Nexus between public debt and economic growth in BRICS countries: new evidence from quantile and frequency approaches

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This study examines the interplay between public debt and economic growth in BRICS nations (Brazil, Russia, India, China, South Africa), focusing on the relatively unexplored quantile-frequency domain, which integrates quantile regression with frequency analysis. Using data spanning from 1994 to 2022, the analysis employs wavelet quantile correlation (WQC) and quantile-on-quantile regression (QQR) techniques. These advanced methodologies facilitate a nuanced understanding of the public debt (DEBT)–economic growth (GDP) relationship across various quantiles and time horizons. The results suggest that public debt has a negative influence on economic growth in the short and medium term, while a positive association emerges over the long term. Furthermore, the findings highlight an asymmetric effect of public debt on economic growth across different quantiles within the region. These insights offer valuable guidance for policymakers, providing tailored recommendations for debt management in BRICS countries by addressing both the beneficial and adverse effects of public debt on economic performance.

Keywords:
public debt,
economic growth,
BRICS,
wavelet analysis,
quantile regression

Introduction

The nexus between public debt (DEBT) and economic growth (GDP) has attracted increasing attention from both academic researchers and policymakers (Makun 2021). The challenge posed by rising DEBT is not a new phenomenon for advanced economies and has also become a significant concern for developing countries (Mohsin et al. 2021, Asteriou et al. 2021, Manasseh et al. 2022, Hung 2022). Public debt arises when governments opt to borrow rather than impose higher tax burdens.

It comprises both short-term and long-term loans acquired by governments to finance public expenditure, typically resulting from insufficient public revenue.

Notably, the rapid increase in public debt in the early 21st century, particularly in the aftermath of the Covid-19 pandemic, has become a critical factor in economic crises across many economies (Yusuf–Mohd 2023). Consequently, discussions surrounding public debt have regained prominence. However, most studies within the debt-to-GDP literature that examine causal effects or threshold levels merely scratch the surface of the issue. The exploration of the quantile-frequency relationship, arguably a fundamental aspect of the problem, has been largely overlooked, with only a limited number of studies addressing it.

The BRICS countries have emerged as a major economic bloc on the global stage. Collectively, they contribute over a quarter of the world's GDP and account for approximately 42% of the global population. Over the past few decades, BRICS nations have steadily expanded their economic influence, becoming key drivers of global economic growth, trade, and investment (Hung 2021). However, the rapid accumulation of public debt in recent decades has become a pressing concern for most countries worldwide (Penzin–Akanegbu 2024). In the BRICS region, significant debt accumulation has been driven by stimulus spending and the high costs of stabilising financial systems, particularly during the Covid-19 pandemic (Suleman et al. 2024). This crisis led to an unprecedented surge in public debt, raising serious concerns about its potential impact on economic growth. Poor management of public debt in BRICS countries could, therefore, have far-reaching consequences for the global economy. The DEBT–GDP nexus is particularly critical in BRICS economies due to their developmental goals, growing global influence, and structural role in the international economic system. These countries face substantial investment needs in education, infrastructure, social welfare, and healthcare to achieve sustainable development, needs often met through significant public borrowing. While moderate levels of public debt may enhance economic growth by financing productive public investment, poorly managed debt can have detrimental effects (Ncanywa–Masoga 2018). Excessive debt can deter private investment, increase borrowing costs, and constrain fiscal space needed to respond to economic crises. As BRICS countries play an increasingly pivotal role in the global economy, responsible debt management is essential – not only for maintaining domestic macroeconomic stability but – also for preserving investor confidence and contributing to global financial resilience. Therefore, understanding and effectively managing the debt–growth relationship is crucial for ensuring long-term, inclusive, and sustainable economic development in these emerging economies.

The relationship between DEBT and GDP is undoubtedly multifaceted (Heimberger 2023, Sandow et al. 2022, Yusuf–Mohd 2023). When channelled into productive sectors, public debt can stimulate economic growth (Herndon et al. 2013, Hung 2024). From a Keynesian perspective, public debt can serve as a countercyclical

fiscal tool during recessions, enhancing growth by increasing disposable income and boosting consumption. However, the risks and adverse effects associated with public debt, such as inflationary pressures or financial market contractions, may also impede economic growth.

The present study investigates the interplay between DEBT and GDP across different quantiles and timescales, using data from BRICS countries. As the largest borrowers among emerging economies, the BRICS nations face a particularly significant challenge concerning the rise in public debt within the region. This research is inspired by the work of Makun (2021) and Bozatli et al. (2024), who highlight the importance of asymmetries and timescale dynamics in shaping the relationship between debt and economic growth. If a quantile-frequency interaction exists between public debt and economic growth, policymakers must carefully consider debt levels in order to foster sustainable growth in these economies.

To address this issue, the study aims to explore the nexus between DEBT and GDP in BRICS countries by employing wavelet-based quantile techniques and quantile-on-quantile regression (QQR) methods. This objective gives rise to the central research question:

How does the relationship between public debt and economic growth in BRICS economies vary across different quantiles and time periods?

Despite its importance, few studies have focused on the interplay between quantiles and timescales. Existing research predominantly relies on traditional approaches such as VAR, causality analysis, ARDL models, and panel data techniques (Manasseh et al. 2022, Law et al. 2021, Ncanywa–Masoga 2018, Silva 2020, Mohsin et al. 2021, Asteriou et al. 2021, Aguilar 2022). This study aims to contribute new insights to the existing body of literature by examining the asymmetric relationship between DEBT and GDP in BRICS nations. It adopts a country-specific perspective, using historical data spanning from 1994 to 2022. The quantile-based methodologies employed, namely, QQR and wavelet quantile correlation (WQC) are innovative tools that facilitate a more nuanced analysis across different levels of GDP and public debt. Given the evident nonlinearity in the data, as confirmed by the Jarque–Bera and nonlinearity tests, the QQR and WQC approaches are well-suited for this investigation. QQR effectively captures asymmetric relationships between variables. Unlike standard quantile regression, QQR offers greater robustness by examining how the effects of regressors vary across multiple quantiles of the dependent variable. Additionally, the WQC model builds on the quantile correlation framework of Li et al. (2015) by incorporating wavelet analysis, allowing for exploration across both time and frequency domains. Unlike conventional wavelet or quantile correlation methods, WQC assesses the relationship between variables simultaneously across quantiles and timescales. This facilitates the identification of short-, medium-, and long-term co-movements between DEBT and GDP, as well as the detection of both immediate and gradual impacts of shocks or policy changes through time-scale decomposition.

These advanced approaches provide deeper insights into the dynamics of public debt and economic growth, thereby supporting the development of more targeted and effective policy recommendations.

Furthermore, this study examines the impact of DEBT on GDP across different quantiles and timescales, employing methodological techniques applied for the first time in this context. The findings offer actionable insights for governments, policymakers, and regulators, emphasizing the importance of maintaining fiscal discipline and ensuring that public borrowing is channelled into well-assessed, high-priority, and self-sustaining projects that contribute meaningfully to GDP growth.

The structure of the paper is as follows: first, the relevant literature is reviewed. Then the data and methodology are outlined, following with the empirical results. Finally, the authors conclude the study.

Literature review

Although economists have long debated the various ways in which debt affects GDP, the relationship between DEBT and GDP has recently attracted more attention (Silva 2020). Since the 1960s, neoclassical economists have argued that tax increases used to finance interest payments on rising domestic and international government debt negatively affect the accumulation of gross capital stock (Mencinger et al. 2014). In contrast, Keynesian economists maintain that rising public debt stimulates productive spending, which benefits the economy as a whole (Law et al. 2021, Manasseh et al. 2022, Yusuf–Mohd 2021).

