

Public Debt and Economic Growth in the CEMAC Zone: A Critical Threshold Analysis: 1990-2024

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Abstract

This work aims to highlight the existence of a critical threshold in the relationship between public debt and economic growth in the CEMAC zone, with a view to updating existing research on the subject and providing the sub-region's monetary and budgetary authorities with empirical data to reassess the relevance of the community debt ceiling of 70% of GDP. The methodology adopted for our work is quantitative, supported by a hypothetico-deductive approach. It is based on an econometric analysis using panel data covering the six CEMAC countries over the period 1990-2024, using secondary data obtained from the IMF, the World Bank, and the BEAC, which were processed using Stata and R software. A panel smooth transition model (PSTR) was used. It emerges that public debt has a non-linear effect on economic growth in the CEMAC zone, with a critical threshold estimated at 51.3% of GDP (an indicative transition point rather than a precisely delimited value), significantly lower than the current community ceiling. Hence our recommendations concern the review of the multilateral surveillance mechanism, the improvement of the quality of public spending financed by borrowing, the creation of countercyclical fiscal buffers, and the acceleration of economic diversification in the sub-region.

Keywords

Public Debt, Economic Growth, PSTR, Critical Threshold, CEMAC

1. Introduction

Public debt is today one of the most widely debated economic phenomena among governments, international institutions, and the scientific community. According to the IMF (2026), global public debt has reached record levels since the end of

the Second World War, exceeding 94% of GDP in 2025, driven by the combined effect of post-pandemic stimulus plans and declining tax revenues. This trend fits into a longer trajectory: after the fiscal consolidation of the 1980s-1990s, three major exogenous shocks (the 2008-2009 financial crisis, the 2014 oil price crisis, and the global health crisis) revived the dynamics of indebtedness. Emerging and developing economies are all the more exposed to this trend as they combine these pressures with the depreciation of their currencies against the dollar, which mechanically increases the burden of their foreign-currency-denominated debt.

In the sense used by the IMF (2001), public debt refers to the total liabilities of general government, that is, the financial obligations it has contracted with its creditors and is required to honor through future payments of interest and principal. This liability mainly comprises borrowed funds (multilateral, bilateral, or bank loans) and debt securities issued on the markets (sovereign bonds, treasury bills); it is in this sense distinct from other current liabilities of general government (payment arrears, provisions), which are not counted within the perimeter retained here. Unlike the budget deficit, which is a flow concept, public debt is a stock concept, resulting from the accumulation of past deficits net of repayments; its dynamics follow the fundamental relationship formalized by Elmendorf and Mankiw (1999), according to which the change in debt from one period to the next equals the primary deficit plus interest due. This relationship also highlights an important difficulty for empirical analysis: debt can influence growth, but growth can itself alter the trajectory of debt. Indeed, weak growth can reduce tax revenues and increase deficits, while stronger growth can improve states' repayment capacity. The debt-growth relationship is therefore likely to be bidirectional, which calls for caution when interpreting the statistical associations obtained between these two variables.

The economic growth referred to here is conventionally defined as the sustained increase in real gross domestic product. However, from the perspective of analyzing living standards, Barro and Sala-i-Martin (2004) favor real GDP per capita, an indicator that is particularly relevant for economies characterized by strong demographic dynamics, such as those of CEMAC. It is also important to distinguish actual growth from potential growth, as well as short-term growth—more strongly determined by fluctuations in aggregate demand and short-term policies (Blanchard & Leigh, 2013)—from long-term growth, which is based on the accumulation of factors of production and technical progress in exogenous (Solow, 1956) and endogenous (Romer, 1986; Lucas, 1988) growth models. This distinction matters for the analysis of public debt, since the favorable effect of indebtedness depends in particular on the capacity of borrowed resources to finance spending capable of durably increasing the economy's productive capacity.

CEMAC is a particularly relevant testing ground for this hypothesis: five of its six member countries are oil producers, and their revenues and growth remain heavily dependent on oil prices (BEAC, 2023). The sub-region has adopted a debt ceiling of 70% of GDP, inspired by the Maastricht Treaty but not empirically

grounded in its own macroeconomic realities—a shortcoming acknowledged by FERDI and by the Commission itself, and which Wyplosz (2012) considers risky for any fiscal rule not anchored in an estimate specific to the zone concerned. The reference study for CEMAC remains that of Kenkouo and Tchuisseu Seuyong (2020), who recommend lowering the community criterion to 62.7%, a conclusion close to the IMF's guidance, which advocates convergence toward 50% for the zone.

These studies nevertheless present two limitations that the present work aims to address: they do not cover the 2018-2024 period, marked by the financing needs linked to the global health crisis and the recovery driven by rising oil prices, with the zone's average debt reaching more than 54% of GDP in 2023 compared with a low of 20.6% in 2010 (BEAC, 2023), and they do not include the price of oil as a control variable, even though it constitutes the dominant cyclical determinant of growth and debt in the zone.

It is within this perspective that the present work is situated, its central question being the following: Does the community ceiling of 70% of GDP reflect a critical threshold that is empirically representative of the current macroeconomic realities of the CEMAC zone? This question breaks down into two subsidiary questions:

Does public debt have a non-linear effect on growth in the CEMAC zone over 1990-2024?

How does the calculated critical threshold compare with the community ceiling of 70%?

The main objective of this study is thus to analyze the non-linear relationship between public debt and economic growth in the six CEMAC countries over the period 1990-2024 and to identify a possible transition threshold. Two specific objectives follow from this: first, to test for the existence of non-linearity in the relationship between the public debt ratio and the growth of real GDP per capita; second, to estimate the debt level corresponding to the regime change and compare it with the community ceiling of 70% of GDP.

