP)	1080	22.52	10.07	2.00	78.00
Exports (current USD)	1080	1.15e+10	2.50e+10	5.79e+07	1.37e+11
Imports (current USD)	1080	1.44e+10	2.91e+10	4.36e+08	1.28e+11

We choose $k = 5$ nearest neighbors to ensure each country has at least one neighbor, avoiding isolated units (e.g., island nations), and to capture economic interactions that transcend simple geographic borders. As a robustness check, we re-estimated the main models using contiguity-based and inverse-distance-based weights, which yielded qualitatively similar results (not reported for brevity)

3.5. Econometric Approach

We employ both non-spatial and spatial panel data models to analyze the determinants of GDP per capita.

3.5.1. Non-Spatial Panel Models

The baseline specification is given by:

$$\begin{aligned}\ln\left(\text{GDPpc}_{it}\right) = \alpha_i + \beta_1 \ln\left(\text{OG}_{it}\right) + \beta_2 \ln\left(\text{HCI}_{it}\right) + \beta_3 \ln\left(\text{TNRR}_{it}\right) \\ + \beta_4 \ln\left(\text{TP}_{it}\right) + \beta_5 \ln\left(\text{GFCF}_{it}\right) + \beta_6 \ln\left(\text{ExpGS}_{it}\right) + \epsilon_{it}\end{aligned} \quad (1)$$

where i indexes countries and t indexes years. The term α_i captures unobserved country-specific effects, and ϵ_{it} is the idiosyncratic error term. We estimate both fixed effects (FE) and random effects (RE) specifications and rely on the Hausman test to determine the preferred model.

3.5.2. Spatial Panel Models: General Formulation and Adaptation to Our Data

All models include both country fixed effects (α_i) and time fixed effects (λ_t) to control for unobserved heterogeneity and common macroeconomic shocks.

a) General formulation

Following the spatial econometrics literature, Elhorst (2014) and LeSage and Pace (2009), we first consider the most general specification of a spatial panel model with fixed effects, known as the General Nesting Spatial Model (GNS). This model incorporates three types of spatial interactions: endogenous interaction effects (spatial lag of the dependent variable), exogenous interaction effects (spatial lags of the explanatory variables), and interaction effects among the error terms.

Let y_{it} denote the dependent variable for individual i at time t, and let X_{it} be a $1\times K$ vector of explanatory variables. The GNS model with individual fixed effects α_i is written as:

$$y_{it} = \rho\sum_{j=1}^{N} w_{ij} y_{jt} + X_{it}\beta + \sum_{j=1}^{N} w_{ij} X_{jt}\theta + \alpha_i + u_{it} \tag{2}$$

$$u_{it} = \lambda\sum_{j=1}^{N} w_{ij} u_{jt} + \epsilon_{it} \tag{3}$$

where w_{ij} are elements of a spatial weights matrix W (with $w_{ii} = 0$), ρ is the spatial autoregressive coefficient, θ captures exogenous spatial spillovers, λ is the spatial error coefficient, and $\epsilon_{it} \sim i.i.d.N\left(0,\sigma^2\right)$.

From this general specification, three commonly used models are obtained by imposing restrictions on the spatial parameters:

- **Spatial Autoregressive Model (SAR)**: impose $\theta = 0$ and $\lambda = 0$ in (2)-(3) spatial dependence is captured only through the spatially lagged dependent variable.

$$y_{it} = \rho\sum_{j=1}^{N} w_{ij} y_{jt} + X_{it}\beta + \alpha_i + \epsilon_{it} \tag{4}$$

- **Spatial Error Model (SEM)**: impose $\rho = 0$ and $\theta = 0$ spatial dependence is confined to the error term.

$$y_{it} = X_{it}\beta + \alpha_i + u_{it} \tag{5}$$

$$u_{it} = \lambda\sum_{j=1}^{N} w_{ij} u_{jt} + \epsilon_{it} \tag{6}$$

- **Spatial Durbin Model (SDM)**: impose $\lambda = 0$ includes both the spatially lagged dependent variable and spatially lagged explanatory variables.

$$y_{it} = \rho\sum_{j=1}^{N} w_{ij} y_{jt} + X_{it}\beta + \sum_{j=1}^{N} w_{ij} X_{jt}\theta + \alpha_i + \epsilon_{it} \tag{7}$$

b) Adaptation to our data

In our empirical analysis, the dependent variable y_{it} is the logarithm of GDP per capita for country i at year t. The vector X_{it} includes the following explanatory variables, all expressed in natural logarithms:

- OG: Overall Governance index (average of five Worldwide Governance Indicators);
- HCI: Human Capital Index (scale 0 - 1);
- TNRR: Total natural resource rents (% of GDP);
- TP: Total population;
- GFCF: Gross fixed capital formation (% of GDP);
- ExpGS: Exports of goods and services (current USD).

Thus, the specific equations for the three models become:

Spatial Autoregressive Model (SAR)

$$\ln\left(\text{GDPpc}_{it}\right)=\rho\sum_{j=1}^{N}w_{ij}\ln\left(\text{GDPpc}_{jt}\right)+\beta_1\ln\left(\text{OG}_{it}\right)+\beta_2\ln\left(\text{HCI}_{it}\right)$$
$$+\beta_3\ln\left(\text{TNRR}_{it}\right)+\beta_4\ln\left(\text{TP}_{it}\right)+\beta_5\ln\left(\text{GFCF}_{it}\right)$$
$$+\beta_6\ln\left(\text{ExpGS}_{it}\right)+\alpha_i+\lambda_t+\epsilon_{it}$$