Elevated and rising levels of DEBT hinder GDP through various channels, including: (1) the crowding out of private investment, which occurs when government borrowing competes for available capital in domestic financial markets (Law et al. 2021, Herndon et al. 2013); (2) higher long-term interest rates, resulting from excessive government debt and increased credit risk (Hilton 2021, Dey–Tareque 2020, Makun 2021); (3) increased taxation to finance future obligations and meet rising debt repayments (Penzin–Akanegbu 2024); and (4) heightened inflationary pressures (Ncanywa–Masoga 2018, Heimberger 2023). Recent analyses further underscore these concerns, suggesting that substantial increases in the debt-to-GDP ratio may lead to significantly higher taxes, lower future incomes, and greater intergenerational inequality (Ighodalo Ehikioya et al. 2020, Makun 2021, Bozatli et al. 2024). Beyond these theoretical perspectives, another strand of thought supports the existence of a nonlinear relationship between DEBT and GDP, namely, the nonlinear effect theory or threshold hypothesis (Herndon et al. 2013, Mencinger et al. 2014). This theory posits that while low levels of government debt can have a positive effect on economic growth, the impact turns negative once debt surpasses a certain threshold.

Past studies on the interaction between public debt and economic growth have produced mixed findings (Ndoricimpa 2020, Yusuf–Mohd 2021, Manasseh et al.

2022). Several studies have identified a negative correlation (Mencinger et al. 2014, Ohiomu 2020, Silva 2020), while others have found a positive one (Mohsin et al. 2021). As a result, the nature of this relationship can be categorised into three main types: no influence, negative influence, and positive influence.

To begin with, empirical research supports the notion that substantial public debt leads to economic stagnation. This perspective posits that government borrowing crowds out private investment due to the high cost of capital, thereby impeding economic growth. Ncanywa–Masoga (2018) examine whether public debt affects public investment and, consequently, economic growth. Their findings indicate a negative long-term relationship between debt and investment. Silva (2020) investigates how foreign debt influences fluctuations in the transmission channels through which external debt would affect economic development in Portugal. He concludes that Portugal's high net external debt-to-GDP ratio has a negative effect. According to Heimberger (2023), a higher public debt-to-GDP ratio is associated with slower real GDP growth. Mohsin et al. (2021) examine the interaction between external debt and GDP in South Asia. Their results suggest that while external debt negatively affects GDP, the stock of external debt has a positive influence. Asteriou et al. (2021) employ an asymmetric panel ARDL model to explore the relationship between public debt and economic growth in Asian economies over both the short and long term. Their results reveal that an increase in government debt is negatively correlated with economic growth in both time horizons. Law et al. (2021) use a dynamic panel threshold model to investigate the nexus between public debt and GDP in developing economies. They argue that high levels of public debt have a negative and statistically significant effect on economic growth, whereas low levels of debt exhibit an insignificant impact. Manasseh et al. (2022) also find that debt has a negative and significant influence on GDP in Sub-Saharan Africa. Similarly, Sandow et al. (2022) report that external debt has a significantly negative effect on economic growth in 31 selected Sub-Saharan African countries, with comparable findings for Nigeria. Faizulayev et al. (2022) apply the ARDL model to examine how external debt stocks influence real GDP in Nigeria. Their study indicates that both external debt stocks and debt servicing significantly affect real economic growth in both the short and long term. Recently, Penzin–Akanegbu (2024) re-examine the nexus between public debt and economic growth, focusing on the West African Monetary Zone (WAMZ). Their findings indicate a negative association between the two indicators.

Research also supports the hypothesis that debt can have a positive impact on GDP. This hypothesis suggests that economic growth increases with rising levels of public debt. Yusuf–Mohd (2021) examine how government debt influences GDP in Nigeria and provide evidence that domestic debt contributes positively to long-term growth, although it has a negative effect in the short term. Their findings imply that the government should allocate borrowed funds towards diversifying the economy's production base. By contrast, Ohiomu (2020) proposes a model of the relationship

between foreign debt and GDP to inform public finance and debt management strategies. The findings reveal that both the debt overhang and crowding-out effect variables reduce investment. Yusuf–Mohd (2023) investigate the asymmetric impact of debt on GDP in Nigeria. Their empirical results show that external debt has a significant, symmetric, and positive effect on GDP in both the short and long term. However, debt service payments, supporting the debt overhang hypothesis, have a symmetric influence that hampers GDP growth. Herndon et al. (2013) document that the relationship between debt and GDP varies significantly across countries and time periods. Similarly, Martín et al. (2024) find that both total and external debt have a positive impact on GDP when the initial GDP level is very low.

Finally, this hypothesis asserts that no causal relationship exists between DEBT and GDP. It is also known as the neutral hypothesis or the debt–growth neutrality hypothesis. Mencinger et al. (2014) investigate the transmission mechanisms of the short-term effects of debt on GDP within the EU. Their results demonstrate a statistically significant non-linear relationship between public debt ratios and annual GDP per capita growth rates. Ndoricimpa (2020) revisits the threshold effects of debt on GDP in Africa, estimating a debt threshold of 62%–66% for the overall sample. The study finds that low levels of debt have a neutral effect on growth, whereas higher levels are detrimental to economic performance. Hilton (2021) employs a dynamic ARDL-based Granger causality model to examine the causal association between debt and GDP in developing countries. The results indicate no causal link in the short term, but reveal unidirectional Granger causality from debt to GDP in the long term. Dey–Tareque (2020) analyse how external debt affects GDP in Bangladesh within a broader macroeconomic context. Their results show that although external debt negatively influences GDP. Ighodalo Ehikioya et al. (2020) investigate the time-varying nexus between external debt and GDP in 43 African economies between 2001 and 2018. Their findings provide evidence of a long-run equilibrium relationship between external debt and GDP in Africa. Makun (2021) indicate that, in the long run, a linear measure of external debt negatively affects GDP, while a nonlinear analysis reveals an asymmetric impact. Bozatli et al. (2024) conduct a comparative analysis of how structural changes and frequency properties influence the nexus between debt and GDP. Their results reveal that the connection between the two variables co-varies or sometimes aligns depending on the time and frequency-domain methods used. A summary of the literature on debt and economic growth is presented in Table 1.

Table 1

Summary of the literature review

Author	Sample	Variables	Methodology	Outcomes
Herndon et al. (2013)	Global	Public debt-to-GDP, economic growth	Dataset re-evaluation, descriptive stats	Negative
Martín et al. (2024)	Developing countries	Public debt-to-GDP, economic growth	Panel threshold regression	Nonlinear effects
Ighodalo Ehikioya et al. (2020)	40 African countries	Public external debt, GDP	GMM	Mixed effects
Ncanywa–Masoga (2018)	South Africa	Public debt-to-GDP, economic growth	ARDL	Positive
Mencinger et al. (2014)	EU countries	Public debt-to-GDP, economic growth	VAR	Negative
Penzin–Akanegbu (2024)	West African	Public debt, GDP	GMM	Negative
Dey–Tareque (2020)	Developing countries	External debt, macroeconomic stability, growth	Panel data	Negative
Bozatli et al. (2024)	G7 countries	Public debt and GDP	Time and frequency domain causality	Bidirectional causality
Faizulayev et al. (2022)	Nigeria	External debt, GDP growth	Cointegration and causality analysis	Short-run impact, long-run neutrality
Mohsin et al. (2021)	South Asia	External debt, GDP	Quantile regression	Mixed effects
Ohiomu (2020)	Nigeria	External debt, GDP	VAR	Negative
Heimberger (2023)	Global	Debt-to-GDP, growth	Meta-regression	Heterogeneity in estimates
Silva (2020)	Portugal	Public/private external debt, GDP	ARDL, causality tests	Negative
Yusuf–Mohd (2023)	Nigeria	Public debt, GDP	Nonlinear ARDL	Nonlinear effects
Sandow et al. (2022)	Sub-Saharan Africa	External debt, public sector quality	Panel data	Negative
Makun (2021)	Fiji Islands	External debt, GDP	ARDL	Nonlinear effects
Ndoricimpa (2020)	African countries	Public debt, GDP growth	Threshold regression	Negative
Hilton (2021)	Developing country	Public debt, GDP	ARDL	Negative
Asteriou et al. (2021)	Asian countries	Public debt, GDP	Panel data	Negative
Yusuf–Mohd (2021)	Nigeria	Government debt, GDP	ARDL	Negative
Law et al. (2021)	Developing countries	Public debt, GDP	Panel data	Nonlinear effects
Manasseh et al. (2022)	Sub-Saharan Africa	External debt, GDP	Panel data	Positive

Overall, the existing literature presents conflicting findings, including some of the most cited and influential studies. Given the strong intercorrelation between DEBT and GDP, understanding their co-movements is crucial for formulating effective investment strategies and growth-oriented policies. It is evident that quantile and frequency dynamics play a significant role in shaping the interactions between debt and GDP. This study investigates the asymmetric relationship between these two variables from a novel perspective, in contrast to previous research, which often focuses on BRICS nations and standard economic conditions. To gain a deeper understanding of this complex relationship, we propose the following hypotheses:

H1: The asymmetric and time-varying relationships between economic growth and public debt co-move across different market conditions and time frequencies.