The central hypothesis is that this criterion does not reflect the empirically representative threshold of the zone's current realities. It breaks down into two subsidiary hypotheses:

- **H1: There is a non-linear relationship between public debt and economic growth in the CEMAC zone.**
- **H2: The estimated transition threshold for the debt-growth relationship is lower than the community ceiling of 70% of GDP.**

This study has a twofold interest. On the scientific level, it fills an empirical gap by updating the work of Kenkouo and Tchuisseu Seuyong (2020) to cover a period incorporating post-2018 dynamics, by including the price of oil as a control variable specific to the zone's energy structure, and by anchoring the estimated threshold in an explicit transmission mechanism. On the practical level, it offers the BEAC and the CEMAC Commission an updated empirical basis for reassessing the convergence criterion, gives member governments benchmarks for calibrating

their debt strategies, and provides international financial institutions with indicators that enrich their debt sustainability analyses.

The remainder of the article is organized as follows. The second section presents the theoretical and empirical literature, as well as the analytical framework for the relationship between public debt and growth in the CEMAC context. The third section describes the data, the variables, and the econometric strategy based on the PSTR model. The fourth section presents the estimation results and robustness analyses. The fifth section discusses the main findings and their implications for economic policy. Finally, the sixth section concludes the study.

2. Literature Review and Theoretical Framework

2.1. Theoretical Foundations

Three schools of thought structure the debate on the effects of public debt. The classical and neoclassical approach, via the Ricardian equivalence theorem (Barro, 1974, 1989), postulates the neutrality, or even the harmfulness, of debt: rational agents anticipating future tax increases raise their savings by an equivalent amount, neutralizing any stimulus effect. The Keynesian approach, by contrast, defends its stabilizing role through the fiscal multiplier (Kahn, 1931) and the IS-LM model (Hicks, 1937), particularly in a liquidity-trap situation where the crowding-out effect is neutralized. Between these two readings, Elmendorf and Mankiw (1999) propose a conditional synthesis: debt stimulates growth below a critical threshold but hinders it beyond that point—that is, its marginal impact changes sign or intensity depending on the level of indebtedness, implying the existence of at least two distinct regimes (Minea & Parent, 2012). Hansen (1999) provides the most operational formalization of this: the critical threshold is defined there as the parameter c that separates observations into a low regime ($\text{debt/GDP} \leq c$) and a high regime ($\text{debt/GDP} > c$), estimated by the grid-search method minimizing the sum of squared residuals. This non-linearity hypothesis has, since Reinhart and Rogoff (2010), given rise to an abundant empirical literature using increasingly sophisticated methods, from bracket regressions to endogenous threshold models and on to the PSTR models of González et al. (2005), which allow for a gradual transition between regimes rather than an abrupt switch.

These schools of thought are not mutually exclusive: they in fact correspond to distinct transmission channels whose relative importance depends on the institutional and financial context under consideration. A first mechanism relates to public investment: when debt finances the accumulation of public and human capital, it generates positive externalities consistent with endogenous growth frameworks (Romer, 1986; Lucas, 1988), but this effect remains conditional on the quality of the spending financed, which explains why it does not hold systematically. Conversely, when the state finances its deficit by issuing securities, it competes with private firms for available savings (Modigliani, 1961): this is the crowding-out channel, whose intensity depends directly on the depth of domestic capital markets. Beyond a certain stock level, a third mechanism takes over with a time

lag: debt service (interest and principal) absorbs a growing share of public revenue, mechanically squeezing productive spending—an intuition that extends, on the fiscal side, the Debt Overhang concept of [Krugman \(1988\)](#) and [Sachs \(1989\)](#), formalized by [Cohen \(1993\)](#). For commodity-exporting economies, this mechanism is compounded by a fourth one, linked to dependence on external financing and vulnerability to price shocks: high debt particularly weakens countries whose fiscal revenues follow world price cycles. Finally, institutional quality and the quality of public spending do not determine the sign of these effects but rather their intensity: for an identical level of indebtedness, stronger institutions limit the capture of spending by special interests ([Nouaili, 2025](#)).

In the specific context of CEMAC, this channel-based framework takes on particular significance. Because domestic capital markets are shallow there, the crowding-out channel is expressed less through rising interest rates, as in financially developed economies, than through the rationing of bank credit: general government, the main borrower in the regional banking system, absorbs a growing share of loanable resources to the detriment of private-sector financing. This structural feature directs the analysis from the outset toward the other two channels (debt service and external vulnerability) rather than toward classic financial crowding-out. Moreover, five of the six member countries are oil producers, and their fiscal revenues and foreign exchange reserves move procyclical with world prices ([BEAC, 2023](#)): high debt, combined with a negative oil shock, thus exposes these economies to a sudden liquidity constraint that forces a procyclical fiscal adjustment, as illustrated by the 2014-2016 shock. It is this interaction that seems to dominate in the CEMAC zone: the critical debt threshold would correspond less to the point at which financial crowding-out stifles private investment than to the point at which debt service becomes heavy enough that any negative oil shock forces a procyclical adjustment.

2.2. Empirical Review

The work of [Reinhart and Rogoff \(2010\)](#), covering forty-four countries over 1790-2009, marked the starting point of the empirical literature by identifying a threshold of 90% of GDP beyond which median growth falls sharply. These results were nevertheless weakened by [Herndon, Ash and Pollin \(2014\)](#), who revealed coding and weighting errors in the original data, bringing average growth above 90% back to a slightly positive level. These controversies steered the literature toward more rigorous econometric methods, notably threshold (PTR) and smooth transition (PSTR) models. [Cecchetti, Mohanty and Zampolli \(2011\)](#) thus estimate a threshold of 85% for eighteen OECD countries; [Checherita-Westphal and Rother \(2012\)](#) identify a threshold between 90% and 95% for the euro area; [Minea and Parent \(2012\)](#), using a PSTR model, identify two transition points at 90% and 115%. [Égert \(2015\)](#), in a systematic meta-analysis, shows that these results are highly sensitive to methodological choices and sample composition, arguing for region-specific estimates. More recent work confirms this heterogeneity: [Petkovski et al. \(2024\)](#)

estimate thresholds between 58% and 73% for eleven new EU member states; [Fetai et al. \(2025\)](#) find 79.4% for emerging European economies; [Mitsi \(2025\)](#) confirms a threshold between 84% and 90% for twenty-seven EU countries, highlighting the moderating role of institutional quality; [Shah et al. \(2025\)](#) show that the threshold rises with the level of development, from 50.2% for lower-middle-income economies to 62.6% for the upper bracket.