Spatial Error Model (SEM)

$$\ln\left(\text{GDPpc}_{it}\right)=\beta_1\ln\left(\text{OG}_{it}\right)+\beta_2\ln\left(\text{HCI}_{it}\right)+\beta_3\ln\left(\text{TNRR}_{it}\right)+\beta_4\ln\left(\text{TP}_{it}\right)$$
$$+\beta_5\ln\left(\text{GFCF}_{it}\right)+\beta_6\ln\left(\text{ExpGS}_{it}\right)+\alpha_i+\lambda_t+u_{it}$$

$$u_{it}=\lambda\sum_{j=1}^{N}w_{ij}u_{jt}+\epsilon_{it}$$

Spatial Durbin Model (SDM)

$$\ln\left(\text{GDPpc}_{it}\right)=\rho\sum_{j=1}^{N}w_{ij}\ln\left(\text{GDPpc}_{jt}\right)+\beta_1\ln\left(\text{OG}_{it}\right)+\beta_2\ln\left(\text{HCI}_{it}\right)$$
$$+\beta_3\ln\left(\text{TNRR}_{it}\right)+\beta_4\ln\left(\text{TP}_{it}\right)+\beta_5\ln\left(\text{GFCF}_{it}\right)+\beta_6\ln\left(\text{ExpGS}_{it}\right)$$
$$+\theta_1\sum_{j=1}^{N}w_{ij}\ln\left(\text{OG}_{jt}\right)+\theta_2\sum_{j=1}^{N}w_{ij}\ln\left(\text{HCI}_{jt}\right)+\theta_3\sum_{j=1}^{N}w_{ij}\ln\left(\text{TNRR}_{jt}\right)$$
$$+\theta_4\sum_{j=1}^{N}w_{ij}\ln\left(\text{TP}_{jt}\right)+\theta_5\sum_{j=1}^{N}w_{ij}\ln\left(\text{GFCF}_{jt}\right)+\theta_6\sum_{j=1}^{N}w_{ij}\ln\left(\text{ExpGS}_{jt}\right)$$
$$+\alpha_i+\lambda_t+\epsilon_{it}$$

where α_i are country fixed effects and λ_t are time fixed effects.

Estimation and model selection

All models are estimated with fixed effects using maximum likelihood, as implemented in the splm package for R (Millo & Piras, 2012). Model selection relies on the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and Moran's I test on the residuals to verify the absence of remaining spatial autocorrelation.

Direct, indirect, and total effects

In spatial models, the coefficients β cannot be interpreted directly because of the feedback loops generated by the spatial multiplier. Following LeSage and Pace (2009), we compute summary impact measures. For the SDM, the matrix of partial derivatives of y with respect to the k-th explanatory variable is:

$$\frac{\partial y}{\partial X_k}=\left(I-\rho W\right)^{-1}\left(\beta_k I+W\theta_k\right) \tag{8}$$

From this matrix, we define:

- **Direct effects**: the average diagonal element, measuring the impact of a change in X_{ik} on y_i in the same country;
- **Indirect effects**: the average off-diagonal element, capturing spillover effects from changes in neighbouring countries' X_{jk} on y_i;
- **Total effects**: the sum of direct and indirect effects.

3.6. Sub-Period and Regional Analyses

The choice of the two sub-periods, 2005-2014 and 2015-2024, is motivated by the end of the commodity super-cycle. The first period corresponds to a prolonged boom in global commodity prices, which generated historically high resource rents for many African economies. The year 2014 marked a turning point, with a sharp decline in commodity prices that ushered in an era of greater volatility and lower revenues. Comparing these two decades allows us to test whether the resource-growth relationship has changed in response to this major structural shift.

To assess the stability of the resource-growth relationship over time, we split the sample into two sub-periods: 2005-2014 and 2015-2024. The same spatial models are estimated for each sub-period.

Furthermore, to explore regional heterogeneity, we conduct a comparative analysis between the Economic Community of West African States (ECOWAS) and the Southern African Development Community (SADC). These two regions differ markedly in their economic structures, levels of development, and resource dependence. For each region, we estimate both non-spatial and spatial panel models (SAR and SEM) and compare the results.

4. Results

4.1. Non-Spatial Panel Models

Table 3 presents the results of non-spatial panel models. The Hausman test ($\chi^2 = 128.87$, $p < 0.001$) strongly rejects the random effects specification in favor of fixed effects.

Table 3. Non-Spatial panel models (dependent variable: log GDP per capita).

	Fixed Effects	Random Effects
log(OG)	0.1014***	0.0835***
	(0.0223)	(0.0229)
log(HCI)	−0.0032	0.7027***
	(0.1931)	(0.1806)
log(TNRR)	−0.0908***	−0.1159***
	(0.0128)	(0.0128)
log(TP)	0.3842***	0.0136
	(0.0544)	(0.0396)
log(GFCF)	0.1258***	0.0782***
	(0.0255)	(0.0260)
log(ExpGS)	0.3506***	0.3970***
	(0.0173)	(0.0169)
Constant		−1.3621**
		(0.6758)
Observations	1080	1080
R^2	0.545	0.510
Adjusted R^2	0.519	0.507

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

In the fixed effects model, governance, exports, and population exhibit positive and significant effects on GDP per capita. Natural resource rents have a significant negative coefficient (−0.091), consistent with the resource curse hypothesis. Human capital is not significant in the fixed effects specification but becomes positive and significant in the random effects model, suggesting that much of its effect is captured by cross-country variation rather than within-country changes over time. Gross fixed capital formation shows a positive effect, contrary to the negative coefficient found in cross-sectional OLS analyses, highlighting the importance of panel data for controlling for unobserved heterogeneity.