H2: The relationship between debt and GDP varies under normal and extreme market conditions and is asymmetric.

By incorporating regime-sensitive, asymmetric, and multi-scale effects into its empirical analysis, this study distinguishes itself from the existing literature. A comprehensive examination of the intercorrelation between these variables is conducted using the WQC method to test **H1**, and the QQR approach to assess **H2**.

Research gap

A substantial body of literature has examined the relationship between DEBT and GDP across various countries. Although numerous empirical studies have explored the interconnection between these two variables using panel data and ARDL models, their findings remain inconsistent, primarily due to the assumption of linearity both across and within regions. These investigations typically focus on the long-term effects of debt on GDP. However, the impact of debt might vary over different time horizons. Therefore, identifying asymmetric relationships between DEBT and GDP across various quantiles and country groups is essential. This study addresses an existing gap by analysing the impact of debt on economic growth in BRICS countries over short-, medium-, and long-term periods. These methodological approaches enable a quantile-based analysis and offer novel policy implications that contribute to existing literature.

Methodology

This analysis employs the innovative WQC technique developed by Kumar–Padakandla (2022), along with the QQR method introduced by Sim–Zhou (2015). Traditional econometric approaches, such as OLS, causality analysis, ARDL, wavelet coherence, and VAR, examine the dynamic relationship between variables over time. However, these methods are limited in their ability to address non-linearities, heterogeneous effects, and dynamic linkages across both the time domain and the

distribution of data. They typically assume homogeneous relationships throughout the entire distribution and are unable to capture shifts in market behaviour under extreme conditions. In contrast, WQC and QQR overcome these limitations by analysing associations between variables that vary across quantiles and over time. This key advantage underpins the rationale for applying the WQC method in this study.

The quantile relationship between X and Y is as follows:

Assume present the τ^{th} quantile of X and $Q_{\tau,Y}(X)$ denote the τ^{th} quantile of Y conditional on X. $Q_{\tau,Y}(X)$ being independent on X just if $I\left(Y-Q_{\tau,Y}\right)>0$ and X is independent. In addition, $I(.)$ show an indicator function and $0 < \tau < 1$. We can define the quantile covariance as follows:

$$q\mathrm{cov}_{\tau}\left\{X,Y\right\}=\mathrm{cov}\left\{I\left(Y-Q_{\tau,Y}>0\right),X\right\}=E\left\{\phi_{\tau}\left(Y-Q_{\tau,Y}\right)\left(X-E(X)\right)\right\} \quad (1)$$

$$\phi_{\tau}(\omega)=\tau-I(w<0) \quad (2)$$

The quantile relationship can be written as follows:

$$q\,\mathrm{cov}_{\tau}(X,Y)=\frac{qcor_{t}(X,Y)}{\sqrt{\mathrm{var}\left\{\phi_{\tau}\left(Y-Q_{\tau,Y}\right)\mathrm{var}(X)\right\}}} \quad (3)$$

Next, we decompose X_t and Y_t pairs of DEBT and GDP by using a maximal overlapping discrete wavelet transform.

$$\begin{aligned} a_1[i]&=p_1[i]*e[i]=\sum_m h_1[i-m]e[m] \\ d_1[i]&=q_1[i]*e[i]=\sum_m q_1[i-m]e[m] \end{aligned} \quad (4)$$

At a particular decomposition J and quantile, we define WQC for two time-series X and Y as:

$$WQC_{\tau}\left(d_j[X],d_j[Y]\right)=\frac{q\,\mathrm{cov}_{\tau}\left(d_j[Y],d_j[X]\right)}{\sqrt{\mathrm{var}\left(\phi_{\tau}\left(d_j[Y]-Q_{\tau,d_j[Y]}\right)\right)\mathrm{var}\left(d_j[X]\right)}} \quad (5)$$

To capture behaviour across different time horizons, we collect data at intervals of 2–4 quarters (short-term), 4–8 quarters (medium-term), and 8–16 quarters (long-term) to analyse underlying trends over time.

Quantile on quantile regression

The QQR model is written as follows:

$$GDP_t = \beta^{\theta}(X_t) + u_t^{\theta} \tag{6}$$

X is DEBT, θ is the θ^{th} quantile of the conditional distribution of GDP_t and u_t^{θ} is the error quantile whose θ^{th} conditional quantile is made-up to be zero, and $\beta^{\theta}(.)$ illustrates slope of this nexus.

Equation (1) can be extended by a first order Taylor expansion of a quantile of X_t as follows:

$$\beta^{\theta}(X_t) \approx \beta^{\theta}(X^{\tau}) + \beta^{\theta'}(X^{\tau})(X_t - X^{\tau}) \tag{7}$$

where $\beta^{\theta'}$ shows the partial derivative of $\beta^{\theta}(X_t)$, as the slope suggests a minimal influence. Clearly, θ is the functional form of $\beta^{\theta}(X^{\tau})$ and $\beta^{\theta'}(X^{\tau})$ while τ is the functional form of X and X^{τ}, therefore θ and τ are functional form of $\beta^{\theta}(X^{\tau})$ and $\beta^{\theta}(X^{\tau})$. If we denote $\beta^{\theta}(X^{\tau})$ and $\beta^{\theta'}(X^{\tau})$ by $\beta_0(\theta,\tau)$ and $\beta_1(\theta,\tau)$, respectively.

$$\beta^{\theta}(X_t) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(X_t - X^{\tau}) \tag{8}$$

Equation (8) can be rewritten as

$$GDP_t = \underbrace{\beta_0(\theta,\tau) + \beta_1(\theta,\tau)(X_t - X^{\tau})}_{*} + u_t^{\theta} \tag{9}$$

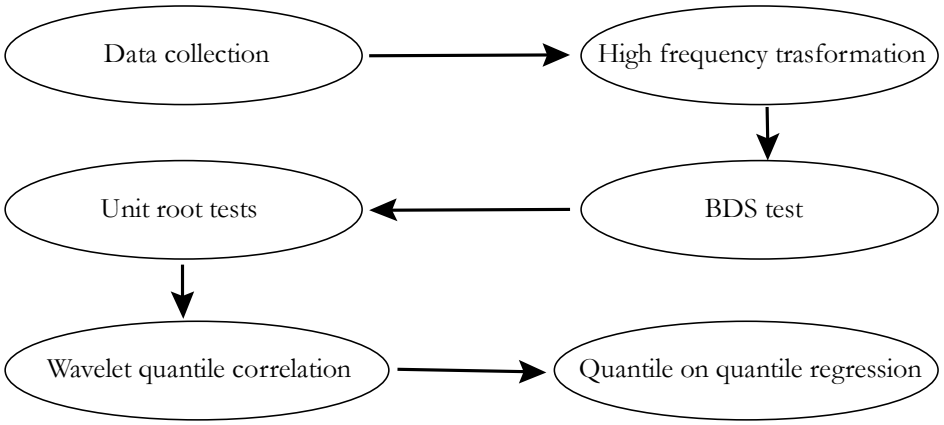
where the part [*] of equation (9) is the conditional quantile of θ^{th} of GDP. The linkage between GDP quantiles and other metrics is shown in these equations. As in ordinary least squares, a similar minimization is applied to arrive at the equation:

$$\min_{b_0,b_1} \sum_{i=1}^{n} \rho_{\theta}\left[GDP_t - b_0 - b_1(\widehat{X_t} - \widehat{X^{\tau}})\right] K\left(\frac{F_n(\widehat{X_t}) - \tau}{h}\right) \tag{10}$$

where $\rho_{\theta}(u)$ is the quantile loss function demonstrating as $\rho_{\theta}(u) = u(\theta - I(u<0))$ and $K(.)$ is the kernel density function and h represents kernel density function bandwidth parameter. Based on past studies like Sim–Zhou (2015), we chose $h = 0.05$ bandwidth of density function for optimal parameters of QQR framework. Figure 1 shows the flow of our analysis.