For Africa, the estimated thresholds are systematically lower than those found for developed economies. [Kitutila \(2024\)](#), combining PSTR and GMM on twenty-two sub-Saharan African countries (1990-2021), estimates a threshold of 53% for the region as a whole, 49% for ECOWAS, and 45% for SADC. [Nouaili \(2025\)](#), using forty-seven African countries (2002-2022), establishes a threshold of 53.49% for external debt, with governance quality mitigating the negative effect beyond this threshold. For CEMAC specifically, [Kenkouo and Tchuisseu Seuyong \(2020\)](#) remain the reference study, with a threshold of 82.3% (95% CI: [62.7%; 109.2%]) over 1990-2017, joined by [Chuaibou \(2018\)](#) for Cameroon (63%).

3. Methodology

3.1. Study Variable

The dependent variable is the growth rate of real GDP per capita, constructed as a forward-looking four-year moving average (t to $t + 3$), in order to smooth out cyclical fluctuations, capture the medium-term effects of indebtedness on growth, and limit endogeneity problems linked to reverse causality between growth and public debt, following [Kenkouo and Tchuisseu Seuyong \(2020\)](#).

The model uses seven explanatory variables. The gross public debt/GDP ratio is the main explanatory variable on which the estimated critical threshold depends. The investment rate (gross fixed capital formation/GDP) captures the accumulation of physical capital in the [Solow \(1956\)](#) tradition. Initial income (the logarithm of real GDP per capita at the start of the period) tests the conditional convergence hypothesis of [Mankiw, Romer and Weil \(1992\)](#). The population growth rate controls for the dilutive effect of population on capital per capita. The degree of trade openness ((exports + imports)/GDP) captures the effect of integration into international trade, in line with [Sachs and Warner \(1995\)](#). Credit to the economy (domestic credit to the private sector/GDP) captures the effect of financial development on growth ([King & Levine, 1993](#)), which is particularly relevant in a zone where financial markets remain underdeveloped. Finally, the international price of oil (the Brent price in constant dollars) is introduced as a control variable specific to the CEMAC context, in order to isolate the effect of debt itself from that of the oil cycle and to avoid omitted-variable bias ([Table 1](#)).

Source hierarchy: For public debt, the reference series is the IMF's (Historical Public Debt Database/Fiscal Monitor), supplemented, where a country-year observation is missing or inconsistent with national publications, by BEAC annual reports ([Kenkouo & Tchuisseu Seuyong, 2020](#)). For GDP per capita growth and the control variables (investment, credit to the economy, trade openness, initial

income, population growth), the reference source is the World Bank's World Development Indicators (WDI); the 2026-2027 observations, not yet available in the WDI at the time the panel was constructed, are supplemented by IMF World Economic Outlook (WEO) projections; these WEO-based years enter the dependent variable's forward-looking four-year average (t to $t+3$) for the final in-sample observations ($t = 2023$ and 2024), each of which therefore includes at least one WEO-projected year. The international oil price is drawn from the World Bank's Commodity Markets (Pink Sheet) database.

Reconciliation rule in case of divergence: Where the IMF, BEAC and WDI series diverge for the same country-year observation, the source closest to the official national publication (BEAC report) is given priority for public debt.

Table 1. Definition of variables.

Variable	Definition	Source
GDP/capita growth (M4)	4-year forward-looking average of the real GDP per capita growth rate (%)	World Bank (WDI), supplemented by IMF (WEO), 2026, and 2027 estimates
Investment	Gross fixed capital formation/GDP (%)	World Bank (WDI)
Credit to the economy	Domestic credit provided to the private sector (% of GDP)	World Bank (WDI), supplemented by BEAC annual reports (Kenkouo & Tchuisseu Seuyong, 2020).
Trade openness	(Exports + Imports)/GDP (%)	World Bank (WDI)
Initial income	Ln (real GDP per capita)	World Bank (WDI)
Population growth	Annual population growth (%)	World Bank (WDI)
Public debt	Gross public debt/GDP (%)	IMF (HPDD), supplemented by BEAC annual reports (Kenkouo & Tchuisseu Seuyong, 2020).
Oil price	Brent price (USD/barrel)	World Bank-Pink Sheet

Source: Authors.

3.2. Econometric Model

To study the non-linear relationship between public debt and economic growth, we use the PSTR (Panel Smooth Transition Regression) model developed by González et al. (2005). This model generalizes Hansen's (1999) threshold model by allowing a gradual and continuous transition between regimes, rather than an abrupt switch at a single threshold—a property considered more realistic for studying the debt-growth relationship, where the adjustments of economic agents are rarely instantaneous.

The two-regime PSTR model is written as:

$$y_{it} = \alpha_i + \lambda t + \beta'_0 X_{it} + \beta'_1 X_{it} G(q_{it}; \gamma, c) + \varepsilon_{it}$$

with $i = 1, \dots, N; t = 1, \dots, T$.

where ε_{it} i.i.d. $(0, \sigma^2 \varepsilon)$ and $G(q_{it}; \gamma, c)$ denotes the transition function associated with the transition variable q_{it} , the threshold parameter c , and the smoothing parameter, α_i and λt is the dependent variable, and X_{it} contains the explanatory variables; β_0 and β_1 denote, respectively, the parameter vectors of the linear and non-linear parts of the model, and ε_{it} is the vector of error terms.