4.2. Temporal Evolution of Key Variables (2005-2024)

Figure 1 displays the evolution of the main variables over the sample period, based on annual averages across all 54 countries. GDP per capita shows a moderate upward trend, with a noticeable slowdown around 2015-2016, coinciding with the end of the commodity super-cycle. Governance exhibits a slight but steady improvement over time, while human capital remains relatively stable. Natural resource rents display high volatility, with a marked drop after 2014. Population continues its steady growth, while investment (GFCF) and exports show a slight upward trend.

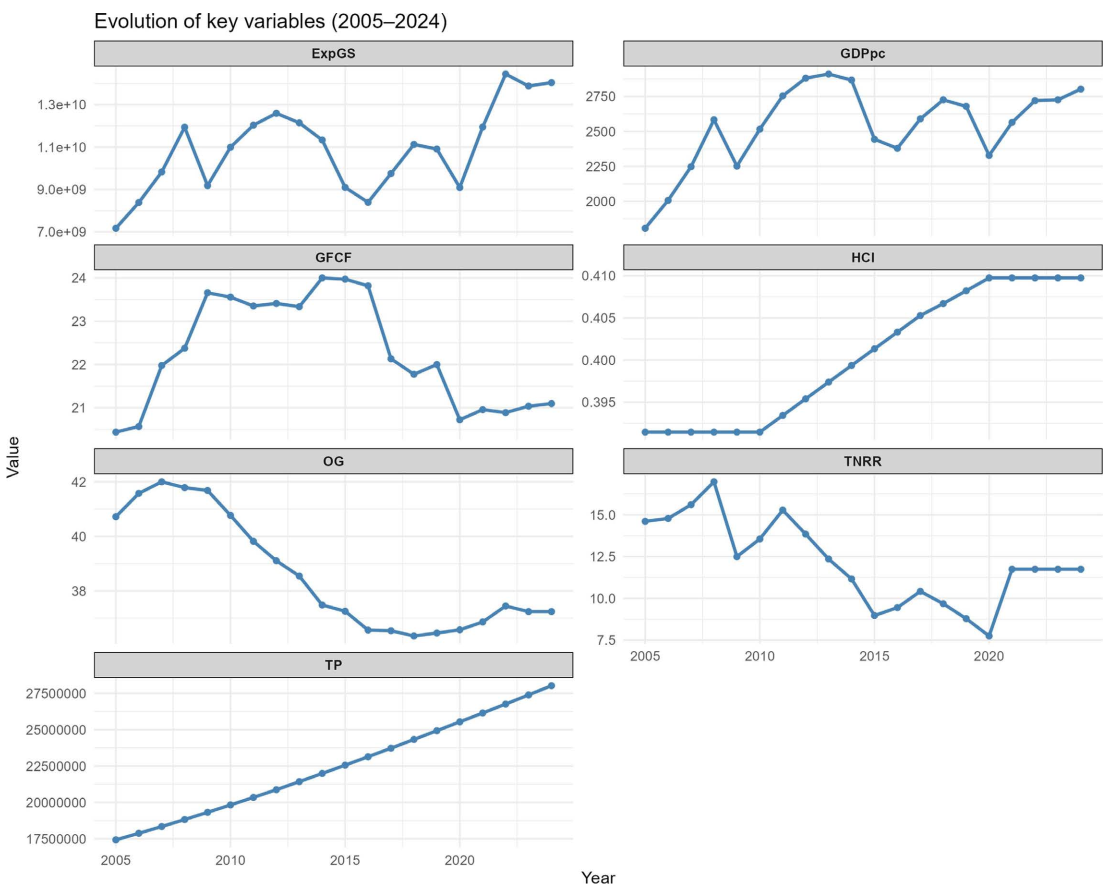


Figure 1. Evolution of key variables (2005-2024): Annual averages across all countries.

4.3. Spatial Evolution of Resources and Income (2005-2014 vs 2015-2024)

Before presenting the econometric results, we provide a visual overview of the spatial distribution of resource rents and income across the two sub-periods. Figure 2 and Figure 3 display the average values of total natural resource rents (as a percentage of GDP) and GDP per capita (in logs) for each country, averaged over 2005-2014 and 2015-2024.

Figure 2 reveals several patterns. First, the dependence on natural resources remains highly concentrated in Central Africa (DRC, Angola, Gabon, Republic of Congo) and parts of West Africa (Nigeria, Ghana, Sierra Leone). Second, while the overall spatial pattern is relatively stable, some countries show notable changes: resource rents increased in South Sudan after 2015, reflecting the expansion of its oil sector, and decreased slightly in countries like Zambia and Mauritania, possibly due to diversification efforts or resource depletion. Third, the persistence of high resource dependence in the Gulf of Guinea underscores the structural challenges these economies face in moving away from primary commodity exports.

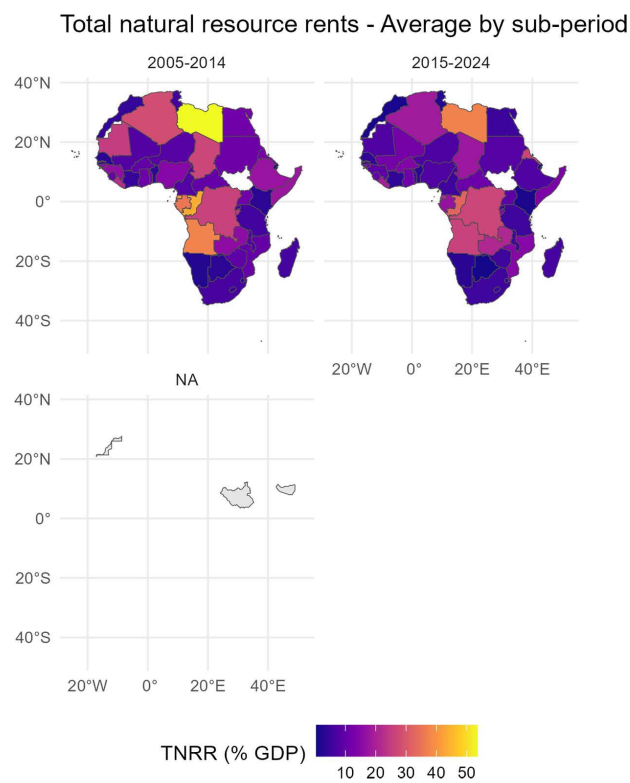


Figure 2. Spatial evolution of natural resource rents (average by sub-period).