Figure 1

Flow of empirical analysis



Data

This study explores the nexus between public debt and economic growth in BRICS countries by employing WQC and QQR methods. The growth rate of real GDP per capita (GDP) is considered as the dependent variable, while public debt (DEBT) serves as the independent variable. The data were compiled from the World Development Indicators (World Bank, 2024), and all selected indicators are expressed in logarithmic form. The data span the period from 2002 to 2022 for Brazil, 2000 to 2022 for China, 1998 to 2022 for India, 2004 to 2022 for Russia, and 1994 to 2022 for South Africa. To address the issue of small sample bias, the study applies a low-to-high frequency conversion approach, specifically the quadratic match method, to transform the annual data into quarterly observations. This approach is consistent with the methodologies employed by Sinha et al. (2020), Ozkan et al. (2024), and Iorember et al. (2025).

Table 2 presents the estimates of three-unit root tests: the augmented Dickey-Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–Phillips-Schmidt–Shin (KPSS) tests, applied to the selected indicators and their first differences. The results suggest that all variables are non-stationary in levels, indicating the presence of a unit root in the sample. However, the tests are statistically significant at the first difference, implying that the series become stationary after differencing. These unit root results confirm that the Δ Debt and Δ GDP data series are suitable for the empirical analysis of the study.

Table 2

Unit root test results

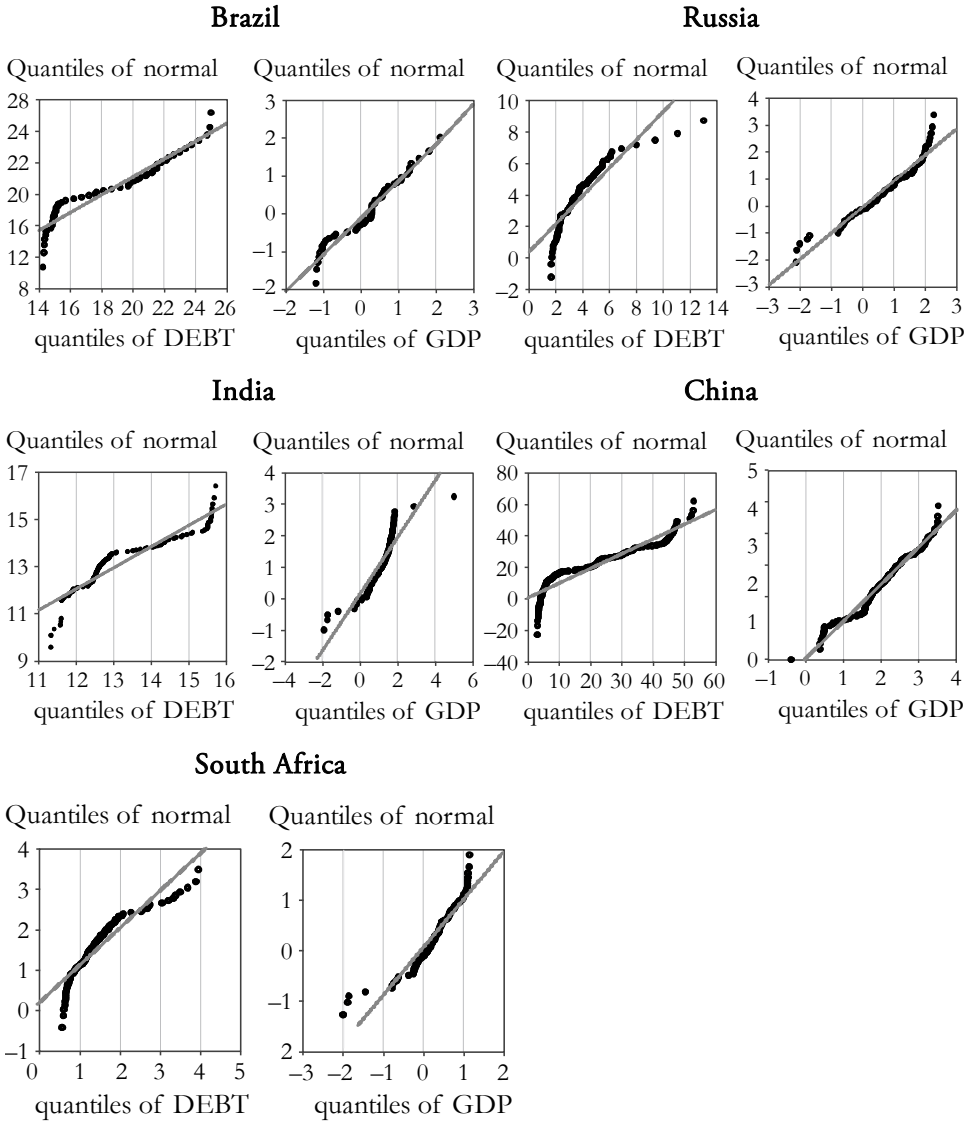
Country	Variable	ADF	PP	KPSS
Brazil	DEBT	–0.108581	–1.798387	0.818380
	GDP	–1.554641	–2.962038	0.365199
	Δ DEBT	–3.330212	–5.467337	0.054413
	Δ GDP	–4.618056	–5.453901	0.026933
Russia	DEBT	–2.021572	–0.470399	0.833553
	GDP	–2.309683	–2.441657	0.470244
	Δ DEBT	–2.795576	–3.030199	0.158730
	Δ GDP	–6.563104	–4.558301	0.049907
India	DEBT	–0.758887	–0.391613	1.076145
	GDP	–5.342669	–2.980000	0.083509
	Δ DEBT	–3.318392	–4.854120	0.100785
	Δ GDP	–3.278664	–2.613227	0.108761
China	DEBT	0.153585	–0.306816	1.035484
	GDP	–2.498849	–2.150887	0.452506
	Δ DEBT	–8.880519	–11.89378	0.102356
	Δ GDP	–10.49628	–12.18264	0.034010
South Africa	DEBT	0.528026	0.104047	0.566280
	GDP	–1.442521	–3.268414	0.485162
	Δ DEBT	–6.055418	–50.23215	0.127911
	Δ GDP	–3.662546	–4.269505	0.039669
Critical value				
At 1%		–3.493129	–3.488063	0.739000
At 5%		–2.888932	–2.886732	0.463000
At 10%		–2.581453	–2.580281	0.347000

Note: Δ symbolizes the first difference, and *** stands for significance at 1%.

Figure 2 represents the quantile–quantile (Q–Q) plots used to validate the results of the Jarque–Bera tests. The Q–Q plots for DEBT and GDP are consistent with the Jarque–Bera findings, indicating that the quarterly data from 1994 to 2022 for the selected indicators do not follow a normal distribution. Moreover, the Q–Q plots reveal deviations from normality across various quantiles in all series.