The transition function $G(q_{it}; \gamma, c)$, which is continuous and bounded between 0 et 1, is a logistic function of order m :

$$G(q_{it}; \gamma, c) = \left[1 + \exp \left(-\gamma \prod_{j=1}^m (q_{it} - c_j) \right) \right]^{-1}$$

avec $\gamma > 0$ et $c_1 < c_2 < \dots < c_m$

where $c = (c_1 \dots c_m)$ is an m -dimensional vector and γ is the smoothing parameter, which governs the speed of transition between regimes. When γ tends toward infinity, this function converges to an indicator function and the PSTR model approaches the PTR model with an abrupt transition; when γ tends toward zero, the coefficients vary in an almost linear fashion and the model approaches a linear model.

The transition variable retained, q_{it} , is the public debt-to-GDP ratio itself, measured at t ; the dependent variable, real GDP per capita growth, is instead measured as a forward-looking average over t to $t + 3$. Among the explanatory variables, only public debt carries a regime-varying coefficient (parameter β_1); all other control variables (investment, credit to the economy, trade openness, initial income, population growth, and the change in the oil price) retain a coefficient that is constant across regimes (parameter β_0). The model further includes time fixed effects in the form of annual dummy variables (λt), whose coefficients, not reported in the results tables below, control for shocks common to all countries at a given date.

4. Results and Discussion

4.1. Descriptive Statistics

The panel studied covers six CEMAC countries over the period 1990-2024 ($N = 210$, balanced panel).

Regarding the dependent variable (**Table 2**), it averages 1.60% over the period, with a high degree of dispersion (standard deviation = 9.35) reflecting the well-documented structural heterogeneity of regional economic trajectories, between episodes of oil rent and recurrent crises. Regarding the exogenous variables: public debt (the main exogenous variable) ranges from 0.47% to 270.18% of GDP with an average of 67.37%, close to the community ceiling of 70%. Its high standard deviation (51.42, coefficient of variation above 75%) reflects marked heterogene-

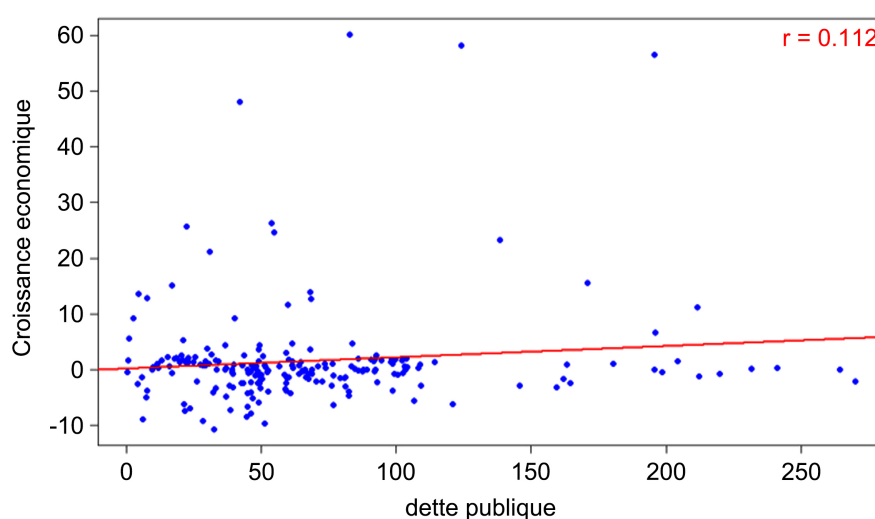
ity, justifying a non-linear specification a priori. Investment averages 24.88% of GDP, with a distribution also skewed to the right (skewness = 2.42), reflecting occasional large oil infrastructure projects. Credit to the economy remains low (9.26% of GDP on average), a sign of the zone's persistent under-banking. Trade openness averages 71.90%, with fairly marked variability depending on the trade structure of each country. Population growth is the most homogeneous variable (mean 2.99%, standard deviation 1.00). Finally, the price of oil ranges from 12.72 to 111.97 USD/barrel, illustrating the volatility of international markets.

Table 2. General descriptive statistics.

Variable	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
GDP/capita growth (M4)	1.60	9.35	-10.72	60.17	4.13	23.59
Public debt	67.37	51.42	0.47	270.18	1.68	6.07
Investment	24.88	16.44	4.62	115.10	2.42	10.81
Credit to the economy	9.26	5.28	1.69	38.23	1.39	7.09
Trade openness	71.90	31.64	26.16	156.86	0.66	2.38
Initial income	8.57	1.10	6.74	10.60	-	-
Population growth	2.99	1.00	-0.80	6.41	-0.21	6.40
Oil price	52.92	31.83	12.72	111.97	0.41	1.85

Source: Authors.

Figure 1 confirms the weakness of the simple linear relationship between public debt and growth ($r = 0.112$), and supports the choice of a non-linear specification.



Source: R Output.

Figure 1. Average public debt and GDP per capita growth.

Investment unsurprisingly appears positively correlated with growth ($r = 0.629$), confirming its role as a growth driver, consistent with neoclassical growth models (Table 3). Credit to the economy, for its part, shows a negative correlation with growth ($r = -0.221$). The price of oil is negatively correlated with both public debt ($r = -0.548$) and growth ($r = -0.245$), reflecting the macro-fiscal sensitivity of the zone's oil economies to world price cycles. No correlation coefficient between explanatory variables exceeds the critical threshold of 0.70; only two pairs show a moderate correlation (investment-openness, $r = 0.505$; initial income-openness, $r = 0.639$), posing no risk of problematic multicollinearity for the estimation.

Table 3. Correlation matrix of model variables.

	GDP/capita growth (M4)	Debt	Investment	Credit to the economy	Trade openness	Initial income	Population growth	Oil price
GDP/capita growth (M4)	1.000							
Debt	0.112	1.000						
Investment	0.623	0.1083	1.000					
Credit to the economy	-0.220	0.1001	-0.065	1.000				
Trade openness	0.054	0.2578	0.505	-0.174	1.000			
Initial income	-0.193	-0.117	0.215	0.1163	0.639	1.000		
Population growth	0.309	-0.137	0.381	-0.320	0.289	0.297	1.000	
Oil price	-0.2448	-0.548	-0.082	0.135	0.058	0.154	-0.117	1.000

Source: Authors.