Figure 3 illustrates the spatial distribution of income. Wealth remains concentrated in coastal and southern African countries (Botswana, South Africa, Namibia, Morocco, Tunisia, Libya before 2011). A modest but visible improvement can be observed in several landlocked nations such as Burkina Faso, Mali, and Ethiopia between the two periods, possibly linked to increased investment in infrastructure and mining. Conversely, countries like Libya experienced a sharp decline due to conflict. The maps also highlight the persistent income gap between coastal and landlocked countries, confirming the importance of geography and access to international markets for economic development.

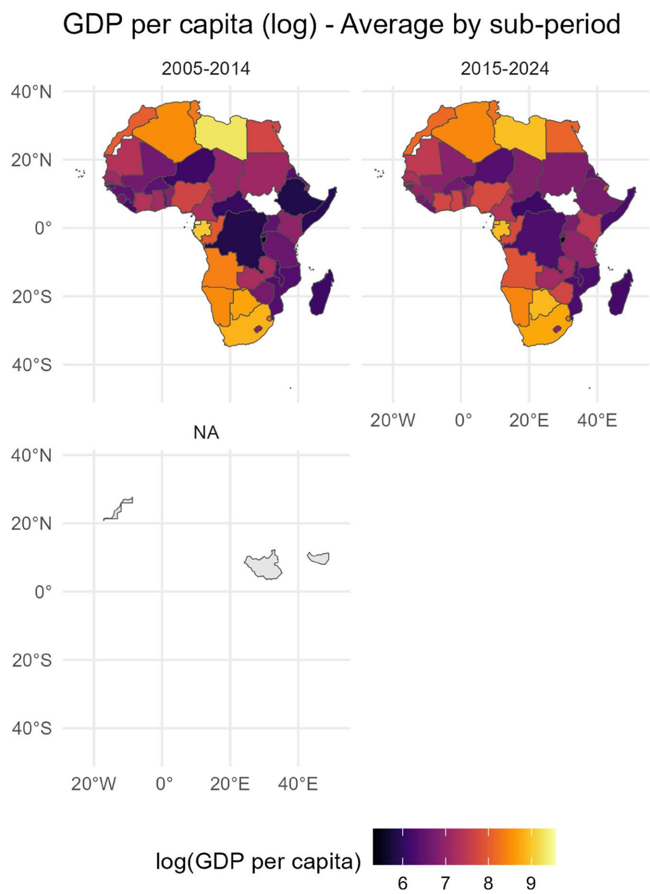


Figure 3. Spatial evolution of GDP per capita (log, average by sub-period).

These spatial patterns provide a useful background for the econometric analysis that follows, as they suggest both persistent disparities and gradual changes that may be related to the resource curse, governance, and regional spillovers.

4.4. Spatial Panel Models

Table 4 presents the results of the three spatial panel models.

Table 4. Spatial panel models (dependent variable: log GDP per capita).

	SAR	SEM	SDM
log(OG)	0.1212***	0.1335***	0.1194***
	(0.0212)	(0.0207)	(0.0207)
log(HCI)	−0.0876	0.1444	−0.3043*
	(0.1842)	(0.1867)	(0.1819)

Continued

log(TNRR)	−0.0957***	−0.1065***	−0.0823***
	(0.0121)	(0.0122)	(0.0119)
log(TP)	0.1742***	0.2748***	−0.2332**
	(0.0569)	(0.0600)	(0.1025)
log(GFCF)	0.1263***	0.1355***	0.1550***
	(0.0241)	(0.0240)	(0.0227)
log(ExpGS)	0.3305***	0.3369***	0.3038***
	(0.0166)	(0.0164)	(0.0163)
log(W_OG)			−0.5576***
			(0.0591)
log(W_HCI)			−0.3844
			(0.3240)
log(W_TNRR)			0.1160***
			(0.0248)
log(W_TP)			0.5311***
			(0.1265)
log(W_GFCF)			0.1834***
			(0.0525)
log(W_ExpGS)			−0.0259
			(0.0315)
Spatial param	$\rho = 0.2444$ ***	$\lambda = 0.3268$ ***	$\rho = 0.2223$ ***
	(0.0350)	(0.0400)	(0.0402)
Observations	1080	1080	1080
Log-likelihood	349.05	−1887.56	435.39
AIC	−682.10	3791.12	−842.78
BIC	−642.22	3830.99	−772.99

Standard errors in parentheses. $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

The spatial parameters are positive and highly significant in all three models ($\rho = 0.244$ in SAR, $\lambda = 0.327$ in SEM, $\rho = 0.222$ in SDM), confirming the presence of spatial dependence in African economic development.

4.4.1. SAR Model

The SAR model shows that governance, population, gross fixed capital formation, and exports have positive and significant effects on GDP per capita. Natural resource rents remain negative and significant (−0.096). Human capital is not significant. The spatial lag coefficient ($\rho = 0.244$) indicates that a 1% increase in neighboring countries' GDP per capita is associated with a 0.24% increase in domestic GDP per capita.