Figure 2

Q–Q plots



Note: grey lines present the theoretical normal distribution, and black dots are actual data values.

Table 3 provides a brief description of the statistical characteristics of both the independent and dependent variables across the BRICS nations. As shown, the mean value of the independent variable, DEBT, ranges from a high of 16.259 to a low of 1.922. Interestingly, the BRICS member countries recorded significantly higher

average economic growth. The standard deviation in Table 3 reflects the degree of volatility in the variables, indicating how far each series deviates from the mean. All indicators under examination are both negatively and positively skewed, suggesting a relatively heavy right tail. In addition, the Jarque–Bera test estimates how the selected series fit a normal distribution in terms of kurtosis and skewness. The null hypothesis is strongly accepted for Brazil and rejected for the other nations.

Table 3

Descriptive statistics of the selected series

Variable	Mean	Median	Maximum	Minimum	Standard deviation	Skew	Kurt	J–B
				Brazil				
DEBT	16.259	15.438	22.622	9.762	3.443	0.375	2.124	4.660
GDP	0.331	0.326	1.781	–1.229	0.751	–0.385	2.558	2.763
				Russia				
DEBT	1.922	1.473	4.9277	0.701	1.104	1.581	4.449	38.333***
GDP	0.626	0.687	2.298	–2.167	1.116	–0.588	2.893	4.416
				India				
DEBT	4.446	0.811	11.874	–0.566	4.313	0.258	1.347	12.485***
GDP	1.144	1.315	5.022	–1.957	0.857	–0.513	9.682	190.443***
				China				
DEBT	5.405	4.112	13.174	2.242	2.697	1.151	3.289	20.658***
GDP	4.774	3.988	12.972	–0.083	2.674	1.140	4.042	24.120***
				South Africa				
DEBT	10.292	9.307	20.123	4.750	3.697	1.305	4.215	40.079***
GDP	0.305	0.366	1.193	–1.981	0.605	–1.360	6.109	82.557***

Note: *** stands for significance at 1%.

Next, we investigate the linearity of the selected series using the BDS test (Broock et al. 1996), as suggested by Ozkan et al. (2024). The results presented in Table 4 indicate that the series exhibit a nonlinear nature, as the null hypothesis of linearity is decisively rejected for all variables. The presence of both non-normality and nonlinearity in the analysed series justifies the application of quantile-based methods to investigate the interplay between GDP and DEBT in the BRICS economies.

Table 4

Nonlinearity test results of the variables

Variable	BDS[2]	BDS[3]	BDS[4]	BDS[5]	BDS[6]
			Brazil		
ΔDEBT	0.170576***	0.277081***	0.341625***	0.381290***	0.403484***
ΔGDP	0.136483***	0.215716***	0.259477***	0.277726***	0.278557***
			Russia		
ΔDEBT	0.176331***	0.285695***	0.352432***	0.390747***	0.408519***
ΔGDP	0.130331***	0.210613***	0.267679***	0.305663***	0.321445***
			India		
ΔDEBT	0.172447***	0.283478***	0.353375***	0.394366***	0.420948***
ΔGDP	0.127065***	0.203595***	0.275165***	0.297305***	0.300556***
			China		
ΔDEBT	0.170591***	0.279951***	0.349170***	0.408362***	0.450558***
ΔGDP	0.180791***	0.299028***	0.375839***	0.423272***	0.459165***
			South Africa		
ΔDEBT	0.177394***	0.290244***	0.362739***	0.408087***	0.435735***
ΔGDP	0.135824***	0.228049***	0.287027***	0.316272***	0.324593***

Note: *** stands for significance at 1%.

Empirical results

We begin by presenting the novel WQC estimates, followed by a sensitivity analysis using the QQR method. In the initial phase of the empirical analysis, the WQC approach is employed to examine the correlation between DEBT and GDP in the BRICS countries. The results are illustrated in Appendix Figure A1.

The x-axis represents quantiles, while the y-axis denotes the short-, medium-, and long-term time horizons. This structure facilitates a comprehensive understanding of the behavioural patterns of the response variable in relation to its explanatory variables. The colours indicate both the type and strength of the relationship: bright yellow boxes signify a strong positive correlation, whereas dark (black) boxes indicate a strong negative quantile correlation.

In Brazil, DEBT has a distinct influence on GDP over the period shown. In the short, medium, and long term, there is a negative nexus between GDP and DEBT at most quantiles, suggesting a primarily negative effect of DEBT on GDP across different quantiles and frequencies. This negative result aligns with the debt overhang hypothesis and suggests that government borrowing from public sources has not been effectively leveraged to expand the productive base of the economy, which is essential for sustained economic growth. From a public policy standpoint, the findings strengthen the case for reducing public debt to enhance long-term GDP

potential in Brazil. Past papers, such as Silva (2020) and Sandow et al. (2022), found similar outcomes in Portugal and Nigeria, respectively.

The DEBT–GDP relationship in Russia is illustrated in Figure A1. The association between the two variables co-moves across quantiles and time horizons. DEBT exhibits a strong negative relationship with GDP across all quantiles in the short and medium term. Additionally, a negative impact on GDP persists throughout the medium term across all quantiles. These findings are consistent with prior studies by Law et al. (2021) and Sandow et al. (2022), which also report that DEBT negatively affects economic growth, thereby constraining economic development. In other words, the observed negative influence of public debt in the short and medium term suggests that lower levels of debt accumulation are associated with higher economic growth. However, in the long run, DEBT positively affects GDP at the lower quantiles (0.05–0.4), indicating that public debt may contribute to economic growth in Russia under certain conditions. These findings are partially aligned with those of Asteriou et al. (2021).

The WQC between DEBT and GDP in China is demonstrated in Figure A1. In the short term, the interplay between these variables is significantly negative across different quantiles and frequencies. Specifically, in the low and medium quantiles [0.01–0.6], the relationship is strongly negative in the medium and long run. Moreover, the strength of the negative correlation co-varies across different quantiles. Therefore, these results reveal that DEBT can be a mitigating factor for economic growth in China, but the degree of negative impact varies across different scales.

Figure A1 presents the WQC between DEBT and GDP in India. The plot reveals that the behaviour of DEBT towards GDP is similar in the short and medium run. It is clear that in all quantiles, a positive interaction is observed but to varying degrees. By contrast, in the low and medium quantiles, a weak negative correlation is found in the long run. Overall, given the time-varying impact, we can conclude that DEBT has a positive effect on economic growth in India. This finding is expected, as government borrowings are moderately directed towards operational expenditure, with a large share invested in developing productive capital. The outcome supports the findings of Ohiomu (2020), Yusuf–Mohd (2023), and Herndon et al. (2013), who argue that DEBT often supports economic development.

Finally, Figure A1 provides information about the WQC findings between DEBT and GDP for South Africa. In both the short and medium run, DEBT effectively contributes to a remarkable decrease in GDP across different quantile distributions [0.1–0.9], though the degree of mitigation varies across different quantiles. This outcome also holds true in the long term. Hence, DEBT has a mitigating role in economic growth in South Africa. We can suggest that DEBT has a negative impact on GDP in this country.

Overall, a positive correlation is observed in India across all quantiles and frequencies, while a significant negative relationship between GDP and debt is

evident in the other BRICS economies across different timescales. The relatively moderate level of DEBT in relation to GDP in India would explain the unexpectedly positive effect of DEBT on GDP, in contrast to the considerably negative impacts observed in the other BRICS countries. As long as a country's debt remains within sustainable limits, borrowing can support GDP by financing infrastructure, education, and other investments that enhance productivity. For India, the debt-to-GDP ratio could still be at a level where public borrowing stimulates economic growth rather than constraining it. In contrast, countries such as Brazil and South Africa may already be carrying heavier debt burdens. This raises concerns about the sustainability of their debt, rising interest payments, and the potential crowding out of private investment. The results of the subsequent empirical analysis, which employs the novel QQR model to examine the influence of the independent indicators on GDP, are illustrated in Appendix Figure A2.