4.2. Econometric Results

The estimation of the econometric model proceeds in several successive steps. Pesaran's cross-sectional dependence test is applied first, in order to determine the unit-root test appropriate to each variable and to identify those requiring differencing to ensure stationarity. Linearity tests and tests for selecting the number of regimes are then conducted to validate the chosen PSTR specification, prior to the actual estimation of the model. Finally, specification tests are carried out to assess the robustness of the results obtained.

• Preliminary tests

Since cross-sectional dependence in macroeconomic panels can bias first-generation unit-root tests, Pesaran's dependence test (CD-test) is applied to each variable in order to determine the appropriate stationarity test—LLC (Levin et al., 2002) or CIPS (Cross-sectionally Augmented IPS) (Table 4).

Table 4. Cross-sectional dependence and stationarity of variables.

Variable	CD-test (p-value)	Test used	Statistic	p-value	Conclusion
GDP/capita growth (M4)	1.33 (0.183)	LLC	−2.361	0.009	Stationary
Debt	14.90 (0.000)	CIPS	−2.801	0.004	Stationary
Investment	2.19 (0.029)	CIPS	−2.430	0.045	Stationary
Credit to the economy	15.11 (0.000)	CIPS	−3.034	0.001	Stationary
Trade openness	3.17 (0.002)	CIPS	−2.474	0.035	Stationary
Population growth	1.12 (0.264)	LLC	−3.261	0.001	Stationary
Initial income	−1.32 (0.186)	LLC	−0.694	0.244	Non-stationary
Oil price (level)	22.91 (0.000)	DF	−1.666	0.449	Non-stationary
Oil price (diff.)	—	DF	−5.348	0.000	Stationary

Source: Authors.

The CD-test results lead to a distinction between two groups of variables: those exhibiting significant cross-sectional dependence (debt, investment, credit to the economy, openness, oil price), for which the CIPS test or the univariate Dickey-Fuller test is used, and those for which independence is not rejected (GDP per capita growth, initial income, population growth), tested using LLC. All variables are stationary in levels, except for initial income and the oil price. The latter, integrated of order one, is differenced for the estimation (DF statistic = -5.348 , $p < 0.01$). Initial income is kept in levels, since differencing it would correspond approximately to the growth rate of GDP per capita, creating a tautological relationship with the dependent variable. This is confirmed empirically: the correlation between differenced initial income and GDP per capita growth is 0.94, and a random-effects panel regression of growth on differenced initial income alone yields a within R^2 of 0.874, with a coefficient of 117.08 ($p < 0.001$); differencing initial income would therefore amount to duplicating the dependent variable rather than introducing an independent control. This choice, common in the conditional-convergence literature (where initial income in level is precisely what captures the gap to the long-run growth path), nonetheless exposes the model to the usual spurious-regression risk associated with non-stationary panel variables; it constitutes, in that sense, a deliberate trade-off between strict econometric validity and the economic interpretability of the coefficient, rather than a complete neutralization of the issue.

Before estimating the PSTR model, the linearity hypothesis must be tested against the alternative of a threshold specification, and the number of transition functions to retain must then be determined, following the sequential procedure of [González et al. \(2005\)](#).

The LM_X and LM_F statistics reject the linearity hypothesis at conventional

thresholds (1% to 5%) for all three values of m tested, confirming the existence of a non-linear relationship between public debt and growth (**Table 5**). The versions corrected for heteroskedasticity and autocorrelation (HAC_X, HAC_F), as well as the cluster wild-bootstrap p-value (WCB_PV), do not, by contrast, reject the linearity hypothesis at the 5% level, and only the wild-bootstrap p-value (WB_PV) rejects it marginally; this divergence, expected given the small number of countries in the panel ($N = 6$), which reduces the power of the corrected asymptotic tests, cautions against over-interpreting the rejection of linearity as a clear-cut result. Since the LM statistics remain the usual reference in the literature [19], linearity is treated as a working hypothesis and the PSTR model is preferred over a linear specification; this relative fragility of the corrected tests nonetheless echoes the indicative (rather than strictly delimited) reading adopted below for the estimated threshold.

The sequential test shows that the first test ($r = 0$ against $r = 1$) rejects linearity (LM_X and LM_F significant at 5%), confirming the need for at least one transition function. The second test ($r = 1$ against $r = 2$) does not reject the null hypothesis, so the procedure stops at $r = 1$. The PSTR model with a single transition function is therefore retained, in line with the most parsimonious specification validated by the data.

Table 5. Linearity test and selection of the number of regimes.

Homogeneity (linearity) test results										
m	LM_X	PV	LM_F	PV	HAC_X	PV	HAC_F	PV	WB_PV	WCB_PV
1	7.771	0.00531	6.032	0.0151	2.428	0.1192	1.885	0.1717	0.04412	0.2538
2	10.210	0.00606	3.939	0.0214	2.534	0.2816	0.9775	0.3785	0.09324	0.2345
3	11.170	0.01086	2.853	0.0390	3.663	0.3003	0.9360	0.4248	0.19070	0.2353
Sequence of tests for selecting the number of transitions m										
m	LM_X	PV	LM_F	PV	HAC_X	PV	HAC_F	PV	WB_PV	WCB_PV
1	7.771	0.00531	6.032	0.0151	2.428	0.1192	1.885	0.1717	0.04412	0.2538
2	2.536	0.11130	1.956	0.1639	0.9471	0.3305	0.7306	0.3940	0.35630	0.6114
3	1.002	0.31680	0.7682	0.3821	2.0960	0.1477	1.6070	0.2068	0.55830	0.2472

Source: prepared by the authors based on R output.

• Model estimation

The PSTR model with a single threshold and a single transition function, whose specification was validated by the preceding linearity tests, is estimated using the BFGS optimizer (**Table 6**).