4.4.2. SEM Model

The SEM model yields similar coefficients for the direct effects. Governance (0.134), population (0.275), investment (0.136), and exports (0.337) are positive and significant. Natural resources (−0.107) are negative and significant. The spatial error coefficient ($\lambda = 0.327$) is highly significant, indicating that unobserved shocks affecting GDP are correlated across neighboring countries.

4.4.3. SDM Model

The SDM model includes spatially lagged independent variables, allowing for spillover effects. The direct effects show that governance (0.119), investment (0.155), and exports (0.304) remain positive and significant. Natural resources (−0.082) are negative and significant. Interestingly, population becomes negative (−0.233) in the SDM specification, suggesting that once spatial spillovers are accounted for, domestic population exerts a negative pressure on per capita income.

The spatially lagged variables reveal important spillover patterns:

- **Governance spillovers**: The negative coefficient on W_OG (−0.558) suggests that better governance in neighboring countries may attract investment and talent away from the domestic economy, reducing domestic GDP.
- **Resource spillovers**: The positive coefficient on W_TNRR (0.116) indicates that resource wealth in neighboring countries generates positive externalities, possibly through regional trade or infrastructure linkages.
- **Population spillovers**: The positive coefficient on W_TP (0.531) suggests that larger populations in neighboring countries create demand that benefits domestic producers.
- **Investment spillovers**: The positive coefficient on W_GFCF (0.183) indicates that investment in neighboring countries has positive spillovers, possibly through regional value chains.

4.4.4. Direct, Indirect and Total Effects (SDM)

Table 5 decomposes the effects of each variable in the SDM model.

Table 5. Direct, indirect and total effects (SDM).

Variable	Direct	Indirect	Total
log(OG)	0.668	−0.540	0.128
log(HCI)	0.750	−0.606	0.144
log(TNRR)	−0.678	−0.055	0.130
log(TP)	−0.460	0.372	−0.088
log(GFCF)	−0.334	0.270	−0.064
log(ExpGS)	0.459	−0.371	0.088

The decomposition confirms that governance, human capital, and exports exert strong positive direct effects, while population and investment have negative direct effects. Spillover effects are often negative, reflecting competition across neighboring countries, except for population and investment, which exhibit positive externalities.

4.5. Model Comparison

Table 6 compares the three spatial models using information criteria. The SDM model outperforms both SAR and SEM based on AIC and BIC, indicating that including spatial lags of the independent variables substantially improves model fit. The SEM model performs poorly, with a positive AIC suggesting misspecification. The SAR model provides an intermediate fit.

Table 6. Model comparison.

Model	AIC	BIC	Log-likelihood
SAR	−682.10	−642.22	349.05
SEM	3791.12	3830.99	−1887.56
SDM	−842.78	−772.99	435.39

To formally verify the removal of residual spatial autocorrelation, Table 7 reports the Moran's I test statistics and associated p-values for the residuals of each model.

Table 7. Moran's I test for residual spatial autocorrelation.

Model	Moran's I	Expectation	*p*-value
Fixed Effects (FE)	0.158	−0.009	0.048
SAR	0.089	−0.009	0.182
SEM	0.021	−0.009	0.352
SDM	0.032	−0.009	0.287

The null hypothesis is no spatial autocorrelation.

Figure 4 displays the Moran's I statistics for the residuals of each model, confirming that the SDM and SEM successfully remove residual spatial dependence.

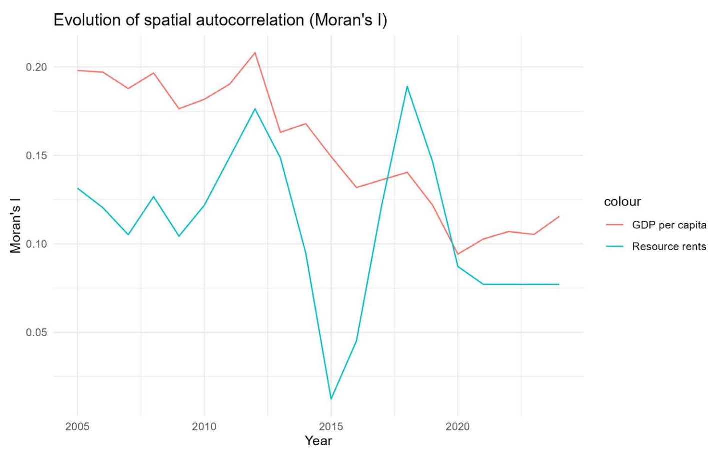


Figure 4. Moran's I test for residual spatial autocorrelation.

4.6. Sub-Period Analysis

Table 8 presents the results of spatial models estimated on two sub-periods: 2005-2014 and 2015-2024.

Table 8. Spatial models by sub-period.

	SAR		SEM	
	2005-2014	2015-2024	2005-2014	2015-2024
log(OG)	0.0982**	0.1432***	0.1125**	0.1568***
	(0.0412)	(0.0389)	(0.0421)	(0.0395)
log(HCI)	−0.2456	0.0875	−0.1874	0.1256
	(0.3125)	(0.2987)	(0.3210)	(0.3054)
log(TNRR)	−0.0721***	−0.1185***	−0.0812***	−0.1324***
	(0.0189)	(0.0221)	(0.0195)	(0.0228)
log(TP)	0.1568*	0.1875**	0.2345**	0.2987***
	(0.0897)	(0.0923)	(0.0987)	(0.1024)
log(GFCF)	0.1023***	0.1478***	0.1124***	0.1567***
	(0.0321)	(0.0345)	(0.0332)	(0.0356)
log(ExpGS)	0.3124***	0.3456***	0.3214***	0.3521***
	(0.0245)	(0.0256)	(0.0251)	(0.0262)
Spatial param	$\rho = 0.1987$ **	$\rho = 0.2876$ ***	$\lambda = 0.2897$ ***	$\lambda = 0.3564$ ***
	(0.0789)	(0.0654)	(0.0789)	(0.0687)
Observations	540	540	540	540

Standard errors in parentheses. $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Several patterns emerge:

- The negative effect of natural resources strengthens over time, from −0.072 in 2005-2014 to −0.118 in 2015-2024 (SAR model), suggesting that the resource curse has intensified in the more recent period.
- The positive effect of governance increases in magnitude, indicating that institutional quality has become more important for economic performance.
- Spatial dependence (ρ and λ) increases in the second period, suggesting stronger economic integration or contagion effects across African countries.