Figure A2 presents a surface plot illustrating the dependency structure between DEBT and GDP in BRICS economies through QQR analysis. This visualization provides an in-depth examination of these interactions across 19 quantiles, showcasing how they differ under various economic situations. Utilizing the quantile-based method proposed by Troster et al. (2018), the quantiles are divided into distinct economic regimes: the lower quantiles [0.05–0.15] reflect extreme bearish conditions, the upper quantiles [0.85–0.95] represent extreme bullish scenarios, and the mid-range quantiles correspond to typical economic conditions. This method effectively captures the strength and direction of dependency across various economic scenarios. In the model, darker shades signify stronger associations, while brighter shades indicate weaker interconnections at specific quantiles.

In Brazil, the slope coefficient ranges from –0.4 to 1.4. A negative nexus is observed in the area combining the low to medium quantiles of GDP with the linkage across all quantiles of DEBT. When GDP is in bearish economic situations, the negative effects of DEBT are more pronounced. By contrast, a strong positive relationship is found when GDP and DEBT are both in normal and bullish economic scenarios. These outcomes are in line with the findings of Makun (2021), who indicates a nonlinear interplay between GDP and DEBT. Similarly, in Russia, a negative and strong GDP–DEBT relationship is observed throughout the quantiles of DEBT and quantiles [0.1–0.3] of GDP. This overwhelmingly negative correlation shows that debt significantly reduces GDP in Russia at the lower to median quantile ranks. On the other hand, a positive association between GDP and DEBT is demonstrated across regions, which unify higher GDP quantiles with all DEBT quantiles in this economy.

Furthermore, in China, a significant negative nexus between DEBT and GDP is identified within the portions running from lower to middle quantiles of GDP [0.05–0.4] with all DEBT quantiles. However, there is a strong positive interplay between the two variables, where DEBT notably decreases GDP at upper-middle to the

highest ranks of GDP in China. Additionally, a weak positive nexus emerges across regions that combine middle-lower to higher DEBT quantiles with higher GDP quantiles. The dominance of a strong and positive relationship between these variables in China over the medium and long term is supported by Yusuf–Mohd (2023) and Martín et al. (2024).

In India, both positive and negative DEBT–GDP relationships are detected across various quantiles and timescales. In the low and high quantiles of GDP, DEBT has negative impacts on GDP in this economy at all quantiles. On the other hand, a positive interplay between the two variables is found in the sample period that runs from middle to high quantiles of GDP with all DEBT quantiles. This positive intercorrelation demonstrates that DEBT significantly promotes GDP under normal economic conditions. Similarly, in South Africa, as shown in Figure A2, DEBT has a negative effect on GDP at low and high quantiles. The detrimental influences of DEBT on GDP reduce as DEBT increases. Nevertheless, at the other quantiles of GDP and DEBT, there is weak positive interaction, suggesting that with lower levels of DEBT, there would be a slight rise in economic growth. Overall, the results underscore the importance of prioritizing DEBT management in South Africa.

Discussion

This section thoroughly examines the potential reasons underlying empirical findings and evaluates their consistency with previous studies. Our results indicate that DEBT has both negative and positive impacts on GDP across various quantiles, frequencies, and countries. In this context, it is first concluded that across all quantiles, the influence of DEBT on GDP is significantly negative. In other words, government borrowing tends to exert a detrimental effect on economic output. This outcome aligns with existing growth literature; Ncanywa–Masoga (2018), Silva (2020), and Law et al. (2021) similarly report a negative influence of government spending on economic growth. According to this study, as public debt increases, its adverse impact on growth diminishes, particularly at the lower and medium quantiles, due to several interrelated economic and institutional factors. The negative association between DEBT and GDP can be attributed to various determinants. One explanation is excessive public spending without corresponding savings or sustainable borrowing against future revenues, which exposes the economy to debt sustainability risks (Mencinger et al. 2014). Another contributing factor is the situation in highly indebted countries, where creditors often demand higher interest rates due to a history of defaults. In such cases, government revenue and export earnings are frequently diverted towards debt servicing, rather than being invested in critical sectors such as healthcare, education, social welfare, infrastructure, or scientific research and development (Dey–Tareque 2020, Makun 2021). Put differently, when governments engage in heavy borrowing, interest rates often rise, making it more difficult for

businesses to access affordable credit. This crowds out private investment and slows economic growth. Elevated public debt also restricts fiscal space, potentially compelling governments to cut essential spending or increase taxes, both of which can dampen aggregate demand. As debt escalates, investor confidence could decline, leading to higher borrowing costs and reduced foreign investment. Significant debt burdens can also trigger exchange rate volatility, deter investors, and increase the cost of imports.

In the BRICS nations, a substantial portion of government revenue is allocated to debt repayment, leaving fewer resources for essential public investments such as infrastructure and education. These challenges are further exacerbated by structural deficiencies and weak institutions, which limit the effectiveness of public expenditure. Numerous studies underscore the negative relationship between DEBT and GDP in such contexts, as debt servicing obligations are typically met through the national budget (Ighodalo Ehikioya et al. 2020, Bozatli et al. 2024). This issue becomes particularly acute during episodes of debt overhang, where the debt burden is so substantial that a significant share of current output is diverted to foreign creditors, thereby discouraging domestic investment and constraining economic growth.

However, when public debt is managed effectively, our estimates indicate a positive trend, particularly in India across all time horizons. Public debt can have a favourable influence on GDP when allocated to productive purposes. For instance, governments in BRICS countries utilise public borrowing to finance large-scale infrastructure projects such as roads, bridges, energy systems, and telecommunications, investments that enhance productivity and facilitate economic activity over the long term. Additionally, borrowing to support government expenditure during economic downturns can stimulate aggregate demand, particularly when private sector demand is weak. Public debt might also be employed to fund investments in education, healthcare, and social programmes, thereby improving the quality of human capital. A healthier, better-educated workforce is typically more productive, fostering innovation and supporting sustained economic growth (Hilton 2021). During periods of economic contraction, public borrowing enables governments to maintain or increase expenditure, stabilising demand and mitigating the effects of the downturn. Overall, when managed prudently, public debt can serve as an important instrument for driving economic development. This conclusion aligns with the findings of Yusuf–Mohd (2021, 2023) and Herndon et al. (2013), who underscore the positive role of public debt in promoting long-term economic growth.

Conclusion

Our study employs novel approaches and an analysis of historical datasets (1994–2022) to highlight the asymmetric influences of public debt on GDP in BRICS countries. By examining how these interactions vary across different levels of

economic growth and public debt, this study offers valuable insights into the existing literature on the relationship between DEBT and GDP. These contributions are made possible through the application of innovative quantile-based methodologies.

Empirical evaluations can be summarized as follows: (i) DEBT negatively impacts GDP in the short and medium run across BRICS countries, (ii) the positive association becomes more pronounced in the long run, and (iii) there exists an asymmetric influence of DEBT on GDP across quantiles in the region. More importantly, this research provides several debt management policy insights based on the positive and detrimental effects of DEBT on GDP. Our findings illustrate the nonlinear interplay between GDP and DEBT at different quantiles and frequencies. In other words, DEBT has both positive and negative influences on GDP in BRICS economies.

The outcomes reveal that increased DEBT negatively affects GDP in most BRICS countries, with the exception of India. This suggests that public debt is inefficiently utilized in these nations. In terms of policy implications, government-funded projects should undergo thorough evaluations to assess their financial viability, technical feasibility, and economic desirability before funds are allocated. This would promote financial discipline and reduce the misuse and inefficient management of public debt. Policymakers should aim to reduce the debt burden through effective debt management policies.