The transition threshold is estimated at 51.31% of GDP. The confidence interval reported in **Table 6**, computed from the asymptotic standard error, is narrow

([51.18; 51.44]), but this is unreliable in itself: the distribution of the threshold parameter in a PSTR model is non-standard. A block bootstrap accounting for within-country residual dependence (block length of 4 years, warm-started BFGS re-estimation, 496 valid replications out of 500) yields a substantially wider 95% confidence interval: [49.83; 55.50] using the percentile method, or [47.13; 52.79] using the bias-corrected basic method (bootstrap mean = 51.49%, median = 51.29%, standard deviation = 1.23 points). This confirms that the naive asymptotic interval understates the true uncertainty around the threshold, and that 51.31% of GDP is better read as an indicative transition point situated in the neighborhood of 50%, rather than as a value precisely delimited to two decimal places. It nevertheless remains markedly below the community ceiling of 70% of GDP, which is consistent with hypothesis H2, according to which this ceiling does not reflect the current empirical realities of CEMAC.

Table 6. PSTR model estimation results.

Variable	Coef.	Std-error	t-ratio	95% CI
Linear part (first extreme regime)				
Public debt	0.0435*	0.0256	1.699	[−0.007; 0.094]
Investment	0.2528***	0.0613	4.12	[0.133; 0.373]
Credit to the economy	−0.7922***	0.1894	−4.18	[−1.163; −0.421]
Trade openness	−0.0115	0.0260	−0.44	[−0.062; 0.040]
Initial income	−11.00***	0.6408	−17.16	[−12.26; −9.74]
Population growth	0.3178	0.5621	0.57	[−0.784; 1.419]
Oil price (diff.)	−0.7300**	0.2848	−2.56	[−1.288; −0.172]
Non-linear part				
Public debt (β_1)	−0.0579**	0.0242	−2.39	[−0.105; −0.010]
Second extreme regime ($\beta_0 + \beta_1$)				
Public debt	−0.0144	0.0192	−0.75	[−0.052; 0.023]
Non-linear parameters				
Gamma (transition speed)	53.41	37.35	1.43	[−19.80; 126.62]
c (threshold, % of GDP)	51.31***	0.0683	751.4	[51.18; 51.44]

Source: Authors (based on R output). Significant level: ***1%, **5%, *10%.

• Specification tests and post-estimation diagnostics

The diagnostic tests complete the validation of the PSTR model. The parameter constancy test checks the temporal stability of the estimated coefficients, a necessary condition for the robustness of the results. The no-remaining-heterogeneity

test examines whether the single-transition-function model ($m = 1$) captures all of the non-linearity in the data, by searching for any residual non-linear structure in the errors (**Table 7**).

Table 7. Post-estimation specification tests ($m = 1$, $m = 2$).

Test	m	LM_X (p)	LM_F (p)	HAC_X(p)	HAC_F(p)	WB_PV	WCB_PV
Constancy	1	64.74 (0.010)	0.917 (0.615)	5.998 (1)	0.085 (1)	1	1
Constancy	2	92.91 (0.193)	0.437 (0.999)	6.102 (1)	0.029 (1)	1	1
Heterogeneity	1	96.7 (0.000)	1.37 (0.096)	5.954 (1)	0.084 (1)	1	0.959
Heterogeneity	2	165.2 (0.000)	0.777 (0.872)	6.512 (1)	0.031 (1)	1	0.974

Source: Authors (based on R output).

The diagnostic tests confirm the robustness of the model retained. Regarding parameter constancy, only the LM_X statistic marginally rejects the stability hypothesis, while the other tests (LM_F, HAC, WB, WCB) show no evidence of temporal instability in the coefficients. For the no-remaining-heterogeneity test, although the non-robust statistics (LM_X and, to a lesser extent, LM_F) suggest residual non-linearity, this conclusion is not confirmed by the robust tests (HAC, WB, WCB), which are better suited to the small cross-sectional dimension of the sample in the case of the residual heterogeneity test. These results indicate that the parameters are stable over time and that a single transition function is sufficient to capture the non-linearity of the debt-growth relationship, thereby validating the final specification of the PSTR model.

4.3. Interpretation of Results

The transition coefficient is negative and significant ($\beta_1 = -0.058$), confirming a regime shift around this threshold. Below 51.31% of GDP, public debt has a positive effect on growth ($\beta_0 = 0.044$). Beyond this threshold, its effect becomes statistically indistinguishable from zero ($\beta_0 + \beta_1 = -0.014$), indicating that debt no longer stimulates growth without being significantly detrimental to it either. The smoothing parameter ($\gamma = 53.41$) reflects a relatively rapid transition between the two regimes.

Among the control variables, investment has a positive and significant effect on growth, while credit to the economy has a negative effect, which may reflect an inefficient allocation of financial resources or the shallow depth of CEMAC's financial system. Similarly, changes in oil prices negatively affect growth, illustrating the sub-region's vulnerability to commodity shocks. Trade openness, on the other hand, has no significant effect, which probably reflects international integration based mainly on the export of natural resources. Finally, initial income shows a negative and significant coefficient, confirming the conditional convergence hypothesis. These results highlight the specific features of growth mecha-

nisms within CEMAC, while recalling that the PSTR model does not allow a causal link to be established between the variables.

4.4. Comparison with Existing Literature

The 51.31% threshold estimated in this study is markedly lower than all of the thresholds reported in the prior empirical literature, whether from studies on samples of developed countries (84% - 115%), developing countries (50% - 88%), or specifically on the CEMAC zone (62.7%).

Several factors may explain this gap. First, the study period was extended from 2017 to 2024, thus including the global health crisis and its train of fiscal deterioration, which is likely to lower the tipping point beyond which the accumulation of debt ceases to be beneficial for growth. Second, several methodological choices differ: the correction of public debt data using BEAC annual reports (Kenkouo & Tchuisseu Seuyong, 2020), the use of income per capita in constant-price purchasing power parity rather than in current currency, and a different decomposition of the control variables. Finally, the robustness of the result, discussed in the following section, suggests that this threshold should be viewed as one empirical benchmark among others rather than as a definitive estimate.