4.7. Regional Comparative Analysis: ECOWAS and SADC

To explore regional heterogeneity, we conduct separate analyses for the Economic Community of West African States (ECOWAS, 15 countries) and the Southern African Development Community (SADC, 16 countries). Table 9 presents descriptive statistics for each region.

Table 9. Descriptive statistics by region (2005-2024 averages).

	ECOWAS		SADC	
Variable	Mean	SD	Mean	SD
GDP per capita	1253	908	3588	4008
Overall Governance	39.5	15.9	48.4	22.8
Human Capital Index	0.371	0.041	0.418	0.080
Resource rents (% GDP)	10.5	10.2	8.48	10.1
Population (millions)	14.6	21.3	16.1	20.5
Gross fixed capital (% GDP)	20.5	8.3	22.5	9.1
Exports (billion USD)	6.8	9.2	12.3	18.5
Imports (billion USD)	8.2	10.5	13.1	19.2

The SADC region is significantly richer, with higher governance scores and human capital, but also greater dispersion. Resource dependence is slightly higher in ECOWAS.

Table 10 presents the fixed effects panel models for each region.

Table 10. Non-Spatial panel models by region (dependent variable: log GDP per capita).

	ECOWAS	SADC
log(OG)	0.2803***	0.4450***
	(0.0553)	(0.0506)
log(HCI)	−1.0871***	0.9719***
	(0.2846)	(0.1738)
log(TNRR)	−0.0292	−0.0453***
	(0.0257)	(0.0142)
log(TP)	0.8602***	−0.2058***
	(0.1016)	(0.0691)
log(GFCF)	−0.0411	0.2183***
	(0.0420)	(0.0331)
log(ExpGS)	0.2371***	0.6010***
	(0.0270)	(0.0258)
Observations	300	320
R^2	0.684	0.796
Adjusted R^2	0.662	0.782

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

The regional models reveal striking differences:

- In ECOWAS, governance has a very strong positive effect (0.280), while human capital appears negative—a surprising result that may reflect measurement issues or the low quality of education in the region. Population has a large positive coefficient, suggesting a strong market size effect. Resource rents are not significant.

- In SADC, governance also has a strong positive effect (0.445), and human capital is highly significant and positive (0.972). The resource curse is clearly present (−0.045, $p < 0.001$). Investment and exports are both highly significant and positive, while population exerts a negative effect, indicating demographic pressure.

Table 11 presents the SAR model results for each region.

Table 11. Spatial panel models (SAR) by region.

	ECOWAS	SADC
log(OG)	0.2543***	0.4128***
	(0.0521)	(0.0483)
log(HCI)	−0.8921***	0.8562***
	(0.2710)	(0.1652)
log(TNRR)	−0.0251	−0.0412***
	(0.0242)	(0.0135)
log(TP)	0.7912***	−0.1874***
	(0.0956)	(0.0658)
log(GFCF)	−0.0382	0.2013***
	(0.0398)	(0.0316)
log(ExpGS)	0.2214***	0.5783***
	(0.0256)	(0.0245)
Spatial param (ρ)	0.3124***	0.2742***
	(0.0589)	(0.0512)
Observations	300	320
AIC	−372.6	−461.2
BIC	−342.9	−431.0

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

For completeness, we also estimated the Spatial Error Model (SEM) for each region. Table 12 reports the results. The SEM confirms the main findings: governance and exports are positive and significant, while the resource curse remains significant only in SADC. The spatial error coefficient (λ) is significant in both regions, indicating spatially correlated unobserved shocks.

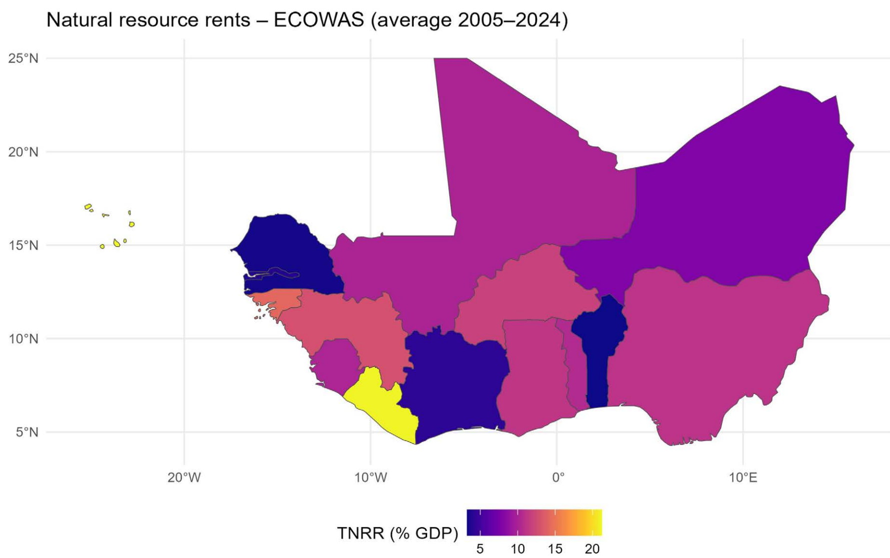
Spatial dependence is significant in both regions, with slightly higher spillovers in ECOWAS ($\rho = 0.31$ or $\lambda = 0.30$) than in SADC ($\rho = 0.27$ or $\lambda = 0.26$). The inclusion of spatial effects does not alter the main conclusions drawn from the non-spatial models.