Governments and policymakers must adopt a more disciplined and strategic fiscal approach to mitigate the negative effects of public debt on GDP and promote fiscal sustainability in BRICS countries. This involves curbing excessive borrowing by maintaining debt levels within sustainable thresholds and aligning borrowing with long-term development goals. Implementing robust fiscal restraint is essential not only to prevent debt from crowding out private investment but also to restore investor confidence and macroeconomic stability. Policymakers should prioritize structural reforms aimed at improving the efficiency of public spending, minimizing fiscal leakages, and enhancing domestic revenue mobilization through more effective and equitable tax collection systems. Additionally, rationalizing expenditures by redirecting resources from unproductive or politically motivated programs toward growth-enhancing sectors such as infrastructure, education, and healthcare can help reduce fiscal deficits and strengthen the long-term economic resilience of BRICS economies. Overall, these measures can help contain the short- and medium-term growth-reducing effects of public debt while laying the foundation for sustainable development.

When public debt contributes positively to GDP growth, it typically reflects the effective use of borrowed funds to finance high-return, growth-enhancing investments. To harness this potential, policymakers in BRICS countries should align public borrowing with national development priorities by channelling funds into productive sectors such as infrastructure, healthcare, education, and innovation.

These investments not only stimulate short-term demand but also build long-term economic capacity and resilience. Equally important is the maintenance of debt sustainability through the adoption of clear fiscal rules, regular debt sustainability assessments, and transparent public financial management. Strengthening institutional capacity and ensuring accountability in public spending are essential to maximizing the developmental impact of debt while preserving market confidence. By taking a strategic and responsible approach to public borrowing, BRICS economies can turn debt into a powerful tool for inclusive and sustained economic growth.

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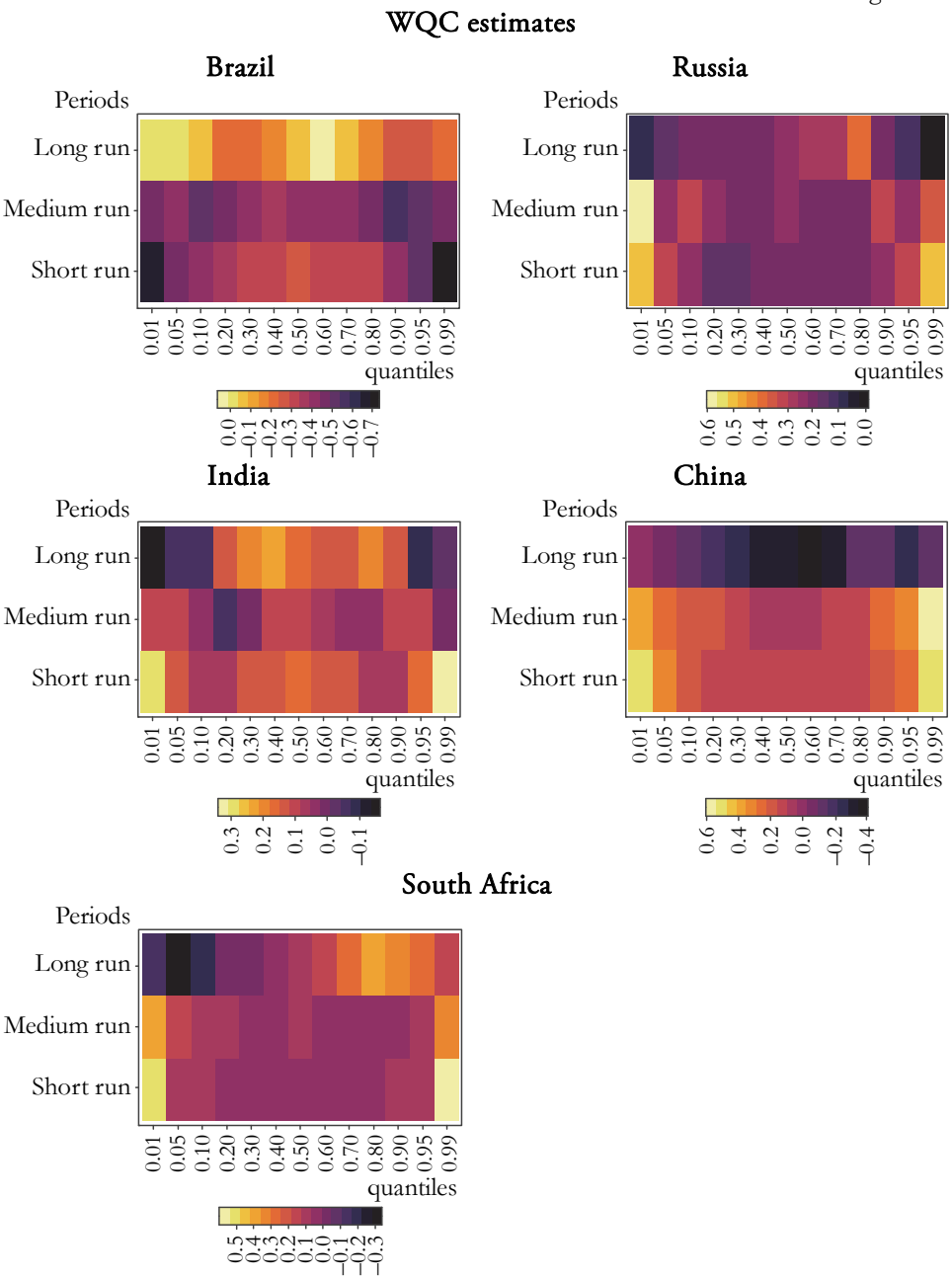
Appendix

Figure A1

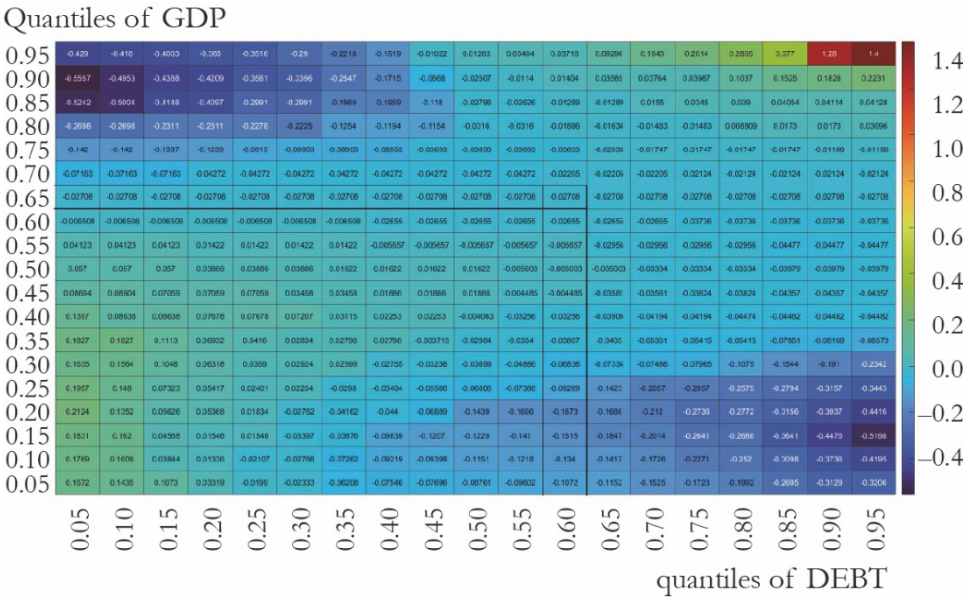


Note: Heatmaps reveal the impact of DEBT on GDP over various time periods and quantiles. The left vertical axis represents various time periods (wavelet scales), while the horizontal axis depicts the quantiles of the joint distribution.