5. Economic Policy Implications

The results obtained make it possible to draw several economic policy implications. These mainly concern the review of the community debt ceiling, the improvement of the quality and efficiency of public spending financed by borrowing, the strengthening of the role of credit to the economy, and the diversification of the sub-region's productive structures.

- **Reviewing the community debt ceiling**

The estimated critical threshold (51.3% of GDP) is lower than the 70% ceiling used in the framework of CEMAC's multilateral surveillance. This finding echoes questions raised in several studies, as well as the deliberations undertaken by regional institutions on the adequacy of the current criterion to the sub-region's macroeconomic realities. It argues for a review of the fiscal surveillance framework, in particular through the introduction of an early-warning mechanism that would alert the authorities when a member state approaches the estimated threshold, without waiting for the community ceiling to be reached.

- **Prioritizing the quality of debt-financed spending and strengthening the evaluation of public investment projects**

The positive and highly significant effect of investment on growth shows that the effectiveness of debt depends as much on how borrowed resources are used as on their volume. From this perspective, it would be worthwhile to consider, over the medium term, an evolution of the community fiscal framework that distinguishes borrowing intended for current spending from that devoted to productive investment, along the lines of golden fiscal rules. To ensure the effectiveness of this orientation, it is necessary to establish or strengthen ex ante evaluation mech-

anisms for major public investment projects (socio-economic profitability studies, multiyear budget prioritization). Such mechanisms would help ensure that the debt contracted actually finances projects with a strong impact on growth, rather than operating expenditure disguised as investment, thereby strengthening the contribution of debt to the sub-region's economic development.

- **Accelerating economic diversification and reducing dependence on hydrocarbons**

The results obtained for the oil price and trade openness converge on the same finding: the still largely extractive structure of CEMAC economies limits their ability to convert external shocks into lasting growth gains. The negative coefficient associated with the change in the oil price highlights the macroeconomic vulnerability generated by excessive dependence on a volatile commodity. Similarly, the absence of a significant effect of trade openness suggests that foreign trade, dominated by the export of largely unprocessed raw products, has not yet generated the productivity and technology-transfer externalities generally expected from international integration.

These results argue for accelerating the diversification strategies already undertaken by several member states, in particular through the development of agro-industrial value chains, the local processing of raw materials, and the strengthening of intra-regional trade integration. Such diversification would help reduce exposure to oil shocks and amplify the gains from better-leveraged trade openness, with a view to more resilient growth that is less dependent on commodity cycles.

6. Conclusion

This study set out to update the analysis of the relationship between public debt and economic growth in the CEMAC zone, using a PSTR model over the period 1990-2024—a seven-year extension relative to the reference study by [Kenkouo and Tchuisseu Seuyong \(2020\)](#), and incorporating the international price of oil as a control variable specific to the sub-region's energy structure.

The results reveal, first, the existence of a non-linear relationship between public debt and growth in the CEMAC zone, thereby validating hypothesis H1: the results of the linearity tests, complemented by the descriptive analysis, provide grounds for rejecting the linear specification in favor of a single-threshold model. Second, the estimated critical threshold, 51.31% of GDP (block-bootstrap 95% CI: [49.83%; 55.50%]), should be understood as an indicative transition point rather than as a precisely delimited value; it nonetheless remains markedly lower than the 70% community ceiling set under CEMAC's multilateral surveillance framework, which is consistent with hypothesis H2. Below this threshold, debt has a positive and significant effect on growth; beyond it, this effect becomes statistically indistinguishable from zero rather than negative, which calls for a nuanced reading in terms of a loss of debt effectiveness rather than proven harm. This finding is consistent with the study's central research question: the community ceiling of 70% of GDP does not appear to reflect the zone's current empirical realities and

may overestimate the debt capacity compatible with a favorable effect on growth.

The analysis of the control variables enriches this central finding. Investment confirms its role as a growth driver, consistent with neoclassical growth models, while credit to the economy, the oil price, and initial income display effects that, while sometimes departing from the usual theoretical predictions, find a coherent explanation in the structural specificities of the sub-region's economies: under-banking, dependence on hydrocarbons, and conditional convergence dynamics.

These results lead to economic policy recommendations concerning the review of the multilateral surveillance framework, the improvement of the quality of public spending financed by borrowing, the strengthening of the evaluation of public investment projects, and the acceleration of the sub-region's economic diversification.

This study nevertheless has limitations that should be noted. The small cross-sectional dimension of the panel (6 countries) reduces the power of robust asymptotic tests (HAC, wild bootstrap), making it necessary to rely primarily on the LM statistics as the decision criterion—a constraint shared by all studies based on small panels, as is the case for CEMAC or other regional zones with limited numbers of members. In addition, the model used rests on the assumption of exogeneity of the explanatory variables and therefore does not allow a formal causal link to be established between these variables and growth. In particular, the relationship between credit to the economy and growth could be subject to reverse causality, insofar as stronger growth stimulates credit demand, just as credit can foster growth.

These limitations open avenues for future research, in particular a sectoral breakdown of credit to the economy in order to identify its precise transmission channels, an extension of the methodology to dynamic endogenous threshold models incorporating the potential endogeneity of debt, and a more fine-grained sub-regional comparison between oil-exporting and non-oil-exporting countries within CEMAC, which could further refine the understanding of the critical debt threshold specific to each economic profile. Finally, the inclusion of institutional variables could help assess the extent to which the quality of governance and public financial management alters the debt-growth relationship and contributes to explaining threshold differences between the sub-region's economies.