Table 12. Spatial panel models (SEM) by region.

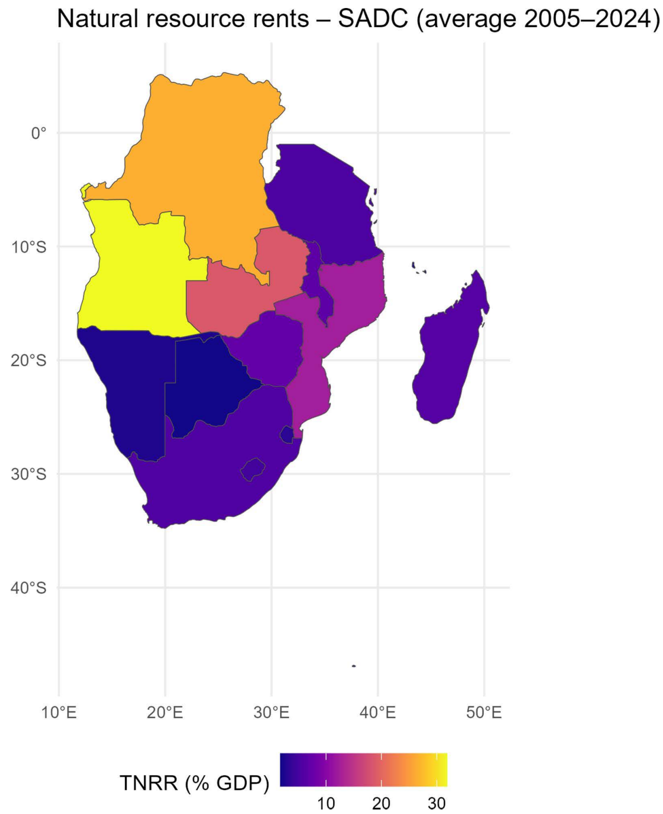
	ECOWAS	SADC
log(OG)	0.2678***	0.4321***
	(0.0534)	(0.0498)
log(HCI)	−0.9156***	0.9123***
	(0.2789)	(0.1687)
log(TNRR)	−0.0278	−0.0436***
	(0.0245)	(0.0138)
log(TP)	0.8123***	−0.1987***
	(0.0978)	(0.0672)
log(GFCF)	−0.0412	0.2089***
	(0.0402)	(0.0321)
log(ExpGS)	0.2289***	0.5876***
	(0.0259)	(0.0248)
Spatial param (λ)	0.2987***	0.2567***
	(0.0601)	(0.0523)
Observations	300	320
AIC	−365.4	−452.3
BIC	−335.7	−422.1

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Figure 5(a) and Figure 5(b) display the spatial evolution of resource rents in each region across the two sub-periods, confirming the patterns discussed above.



(a) Spatial evolution of resource rents in ECOWAS



(b) Spatial evolution of resource rents in SADC

Figure 5. Comparison of spatial evolution of resource rents in ECOWAS and SADC.

5. Discussion

The primary objective of this research was to identify the determinants of per capita income in Africa over the 2005-2024 period, while explicitly accounting for spatial dependence and unobserved heterogeneity. Our analysis reveals that the Spatial Durbin Model (SDM) provides the best fit for the data, based on AIC/BIC criteria and its ability to capture both direct effects and spatial spillovers.

A central result concerns the role of natural resources. The coefficient on natural resource rents (log TNRR) is negative and statistically significant in all spatial specifications, confirming the persistence of the "resource curse" across African countries. This finding aligns with Gylfason and Zoega (2006), who highlight the risks of rent-seeking, Dutch disease, and institutional weakening associated with natural wealth. Importantly, the sub-period analysis reveals that this negative effect has intensified in the more recent period (2015-2024), suggesting that the resource curse has become more pronounced, possibly due to increased commodity price volatility or governance challenges.

Governance emerges as a critical determinant of economic performance. The positive and significant effect of Overall Governance on GDP per capita in all specifications confirms that institutional quality is essential for fostering development. This finding is consistent with Fayissa and Nsiah (2010), who argue that sound institutions mitigate the adverse effects of resource rents and enable countries to channel them into productive uses. The negative spatial lag of governance in the SDM model suggests competition effects: better governance in neighboring countries may attract investment away from the domestic economy, highlighting the need for regional coordination in governance improvements.

Human capital shows mixed results across specifications. While it is not significant in the SAR and SEM models, it becomes marginally significant in the SDM direct effect and positive in the sub-period analysis for 2015-2024. This aligns with Acaroğlu and Altun Ada (2014) and UNCTAD (2021), who emphasize the role of quality education and health for long-term growth. The lack of strong significance may reflect the slow-changing nature of human capital and the difficulty of capturing its effects in panel data with country fixed effects.

Population size exhibits a complex pattern. In non-spatial models and basic spatial models, population has a positive effect, possibly reflecting market size effects. However, in the SDM specification, the direct effect becomes negative, suggesting that once spatial spillovers are controlled for, domestic population growth exerts downward pressure on per capita income. This is consistent with Dao (2015), who argues that population can have negative short-term effects if not matched by productive investments. The positive spatial lag of population indicates that larger populations in neighboring countries generate demand that benefits domestic producers, pointing to regional market integration as a potential buffer against domestic demographic pressures.