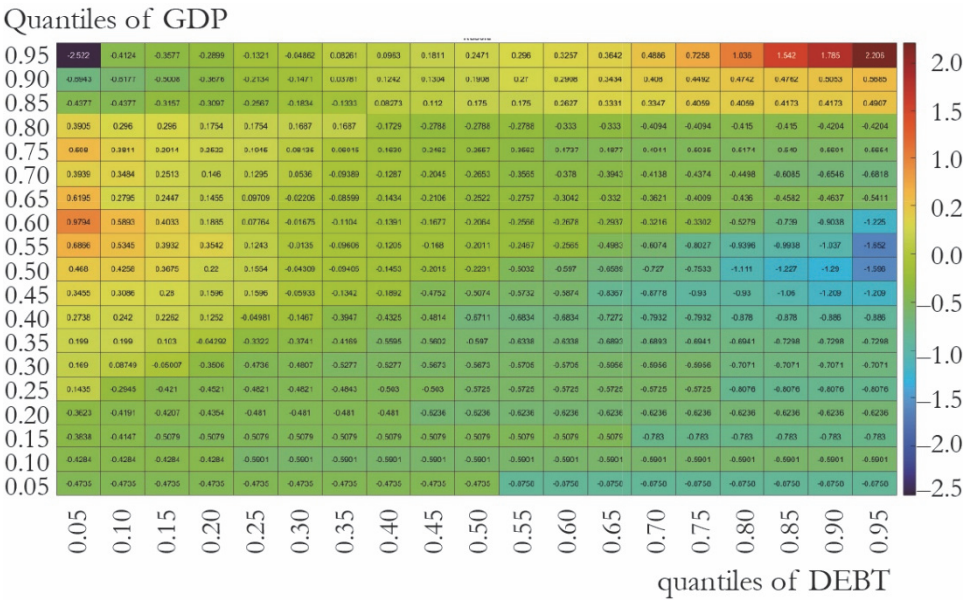
Figure A2

QQR between DEBT and GDP in the selected countries

Brazil



Russia



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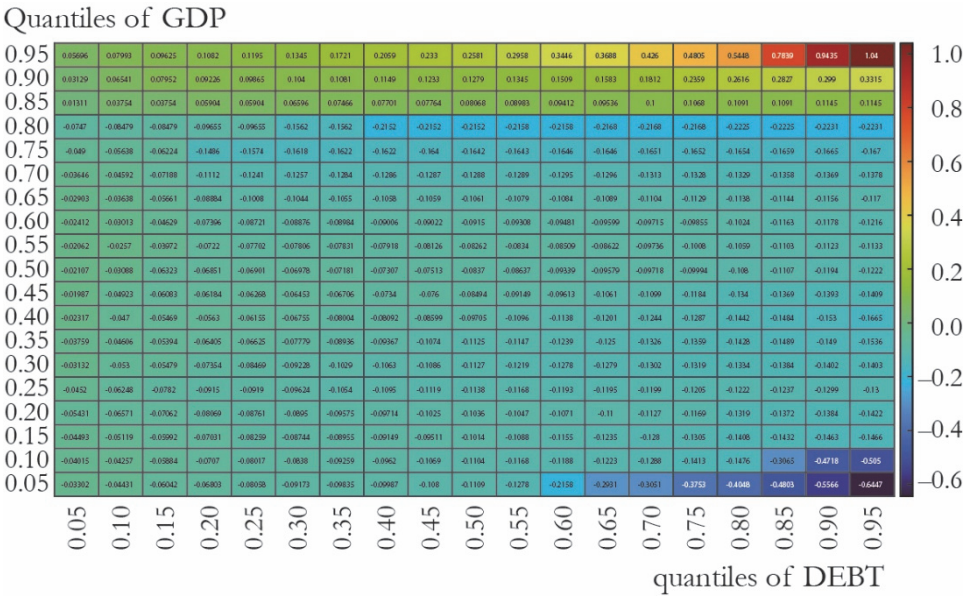
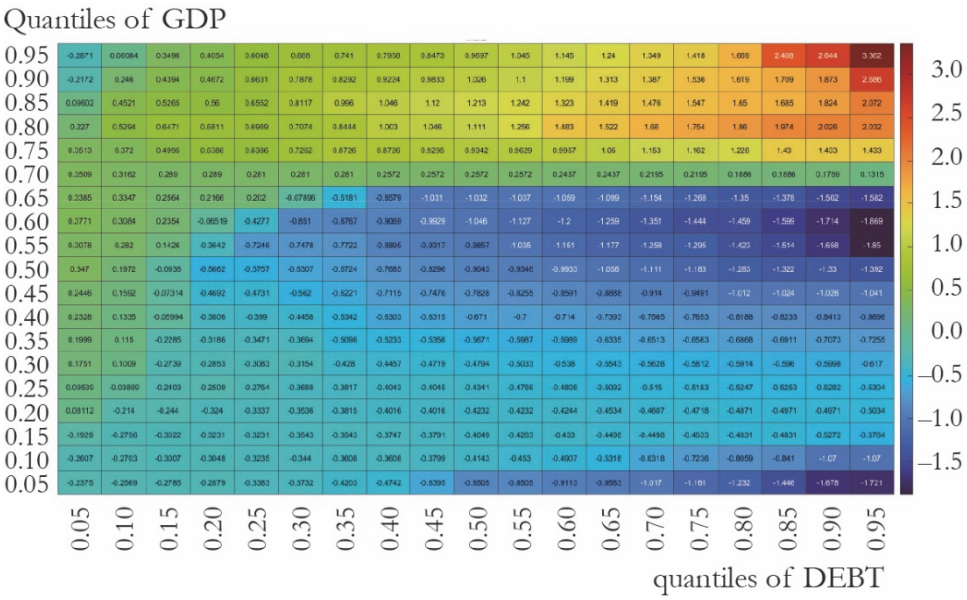
China



India



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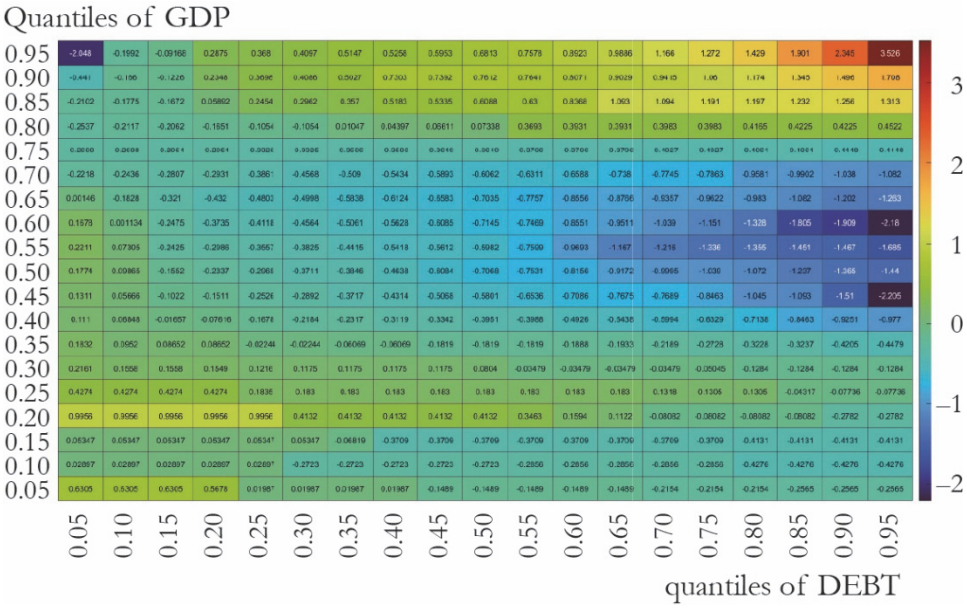
South Africa



Note: The figures display the estimated slope coefficients $\beta_1(\theta,\tau)$, which illustrate the impact of DEBT quantiles (on the x-axis) on GDP quantiles (on the y-axis). For the slope coefficients, red (blue) indicates positive and strong (weak) values, while dark red (light yellow) represents negative and pronounced (moderate) effects. Light green signifies very modest or negligible slope coefficients.

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