Author Contributions

Chuaibou Mounmom: Conceptualization of the study, development of the methodology, coordination of the research work, major contributions to manuscript drafting, and supervision of the review and finalization process. **Ntièche Adamou:** Contributions to the conceptualization of the study, participation in manuscript drafting, and critical review of the manuscript's content. **Nzuko Silapa Jeff Keryl:** Data collection and processing, data analysis and interpretation, contribution to manuscript drafting, and incorporation of comments toward the finalization of the manuscript.

Conflicts of Interest

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

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Appendices

Appendix 1: Specification Test of the Non-Linear Model 1

```
> print(pstrtest, "tests")
#####
## PSTR 1.2.4 (Orange Panel)
#####
*****
Results of the linearity (homogeneity) tests:
-----
LM tests based on transition variable 'dette'
m  LM_X      PV  LM_F      PV HAC_X      PV  HAC_F      PV  WB_PV WCB_PV
1  7.771 0.005310 6.032 0.01510 2.428 0.1192 1.8850 0.1717 0.04412 0.2538
2  10.210 0.006059 3.939 0.02136 2.534 0.2816 0.9775 0.3785 0.09324 0.2345
3  11.170 0.010860 2.853 0.03902 3.663 0.3003 0.9360 0.4248 0.19070 0.2353
*****
Sequence of homogeneity tests for selecting number of switches 'm':
-----
LM tests based on transition variable 'dette'
m  LM_X      PV  LM_F      PV HAC_X      PV  HAC_F      PV  WB_PV WCB_PV
1  7.771 0.005310 6.0320 0.0151 2.4280 0.1192 1.8850 0.1717 0.04412 0.2538
2  2.536 0.11130 1.9560 0.1639 0.9471 0.3305 0.7306 0.3940 0.35630 0.6114
3  1.002 0.31680 0.7682 0.3821 2.0960 0.1477 1.6070 0.2068 0.55830 0.2472
*****
#####
```

Appendix 2: Non-Linear Model Estimation

```
R - R4.1.3 - ~/
#####
## PSTR 1.2.4 (Orange Panel)
#####
*****
Results of the PSTR estimation:
-----
Transition variable 'dette' is used in the estimation.
-----
Parameter estimates in the linear part (first extreme regime) are
dette_0 investissement_0 credit_economie_0 revenu_initial_0 ouverture_economie_0
Est 0.04348 0.25280 -0.7922 -11.0000 -0.01145
s.e. 0.02558 0.06129 0.1894 0.6408 0.02599
croiss_pop_0 d_cours_petrole_0 d1991_0 d1992_0 d1993_0 d1994_0 d1995_0 d1996_0
Est 0.3178 -0.7300 -2.766 -3.745 -6.770 -1.330 0.780 0.586
s.e. 0.5621 0.2848 1.990 1.096 1.301 4.591 4.112 3.914
d1997_0 d1998_0 d1999_0 d2000_0 d2001_0 d2002_0 d2003_0 d2004_0 d2005_0 d2006_0
Est -3.202 -8.750 0.9633 4.377 -3.136 -1.673 1.347 5.999 8.44 3.894
s.e. 3.489 3.902 3.2570 3.955 1.918 2.127 3.036 5.028 6.51 4.847
d2007_0 d2008_0 d2009_0 d2010_0 d2011_0 d2012_0 d2013_0 d2014_0 d2015_0 d2016_0
Est 0.3877 14.630 -30.11 7.999 18.810 -3.806 -7.085 -12.940 -38.03 -8.84
s.e. 3.9180 8.164 10.84 5.473 9.154 1.588 1.608 3.118 12.38 1.21
d2017_0 d2018_0 d2019_0 d2020_0 d2021_0 d2022_0 d2023_0
Est 4.942 10.640 -6.571 -16.430 19.850 21.900 -9.820
s.e. 4.242 6.018 1.324 5.078 8.878 9.025 4.076
-----
Parameter estimates in the non-linear part are
dette_1
Est -0.05787
s.e. 0.02422
-----
Parameter estimates in the second extreme regime are
dette_{0+1}
Est -0.01440
s.e. 0.01924
-----
Non-linear parameter estimates are
gamma c_1
Est 53.41 51.31000
s.e. 37.35 0.06833
-----
Estimated standard deviation of the residuals is 3.859
*****
#####
```

Appendix 3: Specification Test of the Non-Linear Model 2

```
> print(pstr_eval, mode = "evaluation", digits = 10)
#####
## PSTR 1.2.4 (Orange Panel)
#####
Results of the evaluation tests:
-----
Parameter constancy test
m      LM_X      PV      LM_F      PV      HAC_X PV      HAC_F PV
1  64.74190 0.01046242 0.9173649 0.6148040 6.026777 1 0.085396843 1
2  92.90654 0.19266493 0.4370168 0.9998822 6.257217 1 0.029432905 1
3 113.94971 0.70850766 0.1764610 1.0000000 6.099241 1 0.009445205 1
-----
WB and WCB parameter constancy test
m WB_PV WCB_PV
1 1 1
2 1 1
3 1 1
-----
No remaining nonlinearity (heterogeneity) test
m      LM_X      PV      LM_F      PV      HAC_X PV      HAC_F PV
1  96.69745 2.138886e-06 1.3701613 0.09638353 6.186159 1 0.08765521 1
2 165.17362 1.502029e-07 0.7769491 0.87180178 7.587092 1 0.03568841 1
3 201.50996 1.029065e-05 0.3120557 0.99999956 -9.545038 1 -0.01478132 1
-----
WB and WCB no remaining nonlinearity (heterogeneity) test
m WB_PV WCB_PV
1 1 0.959
2 1 0.974
3 1 0.992
#####
```

Appendix 4: Residual Tests

```
R v 4.1.3 . ~/
> t.test(residus)

One Sample t-test

data: residus
t = -5.0708e-15, df = 209, p-value = 1
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.5262361 0.5262361
sample estimates:
 mean of x
-1.353598e-15

R v 4.1.3 . ~/
> white.test(ts(residus))

White Neural Network Test

data: ts(residus)
x-squared = 2.8511, df = 2, p-value = 0.2404
```