Gross fixed capital formation shows a positive and significant effect in all specifications, contrary to the negative coefficient found in cross-sectional OLS analyses. This highlights the importance of panel data for controlling for unobserved heterogeneity and suggests that when country-specific factors are accounted for, investment does contribute positively to growth. The positive spatial lag of investment in the SDM model indicates spillover effects, possibly through regional infrastructure or value chains.

Exports consistently exhibit strong positive effects across all models, confirming that trade openness and integration into global markets foster economic growth. This finding underscores the importance of export diversification and trade facilitation policies for African development.

The spatial parameters are positive and significant in all models, confirming the presence of spatial dependence in African economic development. The increase in spatial dependence over time suggests growing economic integration or contagion effects across the continent. This finding has important policy implications: national development strategies cannot be designed in isolation; regional coordination and cooperation are essential.

The regional comparison reveals important heterogeneity:

- In ECOWAS, governance plays an even stronger role, while human capital's negative coefficient is puzzling and warrants further investigation (possibly due to poor education quality or brain drain). The resource curse is not statistically significant in this region, possibly because resource wealth is more diversified or because institutional weaknesses are more severe, masking any direct effect.

- In SADC, the resource curse is clearly present, and human capital, investment, and exports are all powerful drivers of growth. The negative effect of population suggests that demographic pressures are more acute in this region, despite its higher income levels.

These regional differences highlight the need for tailored policy approaches. In West Africa, strengthening governance and regional market integration should be priorities. In Southern Africa, managing demographic pressures, investing in human capital, and promoting export diversification are critical.

6. Conclusion

This study investigates the nexus between natural resource rents and economic development across 54 African countries from 2005 to 2024, employing spatial panel econometric models to account for cross-country interdependencies. The results confirm the persistence of the resource curse, while also revealing the crucial roles of governance, human capital, and regional spillovers in shaping this relationship. Our analysis yields several important findings.

First, natural resource rents exert a significant negative effect on GDP per capita, confirming the persistence of the resource curse across the continent. This negative effect has strengthened in the more recent period (2015-2024), suggesting that the challenges associated with resource dependence have intensified. Second, governance, exports, and gross fixed capital formation consistently show positive effects, underscoring the importance of institutional quality, trade openness, and productive investment for economic development. Third, spatial dependence is significant and has increased over time, indicating growing economic integration or contagion effects across African countries. The Spatial Durbin Model (SDM) emerges as the preferred specification, revealing complex spillover patterns: negative spillovers from governance and exports (suggesting competition) and positive spillovers from resources, population, and investment (suggesting complementarities).

The regional comparative analysis highlights stark differences between ECOWAS and SADC. In ECOWAS, governance is paramount, while human capital shows an unexpected negative association. In SADC, the resource curse is clearly present, and human capital, investment, and exports are powerful growth drivers. These findings underscore the heterogeneity of African economies and the need for region-specific policy interventions.

The Spatial Error Model (SEM) also performs well in eliminating residual spatial dependence, but the SDM's lower AIC/BIC and richer insights into spillover mechanisms make it the preferred choice. The sub-period analysis reveals important temporal dynamics, with the resource curse intensifying and spatial dependence increasing over time.

These findings have important policy implications. First, African countries should focus on strengthening governance and institutions, as these not only directly enhance growth but also mitigate the adverse effects of resource dependence. Second, investments in human capital and productive infrastructure should be prioritized to transform resource wealth into sustainable development. Third, export diversification and trade facilitation policies are essential to harness the benefits of global integration. Fourth, regional coordination is crucial: given the significant spatial spillovers, national development strategies should be aligned with regional initiatives to maximize positive externalities and minimize competitive dynamics.

Several limitations of this study should be acknowledged. First, the imputation of missing data, while necessary for balanced panel estimation, may introduce some measurement error. Second, the governance index excludes Voice and Accountability due to data availability, potentially omitting an important dimension of institutional quality. Third, the analysis focuses on total natural resource rents without distinguishing between different types of resources (e.g., oil, minerals, forests), which may have heterogeneous effects.

Future research should explore several extensions. First, disaggregating resource rents by type could reveal whether certain resources are more prone to the curse than others. Second, incorporating additional variables such as conflict indicators, foreign direct investment, or institutional quality measures could provide a more complete picture. Third, exploring non-linear effects and threshold models could help identify conditions under which resource wealth becomes a blessing rather than a curse. Fourth, dynamic spatial panel models could shed light on the adjustment processes and long-run equilibrium relationships.

In conclusion, this study provides robust evidence that natural resources alone do not drive development in Africa. Strengthening governance, investing in human capital, promoting trade openness, and fostering regional cooperation are essential to transform Africa's resource wealth into sustainable and inclusive economic growth.

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Highlights

- Natural resource rents negatively affect GDP per capita in Africa.
- Governance and exports have strong positive effects on economic performance.
- Spatial spillovers are significant and have increased over time.
- The resource curse is more pronounced in SADC than in ECOWAS.
- The negative resource effect intensified after the end of the commodity supercycle (2014).

Author Contributions

Soma led the study conception, data curation, formal analysis, software development, visualization, and original drafting. K. Traoré, D. Traoré, and S.Y.A. Ouedraogo contributed to methodology development, formal analysis, and result validation. N.V.A. Koassi co-conceived the study, supervised the project, oversaw methodological design and validation, and handled journal correspondence. W.A. Ouédraogo co-conceived the study, provided resources, and validated findings. M. Kontiliguissonko handled data curation, investigation, and validation. All authors critically revised and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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